Public preferences for ecosystem services of small urban green infrastructures in Guangzhou, China

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Preface

I grew up in Chengdu, Sichuan, which has always enjoyed the reputation of being a "Heavenly Land of Plenty" and was rated as one of the livable cities in China. Since 2013, the air quality in Chengdu has suddenly dropped, becoming a "dust city". The air pollution has a great impact on citizens' life and work. The harmful effects of air pollution on human well-being mainly affect people's cardiovascular system, respiratory disease and mental health. Meanwhile, air pollution has become the main environmental problem in China these years. How will we solve these problems? It is my passion to find out the solution. I want to help mitigate the damages and impacts of these problems, even though cannot completely eliminate them all. When I was in high school, the textbook taught us ecosystems has the ability of self-regulation and self-healing. I believe ecosystems can play an essential role in urban areas with urban planning. That was the reason why I picked urban ecosystem services as my thesis topic. The case study was in Guangzhou, because Guangzhou had ever-green vegetation type and praised as "flower city".

This study aims to enhance the importance of planning for non-market benefits in urban areas and provide scientific support for the management of these new UGIs. This study did field measurements of the ecosystem services (i.e. air quality regulation, temperature regulation, noise control) generated by these UGIs. What's more, it investigated the willingness-to-pay (WTP) of local citizens as well as their perception of these new UGIs. The study was planned for 6 months. However, it took a little bit longer than 6 months, because I need to learn new software, it's not that easy for me, and writing a qualified report required more efforts.

In truth, I could not have achieved my thesis without the help of many people. First of all, Dr. Dolf de Groot who is my supervisor in WUR, he is very responsible. He provided patient advice and guidance throughout the research. And secondly, Dr. Yafei Wang, who helped me with data collection and analysis. She and Prof. Beichen Xia helped me with designing a questionnaire and selecting appropriate data analysis methods. And other 6 master students from Sun Yat-sen University helped me with field measurements. Thank you all for your unwavering support!

Summary

My study assessed and compared ecosystem services of three popular new types of urban green infrastructures (UGIs) in Guangzhou and investigate the public perception to these ecosystem services. UGIs benefit human well-being. My study explored the people's willingness-to-pay (WTP) for UGIsto help improve their resilience and quality of life. My ecosystem services' analysis quantified and assessed some services provided by targeted UGIs (i.e., air-quality regulation, temperature regulation and noise control) through field measurements. The stakeholders' attitude and public preference towards the new UGIs were explored. The monetary value of non-market benefits was calculated by the contingent valuation method (CVM) using WTP and open-ended payment-box approaches.

430 respondents from different neighborhoods responded to my questionnaire. Only 21 questionnaires were incomplete, invalid and thus discarded. About 40% of the respondents visited UGIs at least once a week and 60% visited UGIs less than once a month. 80% of the respondents were willing to pay for using and maintaining the UGIs. This yielded an annual average payment of RMB 29 (c. 4.4 US$) per household. The totalized annual WTP for targeted UGIs was RMB 126 million (c. US$ 18 million/yr). Socio-economic factors played an important role in the respondents' bidding decision. I found that age, education level and monthly income significantly affected people's WTP. Age was negatively correlated with WTP. My results showed that young people would likely pay more than elderly people. Guangzhou's residents preferred a large UGIs and even---more extensive green lane.

My study contributed to the integrated understanding of UGIs, urban ecosystem services and people's preferences for UGIs. It explored the factors that affect people's WTP. My findings improved understanding how residents appreciate UGIs' benefits. My results indicated that most respondents highly value UGIs benefits, that they were concerned with environmental issues, and that they strongly preferred for UGIs. My findings could assist future UGI planning and show that policy makers should incorporate public perception and preference in urban planning to meet the demands for UGIs.

1. Introduction

People's desire to create green space and live near them has globally increased. Such urban green spaces are important for public health (Björk et al., 2008; Mitchell & Popham, 2008). People need a liveable and sustainable city. Most residents highly appreciate green area and some of them are willing to pay for their benefits directly or indirectly (Tyrväinen, 2001). Urban Green infrastructures (UGIs) play a critical role in enhancing human well-being and urban quality of life (Cameron et al., 2012). Green infrastructure is a bridge that links nature and society, bring natural ecosystem services and provide associated benefits to human well-being. Green infrastructures components include a variety of natural and landscape features that make up a system of hubs and links. In the past, green infrastructure is more like an open space for sightseeing, and then it became an ecological corridor which is used for biodiversity protection. Today green infrastructure is more combined with ecosystem benefits. It can provide habitats for wildlife, sustain air quality, regulate runoff, adjust temperature and contribute to the health and quality of life. In China, UGIs are a wide range of natural elements in an urban area such as green lanes, green roofs, green walls, parks, urban forests and wetlands. The three popular new types of UGIs in China include green lanes, green roofs, and green walls, these my study targets. A Green lane uses green stormwater infrastructure to capture and manage rain or runoff directly from the street. Green lanes allow runoff to soak into soil, filtering out pollutants like oil, and reduce the amount of stormwater making its way into city's combined sewer pipes, which reduces the combined sewer overflows that degrade its waterways (Gill et al., 2007; Shashua-Bar & Hoffman, 2000). A basic green roof usually consists of a root barrier, drainage, filter, growing medium and vegetation layer (Bianchini & Hewage, 2012). A green wall consists of plants with supported vertical systems, incorporate vegetation, grow medium, irrigate and drainage into a single system(Alexandri & Jones, 2008). Due to the rapid economic growth and urbanization, many ecosystems were destroyed or deteriorated in China. The degeneration of ecosystems has led to many environmental problems, such as floods, air pollution and water pollution. After experienced these environmental problems, Chinese has realized the importance of the environment and its influence on human well-being. and UGIs are becoming popular among metropolis cities, also in

Guangzhou. By developing and adopting a systematic form of urban planning, the Chinese government has adopted a number of regulations and policies to increase the green infrastructures in the urban area in the last two decades (Chen & Hu, 2015; Zhao et al., 2013).

Guangzhou is one of the model cities that build an ecological city, it has built 507 kilometers ecological forest belts, and upgraded maintain system for communities and UGIs. Because of the construction of these green projects, wetlands, green lanes, parks and green roofs, the ecological environment is gradually optimized. In 2017, the forest coverage rate was 42%, and the green coverage for the urban area was 41%. Guangzhou build 3,000 kilometers of green lanes, 11 wetland parks and 73 forest parks in Guangzhou (Guangzhou government, 2017).

Compared with traditional green infrastructures, the three new UGIs are relatively small and could link the natural and city easier, thereby increasing the property values and decreasing the costs of public services. On a macro scale, the new UGIs are part of the natural life support system, carrying climate regulation, water conservation, runoff regulation and biodiversity conservation. They provide services to maintain national ecological security and the long-term interests of the country. On a mesoscale, they are bridges to link natural and social human well-being. For instance, UGIs could control urban flooding, regulate water pollution, mitigate urban heat islands, and restore urban habitats. At the same time, they provide cultural services, such as recreation aesthetic value and inspiration. Unlike the traditional UGIs, these new UGIs provide limited provisioning services and usually cannot supply food, water, etc. As functional composite application infrastructures, the management of these UGIs calls for close cooperation with many departments. At present, China still has a shortcoming in this respect. Scientific research, engineering technology, design and application are limited because of the lack of cooperation and connection.

1.1 Study area

This study was conducted in Guangzhou (Figure 1), which is the capital city of Guangdong Province. Guangzhou is located in southern China, and in the north of the Pearl River Delta. It was dominated by a typical subtropical oceanic monsoon climate, with a long hot and humid summers. The hottest month is July, with the average air

temperature of 28.7° C and the relative humidity of 50% to 80%. As the largest city in southern China, Guangzhou has a population of 12.7 million (Guangzhou Districts Census Office, 2011).

The study area is in the central built-up portion of Guangzhou with about 186.73 km^2 area. Three targeted UGIs are located at TaiKoo Hui which is a multifunctional building in Tianhe District (green roof), the Parc Central in Guangzhou's new central business district (green wall), and the greenway around Haizhu lake in the Haizhu district (green lane). TaiKoo Hui and Parc Central are both in Tianhe district, which is in the center of the city and is the largest economic zone of Guangzhou. A lot of important cultural facilities such as Guangzhou International Finance Center, Guangdong Provincial Museum are located in Tianhe district. Compared with 2007, the green coverage for the whole urban area increased from 37% to 42% (Guangzhou Statistical Bureau, 2018).

Figure 1 The three study sites in Guangzhou

1.2 Problem statement

City development is overtaking farms and forests at an increasing rate. This expansion often occurs due to poorly designed land-use plans, which results in urban sprawl and disruption of ecological services. Even though the local government of Guangzhou prioritized the development of urban green space and achieved notable developments of large-scale urban forests and parks, the problems still persist. However, during the rapid construction, Guangzhou is facing increasing environmental pressures, and urban green spaces cannot meet people's needs. To build a livable city, some problems

regarding UGIs's planning and management need to be solved. First, the UGIs are not connected in an ecological network, and ecological processes and UGIs planning lack continuity. The connection among parks and other UGIs are rather weak, which fragmente UGI's spatial distribution. The important ecological corridors are not valued and short of maintenance. Second, sometimes the urban green spaces are not properly used and underestimated. The ecological connection is poor. Plant and vegetation lack reasonable distribution and public green space per capita is low. Last, the design and planning of UGIs started relatively late in China, compared to developed countries. The UGIs and their roles in urban development have not yet been well studied. One common problem also exists in China, is for example, that local governments owns the land and control UGIs management, and other stakeholder (i.e., UGIs construction company, expert in urban planning, UGIs user) involvement and participation are insufficient.

1.3 Research objective and questions

As the information on benefits and public preference of UGIs, stakeholder participation and attitudes are insufficient, the benefits are not valued, my study explores people's willingness-to-pay (WTP) for targeted UGIs (Green roof, Green wall, Green lane) in Guangzhou for assessing the UGIs value and the public preferences to these UGIs. A good understanding of the residents' recreational habits and potential influential factors hold the promise of effective planning, design and maintenance of UGIs. My research assessed the ecosystem services of three new UGIs by reviewing literature and website, field measurements, a questionnaire survey, and stakeholder interviews. My study aims to determine the importance of planning for non-market benefits of the three new UGIs and to provide scientific support for the management of these UGIs. My primary research objective is to explore citizens' WTP of the three popular new types of UGIs. Specific objectives to:

1) Assess the environmental performances of the three popular new types of UGIs and evaluate the value of their ecosystem services.

2) Explore the relationship between the socioeconomic and demographic characteristics of citizens and their WTP for the ecosystem services that are provided by these UGIs.

3) Assessing the citizens' attitudes and preferences toward these UGIs.

The main research question focused on which is most preferred by citizens in Guangzhou. The specific research questions are:

1. What are the main ecosystem services of the targeted UGIs?
2. What is the citizens' WTP for the targeted UGIs?
3. What factors can affect citizens' WTP?
4. What is the attitude of stakeholders toward the investigated UGIs in Guangzhou?

1.4 Outline

Chapter 1 gives background information and introduction about UGIs and urban ecosystem services, the general situation of study area and its problems are described. The research objective and research questions of this study are also presented in this chapter. The general information of study area, such as the location, climate, environmental policy, are described in this chapter as well. Chapter 2 introduces the methodology and conceptual framework for this study. It introduces the methods to analyze the UGIs and its provided services (include ecosystem services analysis, contingent valuation method, stakeholder analysis). The contingent valuation method was used for assessing people's WTP. In the third chapter, the description of selected ecosystem services and the results from field measurement on air quality, air temperature and noise are presented. Chapter 4 gives the results from the questionnaire, the respondents' WTP for selected UGIs. A total of 430 questionnaires were handed out. The factors affecting people's WTP for UGIs are presented in Chapter 5, which include socioeconomic characteristic factors and people's concern of five environmental issues. In Chapter 6, the four types of the main stakeholders participated in this study are: Guangzhou municipal goverment, expert consultants, GIs constructors, and local citizens. Moreover, the management of UGIs and stakeholder hierarchy are illustrated. In the end, discussion and conclusion are given in chapter 7 and chapter 8. In Chapter 7, I compared my study with other studies, and found some similarity and differences. Also reflected on my research method and what kinds of uncertainty I have

during my research. Chapter 8 presented the conclusion: what is citizen's WTP for these UGIs; age, education level, income affected their WTP; people preferred larger UGIs.

2. Methodology

This chapter introduces the research methods applied in this study, including conceptual frameworks, analysis methods, and data collection methods.

2.1 Conceptual framework

Based on the literature review, a framework of this study was established (Figure 2). It was adapted from the conceptual framework of the Economics of Ecosystems and Biodiversity (Kumar, 2012).

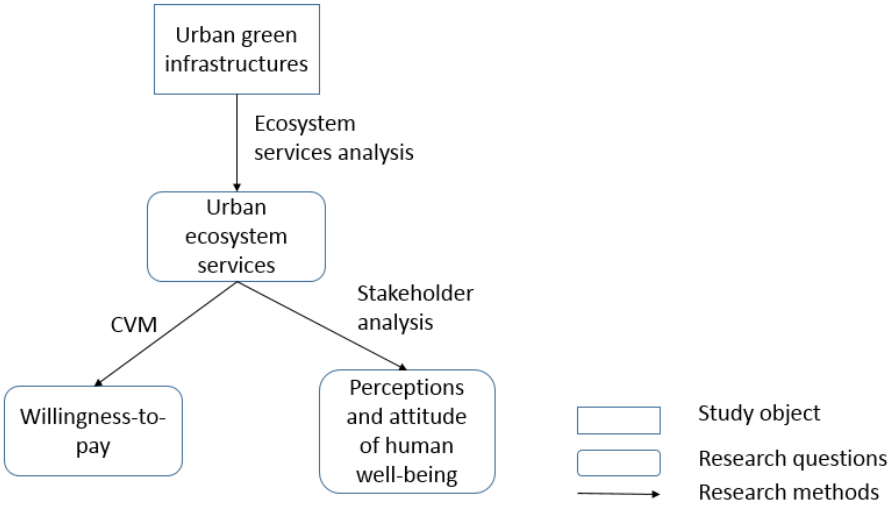

Figure 2 Conceptual framework

Ecosystem services are defined as direct and indirect contributions of ecosystems to human wellbeing. The contribution of ecosystem services to human wellbeing can be socio-cultural, ecological value and economic value (Farber et al., 2002). Figure 2 illustrates the framework of the conceptual background for this study. It shows three different methods applied in this research, ecosystem services analysis, contingent valuation method (CVM) and stakeholder analysis. A wide range of ecosystem functions and their associated goods and services have been referred to literature. Due to time and resource limitation, not all ecosystem services were investigated. This study focused on regulation services, i.e., air quality regulation, temperature regulation, noise control. The public preference of UGIs in Guangzhou was also addressed.

2.2 Research methods

This study applied three research methods: ecosystem service analysis, CVM, and stakeholder analysis. The ecosystem service analysis was used to quantify and assess the services provided by the targeted UGIs (i.e., air quality regulation, temperature regulation, and noise control) through field measurement. Due to time and resources restrictions, the data from the field experiment is not sufficient for all the services. Under this situation, the research also used secondary sources via literature and website reviews. To explore the public preference of the new UGIs, a questionnaire was applied to assess the respondents' WTP. The stakeholder analysis was adopted to explore stakeholders' attitude toward new UGIs by stakeholder interview.

2.2.1 Ecosystem Services Analysis

Ecosystem services are the 'benefits supplied by ecosystems to society' (Millennium Ecosystem Assessment, 2005). In my study, ecosystem services were classified into provisioning, regulating, habitat and cultural services (De Groot et al., 2012). To translate social, economic and environmental impacts into benefits, it is necessary to determine the performance of green infrastructurs through ecosystem service classification. UGIs generate diverse ecosystem services (Elmqvist et al., 2015). Although people started to understand the importance of UGIs, people still lack an understanding of the mechanisms behind the generation of urban ecosystem services. The most common link between UGIs and human well-being in urban planning is through regulation services and cultural services, for example, air quality regulation, temperature regulation and recreation value. This study focused on the link between human well-being through regulating ecosystem services and public preference to UGIs. The studied regulation services include air quality regulation, temperature regulation, and noise control. These services are generated by complex interactions through social-ecological systems (Gómez-Baggethun et al., 2010; Müller et al., 2010; Van Oudenhoven et al., 2012) and are related to environmental problems, such as air pollution, high temperatures and noise pollution.

This study focused on $PM_{2.5}$ and PM_{10} air pollutants, hot air temperature and noisy environments, because they were most harmful to human well-being health and were

regulated by UGIs (Armson et al., 2012; Derkzen et al., 2015; Fang & Ling, 2003; Nowak & Crane, 2000) (see Annex 1). The questionnaire includes people's likeliness of the eight services: air quality regulation service, temperature regulation service, landscape recreation service, biodiversity protection service, aesthetic service, runoff regulation service and education service.

2.2.2 Contingent valuation method

Various approaches have been used in environmental economics to measure the values of ecosystem services, and these approaches can be divided into revealed and stated preference methods. By applying a CVM, my study assessed the value of UGIs' ecosystem services to human well-being in terms of whether people are willing to pay towards maintaining these ecosystem services (Jim & Chen, 2006b; Lo & Jim, 2010). A questionnaire was designed for this purpose. It was based on stated preference method that addresses how the respondents would like to pay for public goods in a hypothetical situation (Mitchell & Carson, 2013). The questionnaires set up a hypothetical market in which respondents were asked to state monetary bids for maintaining UGIs based on the information provided to them. More details can be seen in Section 2.3.1

2.2.3 Stakeholder analysis

Stakeholder analysis was applied through three main steps: identification, characterization, and prioritization of the main stakeholder groups that are relevant to the ecosystem services management in the study area. This study firstly identified and characterized the main stakeholders. The variables were related to the respondents' (1) relationship with the investigated UGIs, (2) perceptions of the importance of eight ecosystem services, (3) socio-demographic characteristics, (4) attitudes to UGIs. This study interviewed four types of stakeholders: an expert in urban ecosystem services, the local government-Guangzhou Municipal Government, a UGIs construction company named Green Town, and local citizens. The local citizens have been interviewed through a questionnaire. For the other three types of stakeholders, five people were interviewed in this study, including two experts, two employees from a construction company, and one from the local government.

Participation and partnership techniques are critical to the accountability and effectiveness of urban planning and implementation processes (Anguelovski & Carmin, 2011; Rosenzweig et al., 2011). Previous studies found that network governance contributed to raising awareness of the need for climate adaptation (Betsill & Bulkeley, 2006). Therefore, a better understanding of local stakeholders in Guangzhou helps with improving and implementing of UGIs. In this study, stakeholder analysis was organized by three main steps in Guangzhou, namely identification, characterization, and prioritization of the main stakeholder groups that are relevant to the UGIs' management in the study area. The outcomes and information from the first and second parts were used to analyze the stakeholders' perception and preferences. The most relevant stakeholders are citizens who live around or work near the investigated UGIs, who are the users of the UGIs, who are the beneficiaries of the urban ecosystem services. Moreover, they are directly affected by environmental problems, but do not have power to change or improve the situation. In this study, a stakeholder analysis was performed to explore the perception of public for five environmental issues and urban ecosystem services on human well-being, in order to get a better figure of the UGIs and help policy-makers get useful information of urban planning.

2.3 data collection

This study was carried out at three green spaces in Guangzhou from September to November 2018. The data were collected by conducting field measurements, questionnaire survey, stakeholder interview, literature and website review. For the questionnaire study, the sample size of approximately 400 was calculated based on a 95% confidence level, 5% confidence interval and the population in Guangzhou (see Equation 1).

1. $n = Z^2 \bullet P(1 - P)/E^2$

P=0.5, Z=1.96, E=0.05

Considering incomplete questionnaires might occur and to ensure sufficient data for analysis, 430 questionnaires were distributed in total.

The field measurements were carried out from 17th September to 30th October 2018. The measurements were conducted in the unshaded place. The main instruments used for measurement include Heat Index WBGT Meter, Hot Wire Anemometer-Thermometer, Air Quality Detector- CW-HAT200s and Noise Dosimeter-HS5618A.

The air temperature, relative humidity, wind velocity, noise level, $PM_{2.5}$ and PM_{10} concentrations were simultaneously recorded once per half hour from 9:00 to 17:00 at the height of 1.5 meters above ground at the three study sites (air temperature, humidity and wind velocity were recorded by Hot Wire Anemometer-Thermometer, $PM_{2.5}$ and PM_{10} concentrations were recorded by Air Quality Detector- CW-HAT200s, noise level was collected by Noise Dosimeter-HS5618A).

2.3.1 Questionnaire survey

The questionnaire design was based on the CVM. It creates a realistic but hypothetical market, which allows people to indicate their WTP. In China, questionnaire design is relatively difficult, because China has a different social, cultural, economic and political environment from Europe. Most Chinese are not familiar with a monetary value to non-priced ecosystem services, and they are lack of the experience to express bids for their preference. Respondents are not used to express their preferences for hypothetical transactions. To tackle this problem, the open-ended payment card approach was adopted. This approach allows the respondents to express the amount if they were not satisfied with the given choices, thereby helping the respondents to reveal their true feelings of ecosystem services.

The questionnaire contains two main parts.(see Annex 2) The first part is about socioeconomic information of respondents, including age, gender, educational level, place of residence and monthly income. These data could help to assess whether the sample is representative of the general population (Bateman et al., 2002), and to further analyze whether socioeconomic status affects recreation pursuits and WTP. The second part contains nine questions regarding respondents' experiences, activities and attitude towards the UGIs, such as "Would you like to replace the current UGI by other UGIs?", "How often do you come to this UGI?", and "Which environmental issue is more serious in Guangzhou?", "How much would you like to pay to maintain UGIs?", etc.

The disadvantage of the questionnaire is that the reliability and validity of the results depend on responses. Are the respondents really willing to pay the amount that they stated in the interview? It is highly subjective due to individual differences in the education level, life experience, etc.

A pilot test was conducted before implementing the questionnaire. The respondents consisted of six postgraduate students from Sun Yat-sen University, two postgraduates from Wageningen University and Research, four experts from Sun Yat-sen University, and 20 residents from a street block. The pilot test aimed at verifying whether the questionnaire was logical and whether respondents could correctly understand it.

The questionnaire was distributed in a neighboring area of three observed UGIs. Three master students helped me to distribute questionnaires, one from Wageningen University and Research, and the others from Sun Yat-sen University. We invited people who were around the study site to fill the questionnaire at that moment. The survey was conducted from 10th October to 15th November 2018. A total of 430 respondents have participated in the survey, while 21 uncompleted questionnaires were invalid and excluded from the analysis. The sampling population was composed of residents living within the study area of Guangzhou and a few visitors.

2.3.2 Literature review

In my study, indicators selection of field measurement and willingness-to-pay regrading UGIs required literature review. I did systematic literature reviews of UGIs regulation services and cultural services. Literature was searched in online databases, through WUR library and Google Scholar. To select indicators of human well-being, i typed the key words were ‘mental health green space’, ‘human health urban green space/infrastructure’. Journals such as Epidemiology Review and Urban Health were included. Indicators for urban ecosystem services measurements, I typed key words were ‘urban green space ecosystem services’, ‘urban green infrastructure air regulation’. Journal of Environmental Management, Urban Forestry&Urban Greening, Environmental Science & Technology, Landscape Research, Landscape and Urban Planning. UGIs are key components of urban ecosystems, contributing to sustainable development, landscape and human well-being. They generate many services,

including air pollutant removal, high-temperature regulation, flood control, noise control, and mental health promotion (De Vries et al., 2003; Takano et al., 2002). UGIs are the link between urban ecosystem services and human well-being, with providing comprehensive ecosystem services the basic function of UGIs (Haines-Young & Potschin, 2010; Lafortezza et al., 2013). Some researches provided a basic framework for the relationship between ecosystem services and human well-being (Gordon et al., 2018; Pakzad & Osmond, 2016). Some others investigated the public preference towards UGIs and residents' perception and attitude (Jim & Chen, 2006a, 2006b; Lo & Jim, 2010). Many studies used the CVM in the environmental analysis to explore the WTP or willingness-to-accept (WTA) of respondents and the influencing factors (Lo & Jim, 2010).

2.4 Statistical analysis

In my study, the data were collected by the field experiment and questionnaire, and further analyzed by multiple methods. The statistical analysis was applied using the SPSS 23 software. In the questionnaire, the respondents were asked to specify their WTP to maintain the UGIs. Moreover, some social status questions were set to be open or ended-open questions, such as the residence time in Guangzhou, the transportation to visit the site. The respondents answered these questions subjectively and sometimes described in words. Afterward, these responses were classified and categorized. Since the survey results were not normally distributed, the relationships between the socioeconomics and WTP, the socioeconomic characteristics and respondents' concern of five environmental issues, and the UGIs and measured services were analyzed by non-parameter Kruskal-Wallis h test. The field measurement data were analyzed by Kruskal-Wallis h test and linear regression analysis.

3. Field measurements and literature review on the ecosystem services of urban green infrastructures

The field measurements focused on air quality, air temperature and noise pollution surrounding the study site. Earlier studies (Konopacki & Akbari, 2000; Thornes et al., 2010) assessed the value of regulation services, cultural services that all are highly related to my study subject. Hence, a literature review about air quality regulation, temperature regulation, noise control and recreation value was carried out. The field measurements and used instruments were explained in Chapter 2.

3.1 Description of selected ecosystem services

This study focused on the regulating and cultural services, including air quality regulation, temperature regulation, noise control, and recreation value. Field measurements were conducted to analyze the regulating service, and the literature review was applied for regulating services and cultural services.

UGIs can affect air quality through the direct removal of air pollutants, including three processes: removal of air pollutants and gaseous pollutants through dry deposition, sequestration of carbon dioxide (CO_2) by the process of photosynthesis, and slowing down smog formation by cooling the ambient temperature (Konopacki & Akbari, 2000; Thornes et al., 2010). Nowak et al. (2018) investigated the effect of urban forest on air quality and human health in 86 cities in 2010. The result showed that the total amount of pollution removal by the urban forest was about 165,000 ton, with a human health value of US$ 227.2 million.

The effect of temperature regulation is exerted through several approaches. Firstly, vegetation absorbs heat from the air through evaporation and transpiration (Hardin & Jensen, 2007). Secondly, trees could provide shade and humidity to moderate local temperatures (Bolund & Hunhammar, 1999).

Noise from traffic, construction, and other human activities affect human health in urban areas. UGIs can reduce noise pollution by providing a direct and indirect barrier (Van Renterghem et al., 2012). The direct barrier of UGIs reduces noise by absorption,

deviation, reflection, and refraction of sound waves. Indirect noise reduction effects are generated by slowing wind speeds (Fang & Ling, 2003).

In an urban area, the small UGIs can be important for human recreation especially when it comes to young people. A study in Helsinki showed that there are various green spaces in the most popular areas. These green spaces were very popular among adolescents (Mäkinen & Tyrväinen, 2008). Furthermore, UGIs have positive influences on public health. Moreover, recreational environment with higher accessibility and higher quality can attract people to exercise, which is important for people who work in the static and computerizing area (Tzoulas & James, 2010). Result for recreational services see Chapter 4.3

3.2 Results from field measurements of air quality, air temperature and noise

The results from field measurement showed that, among the three study sites, the air temperature ranged between 25°C -37°C and the relative humidity varied from 54%-99% during September to October 2018 in Guangzhou. The effect of UGIs on the concentrations of $PM_{2.5}$ and PM_{10}, the air temperature, and the noise level was explored by using non-parametric Kruskal-Wallis h test, since the measurement data were not normally distributed (see Annex 3).

The results found that there was a statistically significant difference in $PM_{2.5}$ and PM_{10} concentrations ($p<0.05$), air temperature ($p<0.05$) among the different UGIs. Furthermore, no statistically significant association was found between the UGIs and noise ($p>0.05$) (see Table 1).

Table 1. The p value from Kruskal-Wallis h test for the difference of $PM_{2.5}$ and PM_{10} concentrations, air temperature and noise level among the three UGIs

	UGIs
$PM_{2.5}$	0.000
PM_{10}	0.000
Air temperature	0.013
Noise	0.174

In this study, green roof had the lowest concentrations of $PM_{2.5}$ (155.9 $\mu g/m^3$) and PM_{10} (207.4 $\mu g/m^3$), whereas green lane had the highest concentration of $PM_{2.5}$ (400.3 $\mu g/m^3$) and PM_{10} (547.9 $\mu g/m^3$). Moreover, the air temperature of 25.3°C in green lane was the lowest, comparing to that in green roof and green wall (both are 26.7°C) (see Table 2).

Table 2 Field measurement results for measured services in three study sites

	Green wall	Green roof	Green lane
Average temperature (°C)	26.7	26.7	25.3
SD temperature (°C)	1.3	1.2	1.3
Average $PM_{2.5}$ ($\mu g/m^3$)	242.9	155.9	400.3
SD $PM_{2.5}$ ($\mu g/m^3$)	28.8	19.9	24.0
Average PM_{10} ($\mu g/m^3$)	320.6	207.4	547.9
SD PM_{10} ($\mu g/m^3$)	40.2	27.7	33.1
Average noise (dB)		57.8	58.2
SD noise (dB)		4.5	2.7

The field measurements were carried out under stable weather conditions, to reduce the impact of severe changes in meteorological factors. Table 3 shows the results of the regression analysis. The air temperature had no significant difference in $PM_{2.5}$ and PM_{10} concentrations ($p>0.05$). A significant association was found between humidity and $PM_{2.5}$ and PM_{10} concentrations ($p<0.01$). With the increase of relative humidity, $PM_{2.5}$ and PM_{10} concentrations in all different UGIs types showed a gradually increasing trend (see Fig. 3).

Table 3 The p value of the relationship between $PM_{2.5}$ & PM_{10} concentrations and meteorological factors

	$PM_{2.5}$ concentrations	PM_{10} concentrations
Temperature	0.317	0.23
Humidity	0.006	0.008

Under the same weather conditions, the variation of PM_{10} concentrations was larger than that of $PM_{2.5}$ concentrations (see Fig. 3).

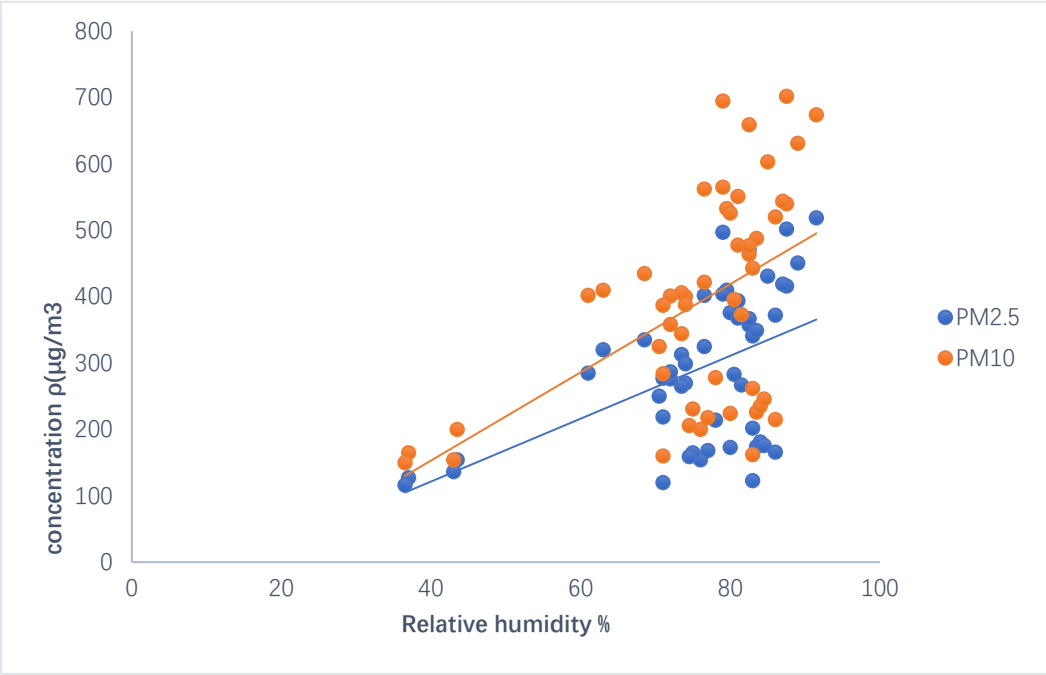

Fig. 1. The relationship between relative humidity and PM $_{2.5}$ & PM $_{10}$ concentrations

4. Willingness-to-pay for urban green infrastructures and ecosystem services

This section shows the results of the questionnaire. A total of 430 questionnaires were handed out, 21 of which were discarded because of uncompleted response and invalid answers. Thus, 409 questionnaires were completed and used for the analysis. These questionnaires were used to analyze the respondents' willingness-to-pay (WTP) and the factors affecting their WTP. The WTP questions began by introducing the hypothetical scenario of using and maintaining the selected UGIs within the next twenty years. The monetary values, unless stated, are Chinese Yuan, at the officially pegged exchange rate of RMB ¥ 6.8=US $ 1

4.1 Characteristics of the respondent, response rate and frequency for visiting urban green infrastructure.

The socio-economic characteristics of the respondents contain five social variables, including gender, age, educational level, occupation, and monthly income (see Annex 4). 70.7% of the respondents have lived in Guangzhou over five years. Female (50.7%) and male (49.3%) were evenly distributed. Among the occupations, the employee group exceeded other groups, being 67.8%, followed by the student group 15.1%. For the education level, the majority were college and bachelor. In terms of the monthly income, RMB 8,000-10,000 (19.2%) was predominant, with RMB 4,000-6,000 (18.8%) and RMB 6,000-8,000 (18.8%) following really closely. Fig. 4 shows the frequency of respondent for visiting the targeted UGIs. Among the respondents, about 60% of them were not very often going to the spot, and they hardly visited or went there once a month. The regular visitors were about 38%, including 16.8% of which went to the UGIs every day and the rest went once or twice a week (Annex 4 Table 8). The regular visitors were mainly the retired people, 58.3% of the retired respondent and 68.4% of the other occupation respondents said they usually go to the UGIs every day or weekly. It seems like Guangzhou residents were not highly active in using UGIs.

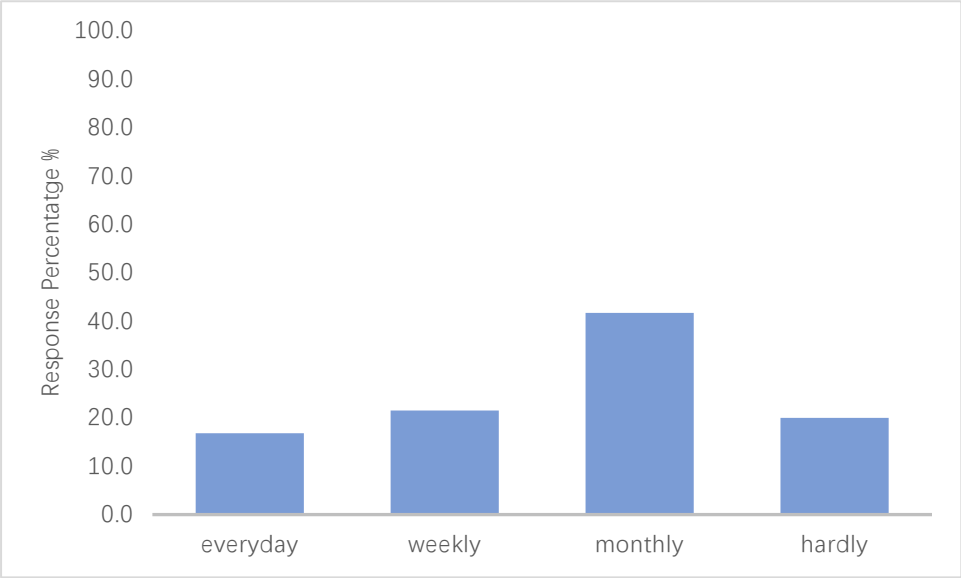

Fig. 4. The percentage of respondents for visiting UGIs in different frequencies

In the questionnaire, the respondents were asked to vote their preference for the three UGIs. Over 70% of the respondents chose the green lane (see Fig. 5). They believed that the green lane is more publicly accessible without entrance limitation. Compared with green lane, only around 17% and 8% of the respondents chose the green wall and green roof, because the two types of UGIs were close to their working area/home.

4.2 Willingness-to-pay of respondents

Fig. 6 shows the distribution of the residents' WTP in Guangzhou. 20.3% of respondents were not willing to pay for the UGIs. They mainly are elderly people who have lower income and lower educational level. The rest of respondents expressed their willingness to pay annually for UGIs, with 11% paying RMB 1-5 per household, 19% RMB 5-10 per household, 20% RMB 10-50 per household, 12.5% RMB 50-100 per household, and 17.2% would like to pay more than RMB100 per household. The highest stated amount was over RMB 500 per household. With 20.3% of the respondents showed zero WTP, the average WTP was calculated as RMB 37 per household. The aggregate monetary value of services provided by targeted UGIs in built-up areas of Guangzhou can be calculated. According to the frequency distribution of the respondents' WTP, the means of WTP (i.e. $\overline{E}(WTP)$) can be obtained by the expectation formula of discrete variables (Einarsdóttir et al., 2019; Mcgurk et al., 2019):

2.

$$\overline{E}(WTP) = \sum_{i=1}^{n} (A_i P_i)$$

Where, A_i was the bidding value, P_i was the possibility of respondent choose the bidding value, n was the bidding group, in this case, n=9 (Figure 5)

By applying above formula, the means of WTP was RMB 29/household/yr ($4.4/household/yr). The value was then multiplied by the number of the affected population living in the study area (total 43,684,370 household based on 2010 census) (Guangzhou Districts Census Office, 2011). The WTP for services generated by targeted UGIs in Guangzhou was computed to be RMB 126.6 million per annum (approx. US$ 18.6 million/yr). The means of WTP amounted to RMB 580/household ($85.3/household) over twenty years, suggesting that Guangzhou residents were willing to pay a certain sum for UGIs.

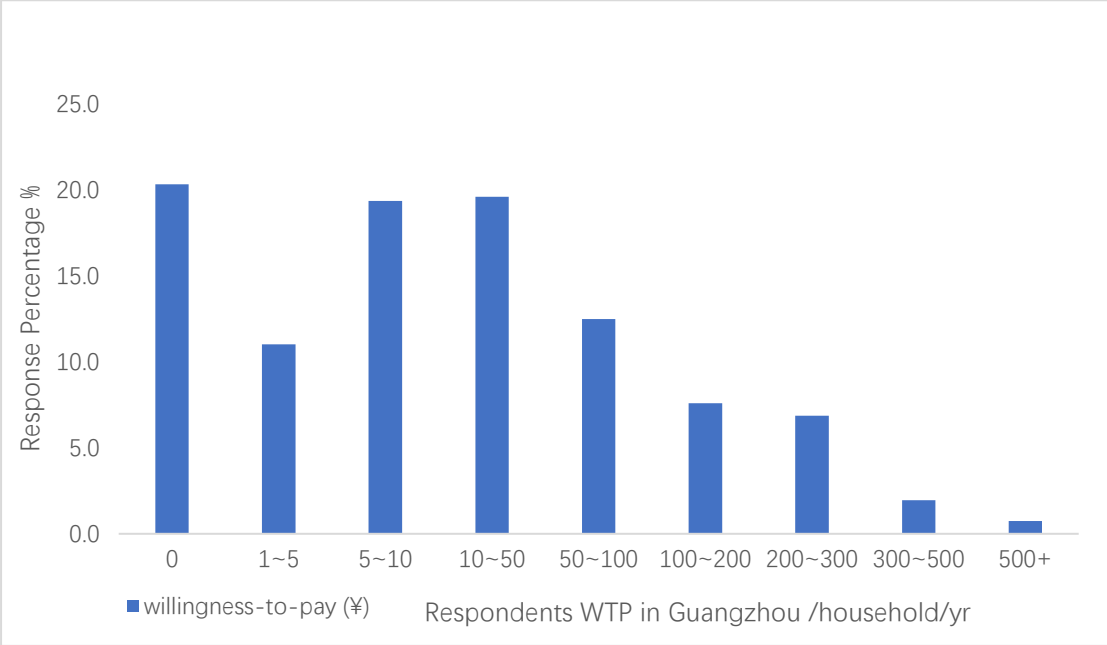

Fig. 5. Distribution of the respondents' WTP

4.3 Perception of ecosystem services generated by UGIs

In the questionnaire, the respondents were supposed to indicate which services they prefer to spend money on. Most respondents thought that ecosystem services generated by UGIs were important. Table 4 shows the percentages of respondents' preferences

for spending money on the eight ecosystem services. Among the eight ecosystem services, the respondents' preference was sorted in descending order as air quality regulation service, temperature regulation service, noise control service, landscape recreation service, biodiversity protection service, aesthetic service, runoff regulation service, and education service. The results showed that the respondents rated air quality regulation service as the most important services, and they would like to spend more money on it. This is to say, the bad air quality has caused great concern from the respondents in Guangzhou. Temperature regulation service was rated as the second important service with a score of 1,051. Noise control service and landscape recreation service were rated equally, with a score of 1,020. This result suggests that a general perception of fresh air, cooling temperature, and quiet environment were what the respondents needed. The score of biodiversity protection and aesthetic value were 894 and 892, respectively. 18.2% of the respondents were very likely to spend their money on runoff regulation service, with a total score of 853. The education service was the last preferred service, with 14.5% of the respondents were very likely to spend their money on it and a total score of 808. This result indicates that a few people would like to spend more money on aesthetic value and educational value.

Table 4. Respondents' preferences for spending money on the eight ecosystem services

Services	Total score[1]	Average score	Very likely	Likely	Neutral	Unlikely	Very unlikely
Air quality regulation	1105	3.40	57.0%	36.5%	6.3%	0.2%	0%
Temperature regulation	1051	3.23	49.1%	42.8%	7.8%	0.3%	0%
Noise control	1028	3.16	44.3%	37.5%	15.7%	1.0%	1.5%
Landscape recreation	1024	3.15	40.5%	41.7%	16.7%	0.4%	0.8%
Biodiversity protection	894	2.75	22.7%	39.7%	30.7%	3.4%	3.5%
Aesthetic value	892	2.74	21.8%	43.5%	27.2%	3%	4.5%
Runoff regulation	853	2.62	18.2%	40%	32.2%	4.9%	4.9%
Education value	808	2.49	14.5%	36.1%	35.1%	7.2%	7.1%

[1] Scores to respondents' rating: very likely=4 likely=3 neutral=2 unlikely=1 very unlikely=0

5. The factors affecting people's willingness-to-pay for UGIs

5.1 Socioeconomic factors

The relationship between respondents' WTP with gender, age, educational level, monthly income and study site were explored (see Table 5). It was found that gender had no significant influence on WTP ($p>0.05$). A negative correlation was found between age and WTP, indicating that younger respondents are willing to pay more than the elderly. The educational level had a significant effect on WTP as well ($p<0.01$). People who have received higher education have a higher environmental consciousness and tend to pay more than the people with lower education level. The significant effect of monthly income ($p<0.01$) on WTP indicates that residents those with relatively higher income could better afford to pay to UGIs. Moreover, the respondents' WTP significantly varied with different study sites ($p<0.05$), while the occupation and visiting frequency had no significant effect on WTP ($p>0.05$).

Table 5. The p-value of Kruskal-Wallis h test between socioeconomic characteristics and people's WTP

	Gender	Age	Education level	Monthly income	Occupation	Visiting frequency	Study site
WTP	0.084	0.003	0.003	0.003	0.394	0.305	0.000

Figure 6 illustrates the distribution of the respondents' WTP on educational level in Guangzhou. Overall, the results showed that 16.5% of respondents who have a relatively lower educational level (i.e. under college degree) would like to pay less than RMB 10/household/yr, while around 18% of respondents would like to pay nothing and 1% of respondents would like to pay over RMB 500/household/yr. But most of higher educated respondents were willing to pay between RMB 10 to RMB 50/household/yr. In the group of RMB 5-10/household/yr, respondents who have bachelor degree is a predominant group (11.2%), which is around three times higher than that under college degree (4%) and almost 4 times higher than that with college degree (3.5%). The effect of educational level was analyzed by using the post hoc test and it was found that the WTP significantly increased with higher educational level.

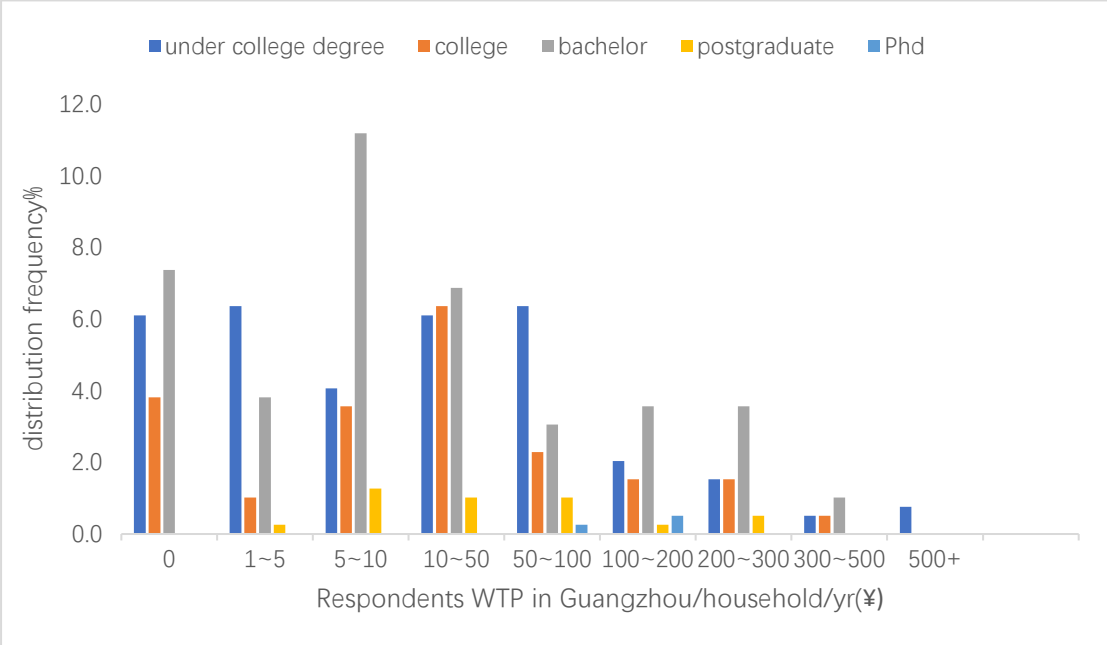

Fig. 6. Distribution of the respondents' WTP on educational level in Guangzhou

The respondents' WTP also showed the different distribution frequencies among the different groups of monthly income. Fig. 7 presents the distribution of the respondents WTP on monthly income level in Guangzhou. The respondents with monthly income < RMB 4,000 were mainly willing to pay less money, i.e. RMB 0-10/household/yr. When the monthly income increased to RMB 6,000-10,000, their WTP raised to RMB 10-50/household/yr. In addition, less than 2% of respondents with monthly income over RMB 6,000, was willing to pay over RMB 300/household/yr. The effect of income was analyzed using the post hoc test. The WTP of the group with income RMB 4,000-6,000/month was lower than the groups with income RMB 6,000-8,000/month, RMB 8,000-10,000/month, and >RMB 10,000/month. It was found that the WTP significantly increased with the increase in income level.

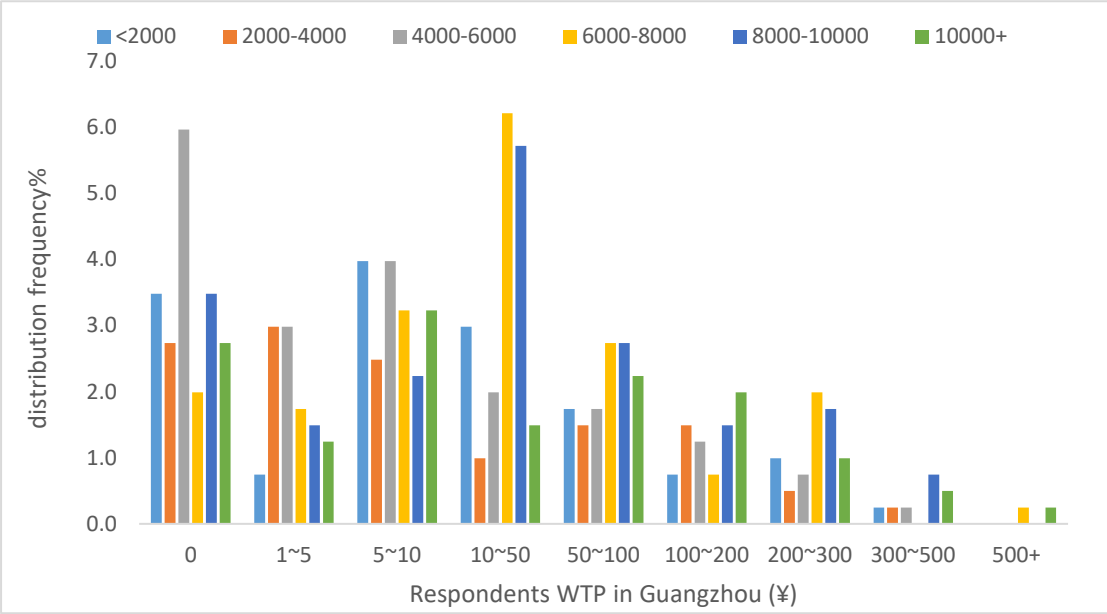

Fig. 7. Distribution of the respondents' WTP on monthly income

5.2 Concern of environmental issues

In Guangzhou, people were facing many environmental issues, such as urban heated island effects, air pollution, noise pollution and etc, especially during the summertime, The respondents were asked to rank these environmental issues in Guangzhou to show their concern about environmental issues. Understanding respondents' concern of environmental issues could help in the designing and managing UGIs, and obtaining a better understanding of people's WTP to ecosystem services of UGIs

In the questionnaire, five environmental issues were listed as: high temperature, air pollution, flood events, noise pollution, biodiversity degradation. The results from Kruskal-Wallis h test showed that the socioeconomic factors significantly influence the ranking of the environmental issues (see Table 6). After comparing the results of questionnaires, it was found that there was a significant difference in ranking noise pollution among occupation, monthly income and visiting frequency ($p<0.05$). No statistically significant association was found in ranking air pollution, high temperature and flood events ($p>0.05$). Furthermore, the educational level had a significant effect on ranking biodiversity degradation ($p<0.05$). The higher educated people took biodiversity degradation more seriously and gave it a higher ranking. The visiting frequency had a significant influence on ranking. Among these respondents, most of the respondents regard to air and noise pollution as the most severe environmental

issues in Guangzhou. High temperature and flood event were regarded as the third and the fourth severe issues, while biodiversity degradation was rated as the fifth severe issue. The results indicated that most residents more focus on the issues which is the most apparently related to their lives.

Table 6. The p-value of Kruskal-Wallis h test between socioeconomic characteristics and ranking environmental issues

Environmental issues	Ranking order[2]	Gender	Education level	Occupation	Monthly income	Visiting frequency
Air pollution	1	0.081	0.132	0.838	0.322	0.692
Noise pollution	2	0.309	0.491	0.038	0.005	0.001
High temperature	3	0.593	0.051	0.970	0.459	0.183
Flood events	4	0.292	0.133	0.788	0.819	0.462
Biodiversity degradation	5	0.261	0.044	0.318	0.447	0.138

Table 7 presents the analysis of the relationship between WTP and the five environmental issues. It shows that air pollution, noise pollution, flood events, and biodiversity degradation had significant effects on respondents' WTP ($p<0.05$), while no significant difference was found between high temperature and WTP ($p>0.05$). The result indicated that residents in Guangzhou were quite adapted with high temperature and this cannot affect their WTP.

Table 7. The p-value of Kruskal-Wallis h test between WTP and ranking environmental issues

	Air pollution	Noise pollution	High temperature	Flood events	Biodiversity degradation
WTP	0.033	0.000	0.093	0.061	0.002

[2] Ranking score: 1= the most severe 2= 2nd severe 3= 3rd severe 4=4th severe 5= 5th severe

6. Attitude of stakeholders toward the current urban green infrastructures in Guangzhou

This section presents the results of the stakeholder analysis. The design and management of UGIs in Guangzhou not only need to be addressed by the government, but also require the participation of others. UGIs serve a variety of citizens' needs (Janse & Konijnendijk, 2007). The decision-making of UGIs is very complex process with various matters to be addressed beforehand, including the designs, locations, costs, and involved stakeholders, etc. (Hjortsø, 2004; Van Herzele et al., 2005).

A traditional top-down approach is not suitable for the Chinese context as it has been criticized to be inappropriate. In China, public participation has been increasingly required by the government in tackling various public issues (Yang et al., 2008).

6.1 Stakeholder hierarchy

As mentioned before, the interviews were carried out with four types of stakeholders: an expert in urban ecosystem services, the local government-Guangzhou Municipal Government, a construction company named Green Town, and local citizens. Before investigating which stakeholders are involved from all those perspectives (private/public, high interest/low interests), it is important to know their degree of influence and dependency. As shown in Fig. 8, the stakeholders have been divided into four sections depending on their degree of interest and power. The local citizens have a high interest in the development of UGIs. However, they do not have the decision power of building it. The same applies to the UGIs' constructors, although they have slightly higher power compared to the citizens. The expert consultants, on the other hand, have a moderate power in the decision-making process but lower interest. Only the Guangzhou municipal has a high interest as well as power in developing the UGIs.

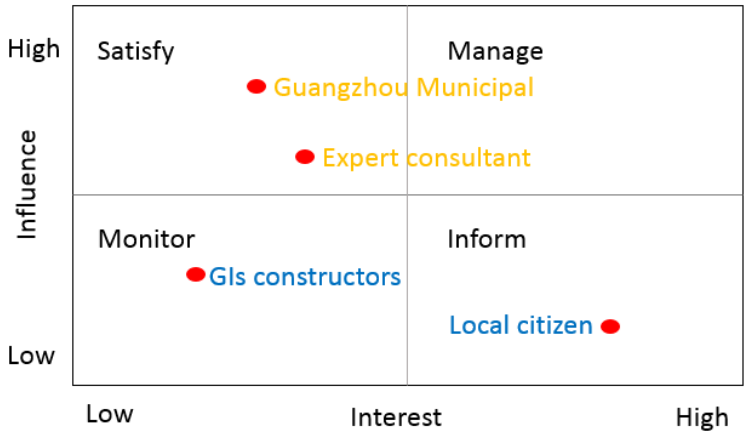

Fig. 8. The importance and interest of stakeholders for UGIs

6.2 The attitude of stakeholders

6.2.1 The attitude of the government

In China, the municipal government owns the land and has the power of city planning. Fig. 9 presents that the urban infrastructures are generated from different sectors and are supposed to serve the public citizens. It can be seen as a simplified process to explain the decision step for urban infrastructures and the roles played by the different stakeholders. The municipal government, Planning and Natural resource Bureau, Finance Bureau are in charge of the design, funding, and management of UGIs. In fact, the Chinese national and municipal governments are very supportive of UGIs' planning. The Chinese government has always emphasized the concept of promoting the construction of ecological civilization. Since the 18th National Congress of the Communist Party of China, Guangzhou has placed the construction of ecological civilization in an unprecedentedly prominent position and entered in a new era. The Guangzhou Government has promoted the prevention and control of air pollution, strengthened the comprehensive management of wastewater treatment, and implemented the green infrastructures. The 13th Five-Year Plan for Energy Conservation and Carbon Reduction in Guangzhou (2016-2020) aims to accelerate the construction of ecological lakes and wetland parks and to improve the urban ecological environment. Several important targets were formulated. For example, the city's forest coverage rate will reach at least 42.5%, and urban household waste harmless treatment

rate will be 100% by 2020. Specifically, the city council affirmed that current urban planning policies give the highest priority to UGIs because they fit the national goal and public needs. Guangzhou would implement green roof renovation and try to achieve a total area of 2.5 million square meters covered by UGIs by 2020.

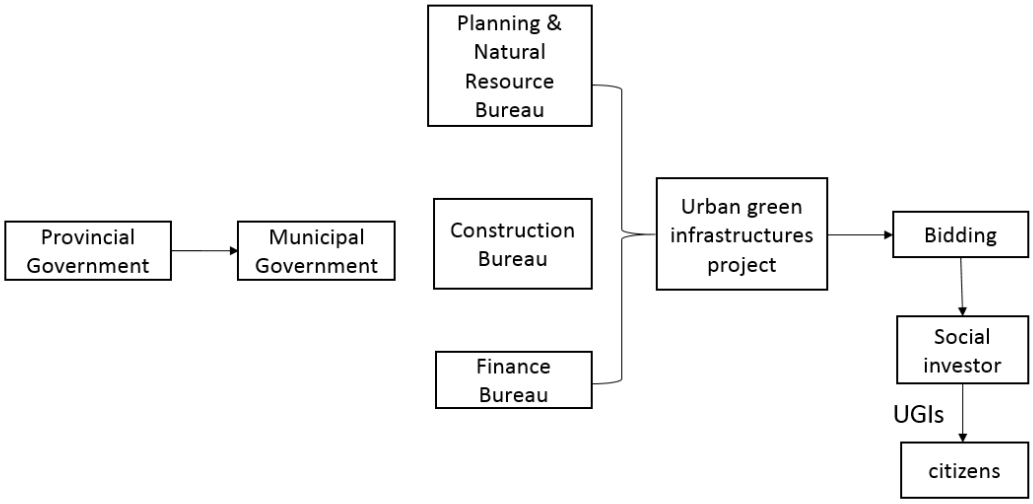

Fig. 9. The institutional context of urban infrastructure managing in Guangzhou, China

6.2.2 The attitude of other stakeholders

The residents, university professors and private companies, such as construction company, were also involved in UGIs' development and management. During the interview, most interviewees had good perception and rated the UGIs fairly well in Guangzhou. Meanwhile, they were satisfied with the condition of UGIs in Guangzhou. When asking if they were willing to participate in the planning and management of UGIs, the expert in urban planning and the employee from a private company named Green Town stated that they were already involved in these actions. Both of them participated in the evaluation and construction of UGIs in Guangzhou. The interviewees held positive attitudes toward UGIs and were willing to participate in the decision-making of UGIs. This result is in line with the finding of Shan (2012) showing that Guangzhou residents held positive attitudes toward UGIs (Shan, 2012). One of the interviewees said that society should be involved in UGIs planning and management more actively to make policymakers and urban planners know more exactly what the

residences demand about UGIs. Currently, a top-down approach is still dominant in urban planning in China. However, there is a need to bring the public and government together in urban planning to enhance the quality of UGIs.

7. Discussion

7.1 Discussion of the research method

In contingent valuation, several potential limitations probably occur from the sampling, questionnaire design, information provided to respondents, respondent's understanding on the questions, and respondents' understanding on their preference (Alberini et al., 2003). For example, the Chinese public is not familiar with the idea of 'paying' the urban ecosystem services or public goods. During the distribution of the questionnaire, many respondents had difficulties in understanding the WTP for the UGIs. Regarding this question, further research could focus on the interpretation of WTP for targeted residence group or providing more realistic details about the hypothetic scenario. Besides, an open-end WTP bidding list (e.g. box, card or table) showing the specific bidding value (i.e. 0,1,5,10,20,30,40) is suggested. In this current case, bidding ranges, like 1-5 and 10-50 were used. This probably leads to uncertainty when people choose WTP bidding value. Such range could not present the actual WTP. In addition, respondents are recommended to revise the stated WTP at the end of the interview and allowed to state their own WTP if the WTP amount is not in the bidding list. To avoid their misunderstanding of the question as a request for real payment, a clear message should be given before respondents stating their WTP, for example, highlighting the WTP unit (i.e. household^{-1}yr^{-1}, person^{-1}yr^{-1}, person^{-1}month^{-1}). In this study, the WTP unit household^{-1}yr^{-1} has been used. Some respondents chose a WTP bidding value without noticing the unit. Such misunderstanding might lead them to vote a lower payment regardless of their real preference, or even lead to an interruption of the interview. Finally, a pilot test is highly recommended. It helps with revising and modifying the questions. In my study, I did the pilot test to help me revising and modifying the questions, to reduce the misunderstanding uncertainties.

7.2 Discussion of the results

The results showed that the measured air temperature, relative humidity, $PM_{2.5}$, and PM_{10} concentrations are higher than the observed values from the local monitoring station in sub-area of Guangzhou city on the same date (see Figure 10 through 13). Monitoring temperature and humidity data were obtained from Guangzhou Meteorological Insititute's website and the monitoring site was set in Sun Yat-sen

Avenue. $PM_{2.5}$, and PM_{10} concentrations data were gathered from the National Meteorological Information Center, the monitoring site was in Tiyu Xi. The three study sites and the monitoring sites are located in the center of the city with high population density and crowdy living environment. It is surprising that those measured data were higher than the monitored in my study. The reason could be that the monitoring sites are near the study sites, but still are hundreds of meters away from study sites. Such distance could lead to a different result. Moreover, previous studies often use models (e.g. UFORE) to calculate the removal of the air pollutants. Due to the limited time and resources, this calculation was not included in this study. Besides, the noise detector sometimes did not work properly, when doing the noise measurement at green wall study site, and lead to invalid data. During the data analysis, the noise data from green wall were deleted. In addition, no control group was set. This would lead to uncertainties in the field measurement result, and could not justify the role of UGI.

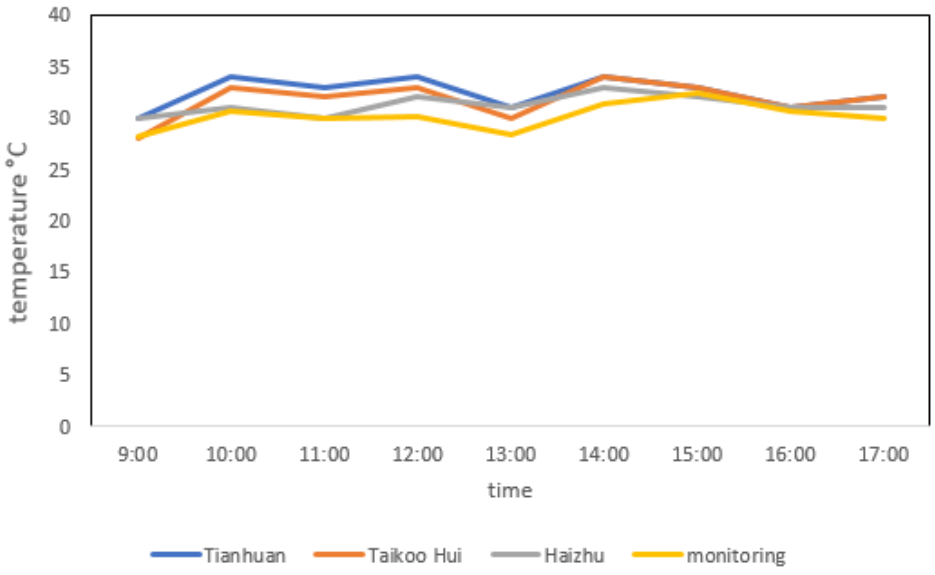

Fig. 10. Temperature from Monitoring data compared with Field measurement data
Sources: http://www.tqyb.com.cn/

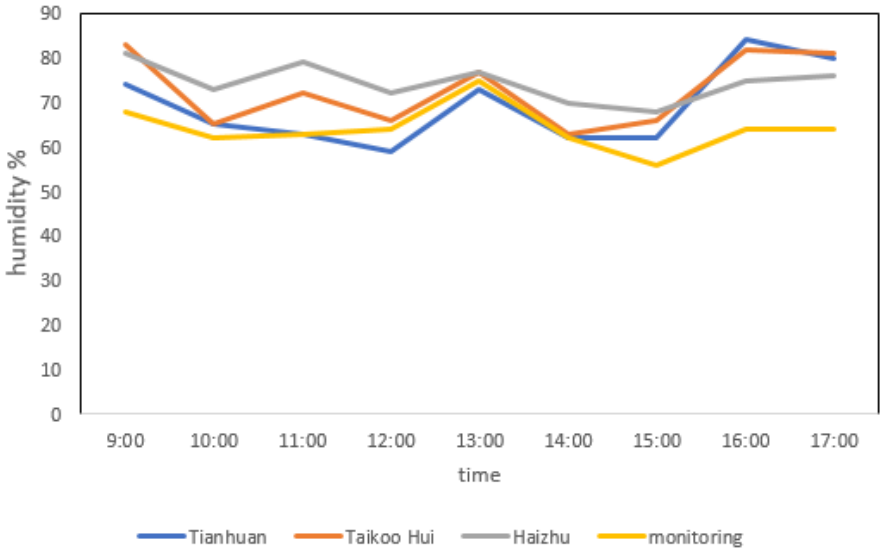

Fig. 11. Humidity from Monitoring and field measurement
Source: http://www.tqyb.com.cn/

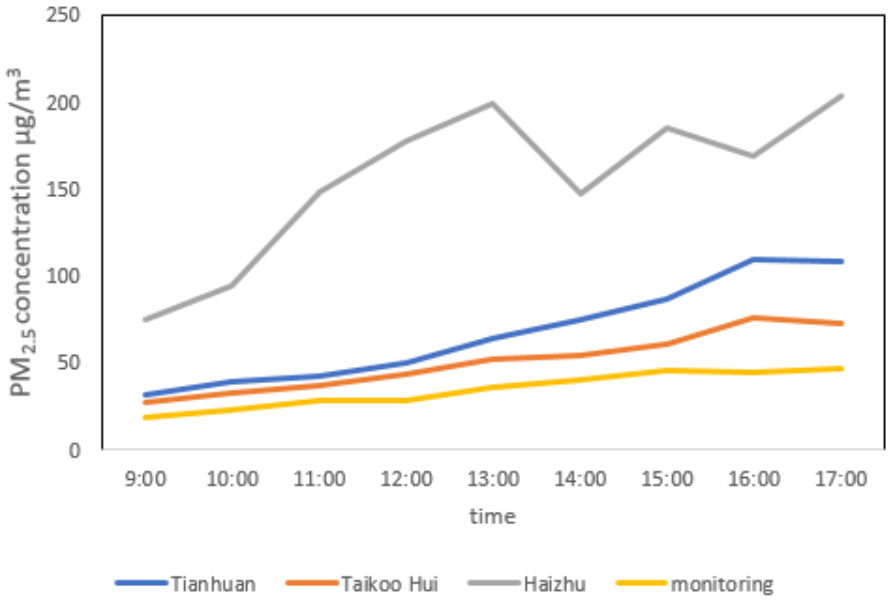

Fig. 12. $PM_{2.5}$ concentration from Monitoring and field measurement
Source: http://www.cma.gov.cn/2011qxfw/2011qsjgx/

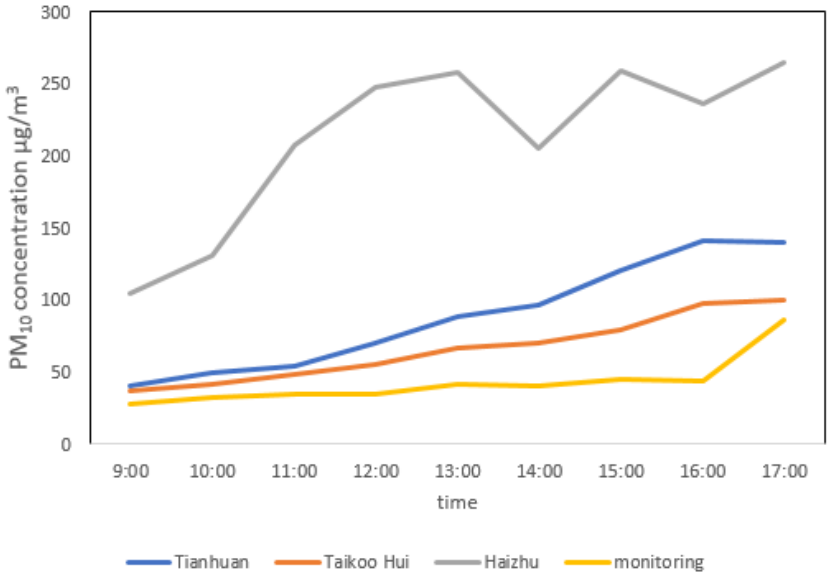

Fig. 13. PM_{10} concentration from Monitoring and field measurement
Source: http://www.cma.gov.cn/2011qxfw/2011qsjgx/

The results of the questionnaires suggested that Guangzhou's residents have a strong preference for the relatively large UGIs. This finding was in agreement with the previous study (Jim & Chen, 2006a). People prefer larger UGIs (in this case, green lane) because of the more natural landscape, or the better green view with fresh air, etc. However, uncertainty could exist in the result of the questionnaire, probably caused by the invalid answers. Some respondents with less high education were not willing to fill the questionnaires because they thought they knew nothing about UGIs, and not all people knew about green roof or green wall. Therefore, much more people preferred the green lane. In China, residences are not familiar with the idea of WTP for UGIs, or the way to pay for using and maintaining the services provided by UGIs. Thus, it's a bit difficult for respondents in this study to understand and when it comes to WTP, the respondents inclined to choose lower payment. Some respondents misunderstood the target of questionnaire or WTP and announced they did not want to pay for those UGIs or they had no cash, this leads to a lower payment. In some cases, the respondents even thought that they were asked to pay to the interviewer at that time. When these occurred, interviewers kindly reminded them to respond based on their actual feelings and explained that this question is asked to indicate their own preference and is not related

to real money. Sometimes, it happens that lower-income people indicated a high payment, higher income people showed a low payment. This is probably because that the lower income people are retired and visited the UGIs quite often, hence they are willing to pay more for the UGIs. Those who are not willing to pay tended to consider the UGIs as a public property which should be taken care by the government or they did not believe the money would be actually used on UGIs. Recently, more and more Chinese have gradually recognized the importance of UGIs and their roles in the sustainability of urban development (Cao et al., 2017; Chen et al., 2012; Jim & Chen, 2006b). Only when people truly understand the value of UGIs and ecosystem services provided by them, and actively participating in urban planning, can the city be better designed and managed to improve environmental quality in the future. The annual mean WTP of this study was RMB 29 household^{-1} (US$4.4 household^{-1}), and amounted to RMB 580 household^{-1} (US$85.3 household^{-1}) over twenty years. As the computation included only the affected population living in Guangzhou, it might underestimate the monetary value of UGIs. Moreover, the CVM excluded the value that could be attributed to some actors, such as those dwelling outside but travel to green sites in the study area, and non-citizens living in the study area.

7.3 Comparison with other studies

Not many contingent valuation surveys were conducted in Guangzhou so far. Conducting a contingent valuation survey needs to consider its applicability and the deeper meanings of the estimated value. The previous studies showed the applicability of the CVM in China (Wei et al., 2014; Xin & Jianzhang, 2012; Xu et al., 2003). This study also indicated that well-designed and refined questionnaire could help to apply the CVM in China.

The questionnaire results suggested that the WTP of residents in Guangzhou city for using and maintaining UGIs is lower than those in other case studies (Cao et al., 2017; Jim & Chen, 2006b). Jim & Chen (2006b) calculated the WTP in Guangzhou as US$65.9 million yr^{-1}, Cao et al. (2017) calculated the annual WTP in Chengdu as US$62 household^{-1}. In my study, annual WTP was calculated to be US$18.6 million and US$4.4 household^{-1}. The reason for this big difference might be that this study used household^{-1}yr^{-1} as the unit of analysis. Some respondents are not aware of stating their

WTP as household. They ignored the WTP unit (household^{-1}yr^{-1}). The WTP to UGIs in Guangzhou showed that people are willing to pay for the services generated by UGIs. The WTP for UGIs seems to be a common perception, transcending geographical and cultural divides. The results show that most residents in the urban area are willing to pay for using and maintenance of the UGIs, implying that citizens are aware of the importance of UGIs. Nevertheless, 20% of respondents were unwilling to pay, partly because they have no demand for UGIs or no ability to afford the entrance fee. Others thought it should be the government that covers the cost rather than citizens.

This study also revealed that people's age, educational level and monthly income affected their WTP. Previous studies also reported similar findings that educational level, income, age was significantly associated with the WTP. Age had a negative association with WTP; income and educational level had a significant positive influence on WTP; people who are with relatively higher income and higher educational level could better afford it (Cao et al., 2017; Jim & Chen, 2006a, 2006b; Lo & Jim, 2010; Mei & Weiping, 2011). These results are also in agreement with the findings from this study, age had a negative association with WTP, income and educational level had positive influences on WTP.

8. Conclusion

This study investigated the three ecosystem services (i.e., air quality regulation, temperature regulation, and noise control) generated by the three popular new types of UGIs (i.e., green roof, green wall, and green lane) and explored Guangzhou residents' WTP for these UGIs.

Selected ecosystem services of the three UGIs

In this study, a statistically significant association between targeted UGIs and measured ecosystem services was found. The targeted UGIs had a significant difference in air temperature, $PM_{2.5}$ and PM_{10} concentration ($p<0.01$). In this case, green roof had the lowest concentrations of $PM_{2.5}$ and PM_{10}, whereas green lane had the highest concentration. Moreover, green lane had the lowest temperature with the average air temperature of 25.3°C, while the average air temperature in both green roof and green wall was around 26.7°C. The result from field measurement also suggested that meteorological factors have significant effects on $PM_{2.5}$ and PM_{10} concentrations. It showed that $PM_{2.5}$ and PM_{10} concentrations increase when relative humidity and temperature go up. The change of PM_{10} concentrations is greater than the variation range of $PM_{2.5}$ concentrations in the same period (Fig. 3).

Citizen's willingness-to-pay for the three UGIs

This study explored people's WTP for UGIs and their understanding of the importance of ecosystem service by applying CVM method. In total 430 questionnaires were filled in, with 409 questionnaires were used for analysis, and 21 questionnaires were discarded because of uncompleted response and invalid answers. The survey result showed that the WTP of residents for using and maintaining UGIs were respectively RMB 29 per household per year ($4.4/household/yr) and RMB 126 million per year ($18.6 million/yr). This result indicated that people in Guangzhou were willing to pay a notable sum for urban green space.

Factors affecting citizen's willingness-to-pay

The WTP for UGIs was influenced by socioeconomic variables. In this study, age, educational level, monthly income, and study sites were found to affect the WTP of

respondents. The younger people would like to pay more than elderly people, especially those who are 18-35 years old would like to pay RMB 10-50/household/yr. Generally, people with lower education and income would like to pay less or nothing. In contrast, people with higher education and monthly income over RMB 6,000 would like to pay RMB 10-50/household/yr. People, who would like to pay less or nothing, perceived UGIs as not important and tended to underestimate the value of ecosystem services provided by UGIs. This perception gap calls for education and publicity to achieve a wider recognition of the importance and value of UGIs.

Attitude of stakeholders towards the three UGIs

The attitude of stakeholders towards UGIs in Guangzhou was quite positive. Most of the respondents rated the UGIs fairly well and were satisfied with the condition of UGIs in Guangzhou. The results contributed to the integrated understanding of UGIs, urban ecosystem services, and people's preference. The results provided useful information for researchers and policy-makers to select better methods and projects to improve UGIs. The local government paid little attention to citizen's concerns and aspirations that often stress the practical considerations from their perspective. There is a need to bring the government and other stakeholders together and merge their respective outlooks so that UGIs could truly serve the local users. To achieve this goal, the government should encourage other stakeholders to take part in the UGIs' decision-making process, and they need to provide public more information on urban ecosystem services through a public education program or non-profit advertisement.

The findings of my study fill the gap of understanding and appreciation of residents towards the benefits of UGIs. It showed that people have a strong preference for a larger UGI and are willing to pay for them. This study explored the relationship between general socioeconomic characteristics with UGIs and found that people's WTP is related to age, income and educational level. Therefore, the education and publicity programs for UGIs should be launched with various groups of people in the future to achieve a comprehensive understanding and knowledge of the public on UGIs and their ecosystem services.

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Annex

Annex1: Performances and measurements of three urban GIs ecosystem services in Guangzhou

Services	Function	Indicator	Method	Instrument	time
Temperature regulating	Influence of ecosystems on local through land-cover and biologically-mediated processes	temperature	Conducting the different GIs' temperature from indoor and outdoor at different time.	Hydro-thermometer	September-October
Air quality regulation	Capacity of ecosystems to extract aerosols & chemicals from the atmosphere	The Amount of PM2.5 ''extracted''— effect on air quality	Measuring the PM2.5 from different places	Air quality monitor-CW-HAT200s	September-October
Noise control	In row plantings of trees, sound waves are reflected and refracted, dispersing the sound energy	traffic noise exposure	Measuring the noise from traffic	Noise dosimeter	October
Aesthetics	Aesthetic quality of the landscape, based on e.g. structural diversity, ''greenness'',	Expressed aesthetic value, e.g.: Number of houses bordering natural areas	Investigate plant species and residents' evaluation of the GI	Questionnaire	October

Annex2: Questionnaire on public preference for ecosystem services of urban green infrastructure

Date: ……; Time: …… ;

Location: ……; No.: ……..;

（filled by researcher）

First part

Age**:** …… Gender**:** M / F

Living period in Guangzhou**:** ……;

Birth city **:** ……..……..;

Occupation:

□student □employed □retired

□unemployed □other……;

Education:

□primary school □junior high school □senior high school □college

□undergraduate □graduate □PhD

Monthly income(¥):

□<2000 □2000-4000 □4000-6000 □6000-8000

□8000-10000 □10000+

Second part

1a. have you ever been this urban green infrastructure ?

☐yes ☐no

1b. would you like use other green infrastructure to replace this green infrastructure ?

☐yes ☐no

If yes, which one you would like choose to replace the old one:

□urban forest □green roof □green wall □green lane

□urban park □wetland □other____

2. how often do you come to this green infrastructure ?

□everyday □weekly □monthly □hardly ever

3. how long it will take you to get the green infrastructure?

□< 10 minutes □ 10-30 minutes □30-60 minutes □> 60minutes

4. which transportation you usually use

□walking □bicycle □public transportation

□private cars □taxi □others_

5. what kind of cost you will spend during you visit the green infrastructure and how much is it?

□transportation fee___¥ □dining fee__ ¥ □accommodation fee__ ¥

□entry tickets__¥ □shopping cost__¥ □others__ ¥

6. which environmental issue is more serious in Guangzhou, please ranking them from 1-5. (1:the most serious, 5: the most not serious)

□high temperature □air pollution □flood events

□biodiversity degradation □noise pollution

7a. Do you think the green infrastructure has the following functions? (multiple choices)

□temperature regulation	□air purification	□runoff regulation	□noise reduction
□sightseeing spot	□aesthetic value	□education information	□biodiversity protection

7b. How much would you like to pay for the function you choose, per year, per household, in 20 years

□¥ 0	□¥ 1-5	□¥ 5-10
□¥ 10-50	□¥ 50-100	□¥ 100-200
□¥ 200-300	□¥ 300-500	□¥ 500+
□other__		

8. Would you like spend the money on the following functions? (0-4, 0: very unlikely, 4 extremely likely)

□temperature regulation	□air purification	□runoff regulation	□noise reduction
□sightseeing spot	□aesthetic value	□education information	□biodiversity protection

9. In which way you would like to pay the money

□included in electricity fee	□ecological tax
□volunteer for managing the green infrastructure	□cash

Annex2: Chinese version of questionnaire

公众对小型绿色设施生态功能支付意愿的社会调查

日期: ……; 地点: ……; 编号: ……..;

（以上部分由调查人员填写）

年龄: ……..; **性别:** 男 / 女

居住在广州的时间: ……; **原籍:** ……（省份/直辖市）;

就职情况: 学生 / 在职 / 退休 / 待业 / 其他……;

学历：小学 /初中 /高中 /大专 /本科 /研究生 /博士

月收入情况： ☐ <2000 ☐ 2000-4000 ☐ 4000-6000 ☐ 6000-8000
☐ 8000-10000 ☐ 10000+ ☐ 其他……;

1a. 你是否曾经到访过植物绿墙？ *（请参考图片）*

☐ 是 ☐ 否

1b. 如果用下列其他绿色设施之一来替代植物绿墙，你是否愿意？*（请参考图片）*

☐ 是 ☐ 否

如果是，你希望是（可多选） ☐ A.城市小树林 ☐ B.绿色屋顶 ☐ C.绿道
☐ D. 公园 ☐ E. 湿地 ☐ D. 其他……;

2. 你去植物绿墙的频率大概是？

☐ 每天 ☐ 每周……次 ☐ 每月……次 ☐ 几乎不来

3. 大多数情况下，你到植物绿墙的路途上所花费的时间大概是？

☐ 小于 10 分钟 ☐ 10-30 分钟 ☐ 30-60 分钟 ☐ 60 分钟以上

4. 大多数情况下，你到植物绿墙的所使用的交通工具大概是？

☐ 步行　　☐ 骑自行车　　☐ 坐公共交通　　☐ 私家车

☐ 出租车　　☐ 其他……;

5. 你去植物绿墙有以下哪些费用？

☐ 总往返交通费……¥　　☐ 餐饮费……¥　　☐ 住宿费……¥

☐ 门票……¥　　☐ 购物……¥　　☐ 其他……¥

6．下列环境风险你认为哪些在广州更为严峻？请按照从 1 至 5 排序。 ***(1 最严重，5 最不严重)***

☐ 高温天气　　☐ 空气污染　　☐ 城市内涝

☐ 噪音严重　　☐ 生物多样性退化

7a. 你认为植物绿墙具有以下哪些服务作用？ ***(可多选)***

☐ 调节温度　　☐ 净化空气　　☐ 调节雨水流量和水质　　☐ 减少噪音

☐ 景观游憩　　☐ 美学价值　　☐ 教育科研价值　　☐ 生态多样性保护

7b. 就以上你选择的服务，**你是否愿意未来 20 年里每年支付一定的费用用于管理和维护植物绿墙？**

☐¥ 0　　☐¥ 1-5　　☐¥ 5-10

☐¥ 10-50　　☐¥ 50-100　　☐¥ 100-200

☐¥ 200-300　　☐¥ 300-500　　☐¥ 500+

☐other__

8c. 你是否愿意将支付的费用用于享受下列服务功能？（***0-4，0：非常不愿意，4：非常愿意***）

a.降低温度　　……..　　b.净化空气　……..　　c.调节雨水流量和水质　……..

d.景观游憩　　……..　　e.美学价值　……..　　f.教育科研价值　　……..

h.生态多样性保护　……..　　i.减少噪声　……..

9. 你愿意以何种方式支付 **6b** 所选费用？

☐ 包含在水电费范围内　　☐ 上交生态税　　☐ 义务劳动和管理该处设施　　☐ 直接资金支付

Annex3: Field measurement results

Table 9. field measurement results for $PM_{2.5}$

Period	green wall		green roof		green lane	
9:00		120	27	27	349	349
9:30		108	29	29	372	372
10:00	283	283	154	154	367	367
10:30		260	174	174	416	416
11:00	410	410	181	181	451	451
11:30	325	325	176	176	519	519
12:00	313	313	165	165	431	431
12:30	357	357	166	166	419	419
13:00	341	341	0	170	502	502
13:30	335	335	173	173	497	497
14:00	276	276	159	159	471	471
14:30	265	265	219	219	394	394
15:00	299	299	287	287	404	404
15:30	250	250	277	277	402	402
16:00	202	202	214	214	376	376
16:30	154	154	127	127	368	368
17:00	154	119	116	116	267	267
Ave	242.9		155.9		400.3	
SD	28.8		19.9		24.0	

Table 10. field measurement results for PM_{10}

Period	green wall		green roof		green lane	
9:00			37	37	488	488
9:30			40	40	520	520
10:00	396	396	200	200	477	477
10:30			226	226	540	540
11:00	533	533	235	235	631	631
11:30	422	422	246	246	674	674
12:00	406	406	231	231	603	603
12:30	464	464	215	215	544	544
13:00	443	443		216	702	702
13:30	435	435	224	224	695	695
14:00	358	358	206	206	659	659
14:30	344	344	284	284	551	551
15:00	388	388	401	401	565	565
15:30	325	325	387	387	562	562
16:00	262	262	278	278	526	526
16:30	200	200	165	165	478	478
17:00	154	154	150	150	373	373
Ave	320.6		207.6		547.9	
SD	40.2		27.2		33.1	

Table 11. field measurement results for air temperature

Period	green wall		green roof		green lane	
9:00	27	27	28	28	26	26
9:30	26	27	31	31	26	26
10:00	25	25	26	26	26	26
10:30	26	28	25	25	25	25
11:00	26	26	26	26	25	25
11:30	28	28	26	26	25	25
12:00	28	28	27	27	26	26
12:30	27	27	25	25	26	26
13:00	28	28	25	25	26	26
13:30	29	29	26	26	25	25
14:00	28	28	27	27	26	26
14:30	28	28	28	28	26	26
15:00	28	28	29	29	26	26
15:30	29	29	29	29	28	28
16:00	28	28	30	30	27	27
16:30	27	27	30	30	27	27
17:00	27	27	30	30	27	27
Ave	26.7		26.7		25.3	
SD	1.2		1.3		1.2	

Table 12. field measurement results for humidity

Period	green wall		green roof		green lane	
9:00		82	83	83	86	86
9:30		84	71	71	88	88
10:00	96	96	87	87	92	92
10:30		97	97	97	96	96
11:00	96	96	96	96	99	99
11:30	89	89	94	94	99	99
12:00	88	88	84	84	98	98
12:30	89	89	93	93	97	97
13:00	93	93	92	92	98	98
13:30	83	83	90	90	98	98
14:00	82	82	86	86	95	95
14:30	84	84	81	81	91	91
15:00	86	86	78	78	90	90
15:30	77	77	75	75	82	82
16:00	82	82	74	74	85	85
16:30	87	87	74	74	87	87
17:00	86	86	73	73	87	87
Ave	76.1		78.6		89.6	
SD	7.7		5.6		4.3	

Table 13. field measurement results for noise

noise	green roof	green lane
9:00	55.6	57
10:00	64.3	57.5
11:00	55.6	57.8
12:00	57.1	55.2
13:00	60.3	53.2
14:00	70	52.6
15:00	60.6	51.4
16:00	62.8	58.3
17:00	55.9	59.3

Annex4: Questionnaire result

Table 8 Socioeconomic characteristics of the respondents

Social variable	category	Respondents (%)
Gender	Male	49.3
	Female	50.7
Educational level	Primary school	2.8
	Junior high school	11.2
	Senior high school	22.5
	College	19.8
	Bachelor	38.9
	Graduate	4.2
	PhD	0.6
Monthly income (¥)	< 2000	14.6
	2000-4000	12.7
	4000-6000	18.8
	6000-8000	18.8
	8000-10000	19.2
	10000+	14.6
	Other	1.3
occupation	Student	15.1
	Employee	67.8
	Retire	5.9
	Unemployed	2.0
	Others	9.2