

# **Residents' understanding of the role of green infrastructure for climate change adaptation in Hangzhou, China**

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## Research highlights

- Urban green-space use impacts green infrastructure efficacy for climate response
- Green-space users may support tree planting for climate adaptation
- Tree planting support appears related to user's age and perceived economic impacts
- Intensity and frequency of recreational use may not predict urban greening support

## 1. Introduction

The concept of ‘green infrastructure’ is rapidly gaining traction in urban planning and environmental management, evidenced by a burgeoning literature on the topic, and by increasing policy uptake. This is especially evident in the potential use of green infrastructure for climate change adaptation. Land use planners, environmental managers and policy makers are increasingly responding to the failure of the international community to reach consensus over strategies for climate change mitigation by directing their efforts towards adaptation initiatives, such as urban greening (Brown, 2011; Bulkeley, 2013; Mees & Driessen, 2011; Emmanuel and Loconsole, 2015; Klemm et al., 2015). Much recent planning and urban design research has investigated how best to adapt urban environments to expected climate change impacts, including better understanding the barriers and enablers to adaptive responses (e.g. Castán Broto & Bulkeley, 2012; Matthews et al., 2015). Using ‘green infrastructure’ for climate adaptation such as green walls, green roofs, urban trees and designed wetlands (Byrne & Yang, 2009; Gill et al., 2007; Abreu-Harbich et al., 2015; Jim, 2015), is increasingly justified by the manifold benefits that such interventions purportedly confer upon urban residents (Byrne & Yang, 2009; Jim, 2011; Lo & Jim, 2012; Roy et al. 2012). While the idea is tantalizing, we presently lack detailed research on the efficacy of green infrastructure for climate change adaptation, especially its acceptability to urban residents and to users of urban green-spaces.

Green infrastructure is believed to possess considerable potential to adapt cities to some emerging climate change impacts such as heat-island impacts, increased flooding, higher wind speeds and more episodic rainfall, especially in higher-density cities where larger green-spaces may be scarce (Brown et al., 2015; Demuzere et al., 2014). Essentially this ecological

modernization response deploys biotechnology and ‘soft’ engineered biological spaces to ameliorate some urban problems including heat, air pollution, and storm-water runoff (Byrne et al., 2009; Howes et al., 2010). This paper reports the results of research investigating citizens’ dispositions towards the use of tree-planting in parks and public green-spaces as a potential climate change adaptation response in Hangzhou, China. Hangzhou is a useful case study because it is a rapidly growing, high-density city with limited green-space in the urban core. Brown et al., (2015) note that many rapidly growing cities globally are in temperate and warm climate regions where heat impacts will manifest strongly; insights from Hangzhou can inform planning in those cities.

We ask the following three research questions: (1) Does the knowledge of Hangzhou residents about climate change, their perception of climate risks, and their understanding of potential adaptive responses, shape their disposition towards the use of green infrastructure (tree-planting) as a climate adaptation intervention?; (2) Do residents’ patterns of green-space use affect their level of acceptance of increasing vegetation density to combat climate change impacts?; (3) Do the socio-demographic characteristics of green-space users play a role in their knowledge about climate change and their attitudes towards using green infrastructure as a climate change adaptive response? The answers to these questions are import because they can inform planners’ understanding of how best to communicate the climate adaptive benefits of urban trees (as a form of green infrastructure) to the general public. Answers can shed light on an understudied aspect of green infrastructure, and thus address an important knowledge gap.

## **2. Background**

Green infrastructure is a term that has been broadly defined in the literature to refer to: “either investment in green-space or as infrastructure with a sustainable objective” (Mell, 2012: 2). While some authors have tended to conflate green infrastructure with green-space generally (e.g. Vandermeulen et al., 2011), the two terms refer to different ideas and should not be used interchangeably. Nor should green infrastructure be thought of as regular infrastructure (e.g. light rail) with ‘green’ benefits. It is useful to briefly review the definition of green infrastructure here, for the purpose of conceptual clarity.

### *2.1. Definition of key terms*

This paper discusses climate change adaptation and in some places climate change mitigation. Mitigation refers to actions to slow, reduce or reverse anthropogenic impacts on the atmosphere, such as reducing carbon dioxide and methane emissions from power stations, switching to alternative energy or energy efficient appliances, promoting public transport use, or planting very large forests to act as carbon sinks (Castán Broto and Bulkeley, 2012). We are not talking about mitigation in this paper, nor do we argue for macro-climatic mitigation functions of urban trees and green infrastructure. We also use the term adaptation. Adaptation refers to actions taken to adjust human settlements (and behaviors) to the anticipated impacts of climate change. If climate change is expected to increase temperatures, raise sea levels or cause flooding of low-lying land during extreme storm events, then adaptive responses include actions such as using insulation in buildings (or green roofs), relocating populations away from floodplains, increasing the height of river levees, or raising the height of buildings above projected flood levels, and using sea walls to reduce coastal erosion (Byrne et al., 2009).

What we are referring to when we talk about green infrastructure are highly modified or engineered ‘intentional landscapes’, not those which are characterized by vegetated natural remnants or left-over spaces occupied by spontaneous vegetation. Roe and Mell (2013) stress that what sets green infrastructure apart from regular green-space is an emphasis on human modification and recognition of the ecosystem services (e.g. water purification, heat reduction) provided by these intentionally designed spaces (see also Lovell & Taylor, 2013). The key idea behind green infrastructure is that it is purposeful, intentional, designed, and deployed primarily for widespread public use and benefit (Beer, 2010), and in this way, it functions like other forms of infrastructure (e.g. highways, power transmission lines, telecommunication cables or airports). To paraphrase Mell et al. (2013: 297) it might best be thought of as: “the biological resources in urban areas that are human modified and primarily serve an overt [socio]ecological function”.

Green-infrastructure is thus comprised of: “parks, public green-space, allotments, green corridors, street trees, urban forests, roof and vertical greening” among other interventions (Cameron et al., 2012: 129). While the term green infrastructure excludes naturally occurring green-spaces such as forest remnants, it encompasses other green and blue spaces such as community gardens, constructed wetlands, green roofs, green walls and greened alleyways, because these spaces are human-modified landscapes, which have been specifically designed and used for social and economic benefits. Green infrastructure is not standard infrastructure that is given a green wash or green spin for its purported sustainability benefits (e.g. wind-farms, co-generation plants, or genetically modified agriculture), but it can refer to the application of biotechnology to existing infrastructure, such as ecologically restored storm-water infrastructure (Hostetler et al., 2011).

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94           Green infrastructure will typically be publicly or communally owned. Moreover, it  
95 usually takes the form of a network of spaces, such as parks or greenways, rather than solitary  
96 and/or fully private spaces, such as backyard gardens (Mell et al., 2013). Green infrastructure  
97 may include corporately or communally-owned spaces such as power transmission corridors,  
98 easements, alleyways and even parking lots, but only if these have been actively (re)designed to  
99 include extensive vegetation and are intended to meet multi-purpose objectives such as  
100 recreation, habitat provision, storm-water attenuation and/or carbon sequestration (Gaffin, et al.,  
101 2012; Lovell and Taylor, 2013; Newell et al., 2013).

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103           We recognize that this conception of green infrastructure challenges some established  
104 definitions, which include what might be called ‘natural’ areas. Our intent is not to perpetuate a  
105 schism about human-nature duality, we recognize that cities are social and ecological entities  
106 (Byrne, 2011), and we see green infrastructure as a socio-natural assemblage. Two reasons  
107 inform our alternative perspective. First, we wish to address the ambiguous and sometimes  
108 misleading claims made by some commentators about the extent of ecosystem service benefits  
109 derived from green infrastructure, based on the inclusion of large forest tracts, broad open spaces  
110 and remnant vegetation in their definitions. Second, and more importantly, there is a very real  
111 risk that characterizing all urban greenery as ‘green infrastructure’ will undermine the  
112 conservation and environmental protection value of lesser disturbed remnant sites, large tracts of  
113 open space, or sites less exposed to anthropogenic impacts, such as urban protected areas. They  
114 will become devalued because they can be subsumed into a philosophy that the biosphere is

available for human appropriation. Such protected areas and reserves can then easily be coopted as just another type of ‘infrastructure’ for human use. This is not an outcome we endorse.

We also note that there is little variation in Chinese and Western conceptions of green infrastructure, possibly because the Chinese literature on green infrastructure has yet to develop. Much of the existing discussion in Chinese journals simply follows international trends, and Chinese scholars are yet to generate and apply a ‘domestic’ definition. Chinese studies are currently limited to trying to introduce, explain and test existing definitions from the international literature, and Chinese scholars are yet to evolve locally specific conceptualizations (Zhang, 2004; Zhang 2009).

## *2.2. Why use green infrastructure for climate adaptation?*

The idea of using green infrastructure for climate change adaptation is relatively recent (Byrne & Yang, 2009; Gill et al., 2007). Planners often regard green infrastructure favorably because it can be seen as a useful tool in a ‘no regrets’ approach to climate adaptation (Heltberg et al., 2009; Mees & Driessen, 2011; Roe & Mell, 2013). Employing green infrastructure can foster a wide range of ecological, social and economic benefits (e.g. improving mental health, increasing physical activity or reducing energy consumption), irrespective of how fast and to what extent climate change impacts manifest in different urban environments (Austin, 2014; Demezure et al., 2014; Wright, 2011).



Green infrastructure may be attractive to planners because it can be less politically contentious than other climate change adaptive responses, and may have broader public appeal (Matthews et al., 2015). Fewer people would likely contest a city-wide street tree program compared to relocating populations away from floodplains, increasing the height of levees, compulsory retrofitting of buildings with insulation or double-glazing, or increased rates or morbidity and mortality from heat-stress (Vollmer et al., 2015). Moreover, improved aesthetics, increased property values, modulated ambient temperatures and reduced storm-water runoff associated with citywide greening have been found to engender widespread citizen support (Jones et al., 2013). However, we acknowledge that tree-planting can be contentious in some cities where proponents may encounter property developer or citizen resistance (Kirkpatrick et al., 2012, 2013; Young and McPherson, 2013), and the ecosystem disservices of some tree species may be harmful to health and property, potentially limiting public support (Roy et al., 2012).

Urban trees are the form of green infrastructure that has received considerable attention as a potential climate change adaptation strategy – via planting out existing green-spaces, adding new street trees, retrofitting ‘grey-spaces’, and boosting the overall area of urban forests. Researchers have been attracted to quantifying the benefits of urban trees that are directly related to climate change adaptation. These include: cooling heat islands, reducing electricity consumption, lowering storm-water runoff and lowering mortality and morbidity associated with heat waves (Bowler et al., 2010; Roy et al., 2012).

Studies have found that built environments could be retrofitted through urban greening to potentially increase tree cover by up to 5% and thus reduce diurnal temperatures by as much as 2.3°C (Hall et al., 2012; see also Hamada & Ohta, 2010). Modeling has demonstrated that densely greening parking lots could reduce ambient temperatures by up to 7°C at the site (Onishi et al., 2010) and that green walls and roofs may cool some urban areas by up to 8°C (Alexandri & Jones, 2008). Studies have also reported that green areas as small as 0.24 ha may reduce temperatures by as much as 6.9°C (Oliveira et al., 2011). Moreover, such green infrastructure strategies may be economically and socially viable, even in developing countries (Kitha & Lyth, 2011), and across a wide range of climatic zones (Alexandri & Jones, 2008; Brown et al., 2015). These findings have important implications for climate change adaptation. As Akbari et al. (2001: 295) have noted: “electricity demand in cities increases by 2-4% for each 1°C increase in temperature”; urban greening therefore has the potential to save more than \$10 billion annually in energy use.

And the benefits of green infrastructure are not limited to economic gains. Several recent studies have also reported that well-vegetated green-spaces can provide a refuge during times of intense heat, contributing to citizen health and wellbeing, and potentially to reducing morbidity and mortality (Brown et al., 2015; Kravchenko et al., 2013; Xu et al., 2013). Because increases in mortality of up to 3% are associated with every 1°C increase in temperature, successfully retrofitting green infrastructure to lower urban temperatures will be critically important to address the heat impacts associated with climate variability in those cities that will experience rising temperatures due to climate change (Brown et al., 2015; Kravchenko et al., 2013).

Unfortunately the socio-cultural dimensions of green infrastructure planning have tended to receive much less attention than biophysical considerations (Byrne & Yang, 2009; Young & McPherson, 2013). We know considerably less about citizen attitudes towards urban greening for climate change adaptation, and about their potential concerns with ecosystem disservices associated with afforestation. A key question for us is whether green-space users would be prepared to accept an increase in vegetation density (potentially reducing areas available for active recreation) as a trade-off for cooler built environments and other climate-adaptive benefits of urban trees. European researchers suggest they might (Bjerke et al., 2006) and assert that even small green-spaces may foster stress relief and mental restoration (Nordh et al., 2009). But we know comparatively little about Asian cities – where residential densities are very high, heat island impacts are magnified, larger areas of green-space are scarce, and populations are burgeoning.

We believe that important questions include: how do urban residents feel about using green infrastructure for climate change adaptation? Are they willing to accept more tree-planting in parks and open spaces to help adapt to climate change impacts? Do they understand the benefits that urban trees confer upon built environments? Do they have concerns about the costs (ecosystem disservices) of urban trees? And does this shape residents' beliefs about the efficacy of urban trees as a climate adaptive response for built environments? The answers to these questions are not clearly identifiable in the green infrastructure literature, as research on this topic is nascent (e.g. Mell et al., 2013). We now turn our attention to probing these issues.

### **3. Methods**

The specific hypothesis underpinning our research is: ‘how Hangzhou residents perceive the contributions of urban trees for climate change adaptation will be related to: (i) how they understand climate change (which is broadly defined in terms of awareness, concern, expectation of impacts), and their perceived self-efficacy in managing impacts; (ii) their perceptions of tree services and disservices, (iii), their patterns of green-space use; and (iv) their socio-demographic characteristics’.

### *3.1. Case study: Hangzhou, China*

Hangzhou is one of China’s oldest inhabited settlements (Altenburger & Chu, 2010) (see figure 1). It is also one of China’s faster growing cities, with annual population growth rates of around 100,000 per annum. Residential densities in the core districts of this metropolis of about 6 million people range between 16,000 and 19,000 persons per km<sup>2</sup> (Spiekermann et al., 2013). Rapid urbanization is profoundly impacting the city’s environmental quality (Spiekermann et al., 2013). Unfettered property development has devoured much of the city’s outlying agricultural land, and the city is often blanketed in air pollution (Wu et al., 2012). The city’s annual average temperatures are now the second-hottest in China, reflecting a loss in urban green-space (Shen et al., 2013). But Hangzhou has begun to embrace a range of innovative efforts to restore lost green-space (Dao, 2011; Wu et al., 2012). Such efforts are earning this city a national reputation for green leadership (Delman, 2014).

<INSERT FIGURE 1 AROUND HERE>

#### *3.1.1. Green-space in Hangzhou*

According to the City Government's website, Hangzhou has 166.5 km<sup>2</sup> of green -space (about 40% of the city area). Moreover, almost two thirds of the municipal area is devoted to green and open space. In 2012, the amount of urban green-space increased by 14.4 million m<sup>2</sup>; the 2013, the target was for an additional 13 million m<sup>2</sup> of green-space. The official ratio of green-space is about 15m<sup>2</sup> per capita, and some commentators suggest that over 90% of the city's population has easy access to some form of green-space (Sang et al., 2013). The city has also embarked upon large-scale urban reforestation.

However, official statistics mask the paradoxical nature of green-space in Hangzhou. Although much of the city's official green-space actually lies within the municipal boundary, it is not within the urban area. This is because large areas of undeveloped land are included in the city's administrative jurisdiction, though they are mostly rural in character. Further, many of Hangzhou's urban green-spaces are actually quite small and contain few facilities, especially those in the urban core (Wolch et al., 2014). Although they are aesthetically pleasing, many are ill-suited to active recreation. Indeed, most parks in Hangzhou are what Western scholars would call elaborately landscaped 'pleasure gardens' (Cheng et al., 2009), intended mainly for passive recreation (e.g. promenading, sitting, relaxing, fishing, kite flying, dancing, practicing calligraphy, and people-watching (Cheng et al., 2006). Many of these spaces also have extensive paved surfaces to accommodate high volumes of use (see figure 3), making them hot in the summer months, and less able to infiltrate storm-water. Those green-spaces that are conducive to active recreation are highly valued.

<INSERT FIGURE 2 AROUND HERE>

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250       3.1.2. Urban greening strategies in Hangzhou

251 Hangzhou's ambitious urban greening hinges upon activating spaces that would likely remain  
252 under-utilized in most North American, European and Australian cities. For instance, the city  
253 government has been developing green-spaces adjacent to and underneath freeways, alongside  
254 railway lines, along the banks of canals that transect the older urban core, and on former factory  
255 sites (Wolch et al., 2014; Yang et al., 2008). This large-scale greening effort is expected to:  
256 reduce heat island impacts, lessen flooding, intercept pollutants, and reduce wind speed – among  
257 other benefits (Cheng et al., 2006). Chinese researchers report that urban greening is paying  
258 dividends, with temperature reductions of between 4 and 6 degrees in some parts of Hangzhou  
259 (Wenting et al., 2012). But scant research has considered how green-space users might feel about  
260 reforesting the green-spaces that they rely on for recreation.

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262       3.2. *The green-space survey locations*

263 We administered a survey questionnaire to users of three public urban green-spaces in Hangzhou  
264 and one communally-owned garden in a large residential complex. The public spaces were  
265 chosen because they are representative of the spectrum of green and open spaces in Hangzhou,  
266 have been deliberately constructed as green interventions, enable a range of more active  
267 recreational pursuits, and have varying levels of tree canopy cover (see figure 2). The public  
268 spaces were: (1) Cheng Dong Park; (2) Wu Shan Plaza and (3) Xi Cheng Square (see figures 3-  
269 5). In addition, we administered the survey to residents of a larger residential community on  
270 Feng Qi Road (approximately 5,000 residents) located in close proximity to Cheng Dong Park,

and within the city's urban core. This community has access to its own internal communally-owned, park-like garden, which is increasingly common in newer residential developments. The communal green-space is about 0.66 ha in area. Residents use the garden for daily walks, supervising small children at play, for informal exercise (Tai Chi and dancing) and for walking their dogs. They tend to use nearby Cheng Dong Park for more active recreation, for family gatherings, as well as for finding a space for quiet reflection and mental restoration.

<INSERT FIGURES 3 a & b AROUND HERE>

Cheng Dong Park is a recently developed linear green-space (construction began in 2007), sandwiched between a high-speed rail line and an urban canal. It is approximately 17.9 ha in area (although we focused on the 6.3 ha core between Tiychang Road and Genshan West Road). The park is quite flat and has extensive tree canopy coverage. However, these trees were only recently planted, with numerous large trees being translocated to the site en masse from local 'tree-farms'. The park includes a large ornamental lake, lawn areas, plazas, exercise equipment and walking and cycling trails. Residents use the space for a very wide range of activities including morning exercise, informal farmers markets, promenading, dancing, kite flying, fishing, interacting with nature and people-watching.

<INSERT FIGURES 4 a & b AROUND HERE>

In contrast, Wu Shan Plaza is a long-standing green-space that has undergone successive waves of redevelopment throughout the city's history. It is about 5.5 ha in area and includes a very large plaza, civic buildings, landscaped gardens and a temple/pagoda. The site has both undulating steeper terrain and flat areas, and is relatively close to the city's renowned West Lake National Park. It also includes a pond, but it is only small and is used for amusement rides (e.g. paddle boats). Canopy cover ranges from extensive on the hillside to sparse near the plaza. The park is also used for a range of activities including: morning exercise (Tai Chi & sword dancing), dancing, promenading, people-watching, civic entertainment, and cultural activities. Wu Shan Plaza is located around 4.5 km south west of Cheng Dong Park, near the West Lake.

Finally, Xi Cheng Square is located in a newer part of the city. It is extensively paved and has only small areas that are planted with vegetation. Around 2 ha in area, only 20% of the site has vegetation cover. The square features a fountain and a large plaza, and is located adjacent a shopping mall (West City Plaza). Residents use the plaza space for morning and evening exercise, but it is not intensively used during the day. Some residents sit beneath the small stands of trees to read newspapers or people watch – but only for short periods of time. Xi Cheng Square is located around 9 km west-north-west of Cheng Dong Park.

<INSERT FIGURES 5 a & b AROUND HERE>

### *3.3. The green infrastructure survey instrument*



We used almost identical survey instruments for the three public green-spaces and the one communal green-space. The two instruments were pilot-tested first in English and then in Mandarin, and minor changes were made based on feedback we received. There were minor variations to the two instruments to accommodate different methods of recruiting participants. The instruments were approved by the home-institution's Human Subjects Research Ethics Committee (ENV/21/09/HREC).

The public green-space surveys used a randomized intercept method for recruiting whereas the community green-space used a mail-box drop. For the latter, an introduction letter was placed in every mailbox, followed one week later by a survey questionnaire, information sheet and return envelope. Return envelopes were placed in an anonymous, sealed drop-box in the foyer of each building. The community green-space survey did not contain questions about nearest park distance (as that was known) and the questions about the condition of the green-space were modified slightly to reflect collective ownership. Both the community survey participants and the public space participants received a small incentive for completing the survey (an ice-cream or dumpling voucher). The public space participants received the voucher upon completing the survey whereas the community residents received the voucher after returning the survey to the drop-box in their building.

It should be noted that it can be difficult to collect survey data in China, where residents are suspicious of divulging personal information and where local and state authorities may be reluctant to approve activities that could create unrest or reflect poorly upon government (Roy et al., 2001). To circumvent these problems, the survey instrument was approved for use by the

residential management committee of the apartment complex and permission was sought from city authorities in the parks and urban planning departments. Survey administrators were subsequently provided with an official letter of permission from the Chinese research partner, authorizing the collection of survey data in public spaces.

The survey instrument consisted of 52 questions, which were divided into six different sections. The first section asked respondents about their knowledge of climate change and whether they knew of any climate-change related impacts that would affect Hangzhou. The second section asked respondents if they thought that measures could be taken to adapt to the identified impacts; it specifically focused on the acceptability (or otherwise) of tree-planting as an adaptive strategy. This section asked respondents about perceived tree benefits (ecosystem services) and tree costs (ecosystem disservices). The tree benefits included response options such as cooling temperatures, improved esthetics and reducing flooding whereas the tree costs included options such as damaging sidewalks, reducing sunlight, attracting pests, and increasing crime. The third section asked respondents about how they used the green-space (activities, duration, travel patterns etc.). The fourth section asked respondents about their level of agreement with a series of Likert scale questions, modeled on Dunlap's (2008) NEP, designed to elicit respondents' environmental values. The fifth section assessed respondents' attitudes towards other park users, barriers to access and experiences of conflict in the green-space. The final section of the survey collected socio-demographic information about the users (age, sex, income, home-ownership, education and household composition). Copies of the instrument are available upon request.

The survey questions were specifically designed to test some of the assertions of Byrne and Yang (2009), who suggested that a range of potential factors, which are linked to residents' perceptions and patterns of recreation, are likely to impact the utility of green-space (and by implication green infrastructure), as a climate change adaptive response. Specifically, they asserted that these are likely to include: concerns about vegetation density and personal safety; the potential loss of space available for active recreation (and perhaps increased user conflict); increased potential of human-wildlife conflict; increased likelihood of hard infrastructure damage (e.g. trees uplifting sidewalks); and potential loss of sunlight. Measures on the questionnaires specifically assessed these issues.

Surveying occurred during the course of two weeks during late summer and early autumn, as prior research has demonstrated that this is when most people visit and use parks in Hangzhou (Chen et al., 2009; Zhang et al., 2013). A team of trained student volunteers from Zhejiang University randomly intercepted park users between 6 am and 9 pm during weekdays and weekends. They were instructed to collect surveys from people 15 years of age and older and to randomize their intercepts to remove potential bias by approaching every 5<sup>th</sup> person, irrespective of sex, activity-type, appearance etc. The survey took respondents approximately 15 minutes to complete and was accompanied by a detailed information sheet. Informed consent was provided by completing and returning the questionnaires, in accordance with the home institution's ethics approval. A total of 152 surveys were completed among the three parks and a further 137 surveys for the communal garden in the apartment complex, resulting in a total sample size of 289 green-space users (hereafter termed respondents). The survey was administered in Mandarin. It managed to achieve an overall response rate of 23% due to inherent difficulties in recruiting

survey participants in China. For example, public opinion surveys are still comparatively new for residents, and potential respondents have concerns about divulging personal information (Roy et al., 2001). As such, we do not claim demographic representativeness of the sample, but focus on ascertaining the relationships between selected attitudinal and socioeconomic variables.

#### **4. Analysis**

Green infrastructure users' responses to selected survey questions helped create a series of variables to be used in the subsequent regression analysis, described below.

##### *4.1. Dependent variable*

Specifying the dependent variable involved combining five survey items concerning residents' perception of the benefits of urban trees for adapting cities to climate change. Each of these items described a specific function of urban trees and requested the respondent to indicate whether or not they considered it as an important benefit of planting trees. These functions are either directly or indirectly related to climate change. For instance, urban trees can lessen the impacts of adverse weather events, such as high urban temperatures, heavy rains, and strong winds (in China this is sometimes accompanied by dust storms). In addition, collectively managed urban green-spaces, in the form of communal gardens, can provide an alternative source of food and enhance food security in the event that weather extremes impact food supply. The five survey items captured these functions, namely, reducing air temperature, reducing floodwater runoff, providing food, etc. They were combined to create a composite variable to represent the *perceived benefits of urban trees*.

#### 4.2. Independent variables

The independent variables comprised a battery of survey items that solicited climate change belief. These included two binary questions concerning whether or not the respondent had heard of climate change and worried about it, which denote *Awareness* and *Concern* respectively and are entered as individual items in the analysis. Several follow-up questions then probed respondents' expectation as to what kind of climate change impacts would affect the city they were living in (i.e. Hangzhou). These questions were grouped into two composite variables, i.e. *Weather Changes* and *Economic Disruptions*. The former included five items that described expected impacts of climate change on weather, such as temperature rises, flooding, storms, etc. The latter had six items describing adverse economic consequences, such as increasing the demand for food and electricity, slowing down economic growth, and damaging infrastructure. The two composite variables indicate two different ways in which climate change impacts can be understood, i.e. as an environmental stressor or an economic threat, which are logically related but have different cognitive implications.

Respondents were also requested to express their *Confidence* in the capacity of human beings to manage climate change impacts. A binary question gauged their view as to whether or not human action can stop climate change from impacting cities. Respondents were then presented a list of energy-related household practices and invited to nominate which ones could help effectively lessen climate change impacts on the city of Hangzhou. Available options described different ways of managing emissions (e.g. driving less often, installing solar hot water heater, using less electricity, using alternative energy, using fans instead of air-conditioners, etc.).

There were seven items, and they formed a composite variable representing *Effective Mitigation Actions*, indicating the sense of efficacy in responding to climate change.

Five questions at the end of the questionnaire gauged the socio-economic information of respondents, including age (continuous scale), sex, education (university holder or not), tenure (owned the house/unit currently living in or renting), and children (have children under 18 living at home). Home ownership is used as a proxy for household wealth since a high proportion (20%) of respondents refused to provide information on household incomes. These items were used as independent variables in the regression analysis to ascertain socio-economic effects on the perception of urban trees.

Bivariate correlation and linear regression analyses were conducted using a standard statistical package (SPSS) to address the proposed hypothesis. We used climate change belief and socio-economic variables as independent variables to predict the perceived contributions of urban trees in reducing climate change impacts (the dependent variable). We identified their relationships in terms of statistical significance. Results are presented in the next section.

It is appropriate here to acknowledge a limitation of our analysis. In question 8 (Q8) of the survey the instrument, respondents were explicitly informed of tree disservices and were asked to respond to questions about these disservices. Few respondents reported problems with trees. We ran the regression with tree costs (ecosystem disservices) items (i.e. Q8), but we had a very low R square (2%), meaning our model had limited utility. This is due to limited variations

among respondents to that question. Most respondents identified few 'yes/agree' responses to potential disservices (<5%). The majority of responses were thus identical ( i.e. '0'). With limited variation, we were unable to obtain meaningful regression results. This is not an error; it simply reflects the fact that most respondents did not identify negative tree impacts. Due to limited variations, it is statistically not meaningful to present these regression results.

## **5. Results**

### *5.1. Descriptive statistics*

The analysis combined the two datasets collected from the survey sites, namely, Cheng Dong Park, Wu Shan Plaza and Xichen Square with the communal green-space. This produced a total of 289 observations. Table 1 describes the socio-economic characteristics of the respondents. The average respondent was in their middle age, around 44 years old. The youngest respondent was 15 and the oldest one was 82 (the ethics approval limited the survey to children 15 years and older, due to concerns about difficulties in parental consent and the cognitive capacity of younger children to understand survey constructs). The sample was equally split between the two sexes: 50.5% were female and 49.5% were male. Just over half of them (53.3%) completed a university degree. Furthermore, many respondents declared ownership of the house or unit in which they resided (75.8%). Nearly one-third (31.5%) reported that they had children under 18 years of age living at home.

<INSERT TABLE 1 AROUND HERE>

Table 2 displays the descriptive statistics used in the regression analysis. The *Perceived Benefits* variable yielded an average value of 3.31 and an alpha value of .69, which means that this composite item achieved internal consistency. Most of the Hangzhou green-space users (60-80%) we surveyed recognized the various adaptive benefits of urban trees, although trees as an alternative source of food did not attract considerable attention (just 25% of respondents).

The *Awareness* and *Concern* variables recorded relatively high values, indicating that most respondents were aware of and concerned about climate change. The *Weather Changes* variable yielded an average value of 2.45, with a modest degree of variation between its constituent items. Most of the respondents (>50%) believed that climate change impacts will materialize in the form of hotter weather and more flooding events, but thought less likely (<30%) to occur would be more rain (frequency) and heavier rain (intensity). This variable produced a marginally acceptable alpha value of .64. On the other impact variable, (i.e. *Economic Disruptions*), more than half of the respondents (50-70%) articulated climate change impacts in terms of crop damage and increasing demand for goods, while less than 30% of them selected damage to infrastructure and the economy. Still, this variable generated a satisfactory alpha value of .78.

<INSERT TABLE 2 AROUND HERE>

The *Confidence* variable recorded 182 positive observations, or 63% of the sample. This suggests a modest degree of optimism in the ability of human beings to manage climate change



impacts. Most respondents (64-81%) suggested that they could manage climate change impacts by using less energy or using non-renewable energy (e.g. by harvesting solar heat), with one exception; ‘using fans instead of air-conditioners’ only attracted 46% positive responses. This variable, labeled as *Effective Actions*, had a satisfactory alpha value of .74.

The *Park Use* variable combined a number of recreational pursuits of park visitors. Respondents indicated the types of active and passive recreational activities they engaged in when visiting the green-spaces. To facilitate response, we provided a list of 19 common recreational activities for selection, including walking, riding bicycles, dancing, Tai Chi, etc. This variable had an alpha value of .68.

<INSERT TABLE 3 AROUND HERE>

## *5.2. Correlated and regression analyses*

Bivariate correlation coefficients of the model variables are listed in Table 3. The *Perceived Benefits* variable was positively related to all other variables, except *Awareness and Concern*. There are strong associations between some of the independent variables. This begs the question whether collinearity exists between predictors. We further examined these relationships through a regression analysis.

Table 4 shows a regression model using the listed dependent and independent variables. Only three of the tested variables achieved statistical significance in the model, and they

accounted for 30% of variance in the dependent variable. The Tolerance and VIF values were acceptable and cleared away concerns about collinearity. Tolerance values indicate the percent of variance in the predictor that cannot be accounted for by the other predictors. Small values mean that a predictor is redundant - anything less than .10 may merit further investigation. The VIF stands for variance inflation factor. As a rule of thumb, a variable with a VIF value greater than 10 may merit further investigation. The model estimates suggest that *Perceived Benefits of Urban Trees* demonstrated no observable relationship with *Awareness* and *Concern*. This means that those individuals who are aware of, and concerned about, climate change are no more likely to recognize the related adaptive functions of urban trees.

Expectations about climate change impacts generated mixed results. The *Weather Changes* variable lost significance when other factors were controlled for, whereas *Economic Disruptions* predicted *Perceived Benefits* and were statistically significant at 1% level. The positive sign suggests that the selected functions of urban trees were more likely to attract attention if the respondent expected that climate change would lead to adverse economic consequences. Pragmatic (economic) considerations concerning climate change impacts are associated with perceived benefits of urban trees.

<INSERT TABLE 4 AROUND HERE>

Confidence was not related to perception of urban tree benefits when other factors were controlled for, but *Effective Actions* sustained a highly significant positive relationship with the

dependent variable. This indicates that those respondents who nominated a greater number of possible actions to mitigate climate change impacts tended to recognize the functions of urban trees. Belief in the collective efficacy in tackling the problem is associated with perceived contributions of urban trees.

*Park Use* was positively associated with *Perceived Benefits*. Regression results however, did not suggest a significant relationship between these two variables. This means that recreational use of the green-spaces was unlikely to be a predictor of the tendency for recognizing the benefits of urban trees when other factors were included in the analysis.

Socio-economic variables managed to produce significant observations. Sex, Education, Tenure, and Dependent Children failed to predict the dependent variable. Yet, Age was a key predictor with a positive effect, i.e. the older the individual, the more likely they were to appreciate the role of urban trees in adapting cities to climate change.

## **6. Discussion and Conclusions**

In recent years there has been growing concern among planners about the impacts of climate change on cities. Attention has turned to how best to adapt built environments to expected impacts such as heat waves, intense storms, increased wind speeds and flooding. Green infrastructure, including parks, green-spaces, green roofs and urban trees is increasingly being recognized for the adaptive benefits that it can confer on cities, including cooling, reducing

storm-water runoff, and potentially food production (Maes et al., 2014). But the perceptions, attitudes, and values of green-space users towards green-infrastructure interventions are not well understood – including the perceived issues associated with urban trees (Faehnle et al., 2014). This is a potential problem if urban green-spaces are targeted for reforestation as an adaptive response, without an adequate understanding of the potential for citizen concern and resistance (Young and McPherson, 2013)

We undertook research in Hangzhou, China – a rapidly growing city with high densities in the urban core. It is a useful case study because other cities in Asia, Canada and Australia are also growing rapidly, increasing in density and are expected to be strongly impacted by climate change (Brown et al., 2015; Mazhar et al., 2015). Many lessons learned from Hangzhou could be applied to those cities. The results of our research show that green-space users in Hangzhou, China are more likely to recognize a wider range of climate-adaptive benefits of tree-planting if they believe that climate change will create adverse economic impacts on their city (pragmatic, utilitarian motivation). Results also suggest that green-space users in Hangzhou tend to appreciate those benefits if they feel that they can manage climate change impacts by altering their consumption practices (a sense of collective efficacy). These findings could inform how planners frame the problem of climate change and the potential adaptive responses they advocate. Importantly, communicating the adaptive benefits of urban trees in Hangzhou should emphasize their potential to lessen economic impacts stemming from climate change.

These results are important because they suggest that emphasizing the deleterious impacts of climate change on cities (other than economic impacts), will not be as conducive to

fostering residents' acceptance of adaptive responses as would stressing the benefits of self-efficacy. In other words, planners and environmental managers may want to focus their attention on the positive message that individuals can make a difference in adapting their cities to climate change, and that green-infrastructure, such as tree planting, is a good place to begin. Cities that have already embarked on massive tree-planting programs to combat future climate change impacts will likely find supportive allies in green-space users. But targeting green-spaces for more intensive tree planting could be problematic.

One surprising result of our research was that recreationists in Hangzhou did not appear to oppose using trees for climate adaptation, and recognized the many benefits that trees confer upon built environments. This is promising because it suggests that planners may be able to increase tree densities in existing green-spaces in Hangzhou, without facing a backlash from recreationists. But this may not be the case for cities outside China. A telling aspect of green-spaces in Chinese cities is that there are few large spaces dedicated to active recreation. It is rare to see playing fields, basketball courts, skate parks or other larger and more intensive recreational spaces that characterize cities in North America, Australia and Europe (Dong & Chick, 2012). It is also rare to see children's playgrounds in parks and green-spaces in most Chinese cities. Further research is therefore required in cities outside China to ascertain if green-space users would be as favorably disposed to using trees to adapt to climate change as they are in Hangzhou. It is too early to tell if the large scale greening that is occurring in Chinese cities like Hangzhou could also be successful in Western countries, although Young and McPherson (2013) have found evidence that tree large scale tree planting can be problematic in some cities

in the United States, and Kirkpatrick et al. (2013) have found related issues in some Australian cities.

An age-effect is also present in our results. Older green-space users in Hangzhou were more likely to recognize the adaptive benefits of urban trees. There could be several reasons for this finding. In China, older people seem more likely to use green-spaces because they have more leisure time. They may also be more likely to remember the time before large-scale urbanization, when Chinese cities were greener and cooler. And they may also have stronger affinities for nature, having grown up in more naturalistic settings. Further research will need to test these potential explanations.

Our results do suggest that age-based communication strategies might work well in the Chinese context; many elderly do regular morning exercises in public parks. This finding is encouraging because there is often a tendency to write-off the opinions of older people about climate change, since they are likely to die before the worst impacts manifest, and in some places have been shown to be more skeptical about climate change (Whitmarsh, 2011). Perhaps we should not be so hasty in discounting the role of older people in adaptation. Planners should remember that older people often have more time for child-care. In China, it is grandparents, not parents, who tend to take primary responsibility for child-rearing, as parents are often working very long hours (Goh & Kuczynski, 2010). Our results suggest that if planners in China target climate change adaptation messages to older people, there could be a pay-off, where their knowledge and values are transmitted to the next generation, paving the way for greater acceptance of green-infrastructure as an adaptive response. There could be similar benefits

outside China, especially in cultures where older people are valued for their contributions to society, but further research is needed, to test these postulates.

### *6.1 Potential limitation of this study*

It is worth noting some potential limitations of this study. We did not obtain a representative sample of Hangzhou residents, due to the inherent difficulties of securing socio-demographic census data in China – making sampling problematic (Goodkind and West, 2002). Unlike Western cities, demographic data is not available in fine detail for Chinese cities because it is aggregated to a very broad scale, making generalization of survey findings challenging, if not impossible. In this paper we have also focused on climate change adaptation, not mitigation. We recognize that more research is required to test the efficacy of green infrastructure for mitigation, but that was outside the scope of this study. We also acknowledge that some adaptive responses may prove mal-adaptive in the longer term. For example, large scale afforestation could lower groundwater, might damage grey infrastructure (e.g. sidewalks), could increase fire hazards, and may increase the incidence of asthma if inappropriate species were chosen (Demuzere et al., 2014; Roy et al., 2012). And we acknowledge that outside China, tree planting for climate change adaptation could prove to be contentious due to maintenance costs, or because trees might increase greenhouse gas emissions if planting and maintenance are highly mechanized (or through composting green waste). In China, where labor is cheap, and mature trees are translocated en-masse from local tree farms, the benefits (and costs) are quickly apparent. Outside China, where small trees are often planted, it may take decades for the trees to mature and for the full suite of benefits (and costs) to manifest. However, these limitations also suggest three useful directions for further research.

649

650        *6.2 Directions for further research*

651        First, more research is required to understand the ‘macroclimate’ contributions of green  
652        infrastructure, for both adaptation and mitigation. We know little about this topic. Can  
653        metropolitan-scale green infrastructure interventions aggregate to contribute to regional, national  
654        or even global climate change response outcomes? For example, it is highly improbable that  
655        even the most ambitious urban greening programs could lessen the chances of sea-level rise or  
656        reduce flooding from high-intensity storm events in the absence of aggressive international  
657        action for emissions abatement. So what are the aggregate benefits (and costs) of green  
658        infrastructure at larger scales? More research is required to explore the cumulative benefits (and  
659        costs) of urban greening as a climate change response.

660

661        Second, it must be acknowledged that urban trees are just one component of green  
662        infrastructure. What are the synergistic effects of other forms of greening, and would residents  
663        have similar dispositions towards green roofs, green walls or constructed wetlands as we have  
664        found in this study – both in China and elsewhere? And how might residents’ attitudes change  
665        when comparing new, small tree plantings with the more mature plantings we examined in this  
666        study? Would residents perceive the same type and scale of benefits and/or costs? Do the esthetic  
667        characteristics of species matter?

668

669        Last, more research is required to assess the potential mal-adaptive impacts of large-scale  
670        urban greening – on greenhouse gas emissions, on residents’ health, on ecosystems and



671 ultimately on urban policy and land use decision-making. While we have not been able to  
672 address these complex issues in this paper, our findings suggest that there is nonetheless  
673 considerable potential to use green infrastructure for climate change adaptation, and that  
674 residents may be favorably disposed towards green infrastructure if they feel they can take action  
675 themselves to lessen climate change, and if they can recognize the economic benefits of green  
676 infrastructure. This study is just a first step towards engaging with the socio-cultural dimensions  
677 of green infrastructure for climate change adaptation. Our encouraging findings suggest it is a  
678 research agenda warranting further investigation.

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Table 1 - Socio-demographic characteristics of respondents

Table 2 - Descriptive statistics for model variables

Table 3 - Correlation coefficients for the dependent and independent variables

Table 4 - Regression model for perceived benefits of urban trees

Table 1 Socio-demographic characteristics of respondents (n = 289)

<i>Age</i>		
Average		44.1 years
Range		15 - 82 years
<i>Sex</i>		
Female		50.5%
Male		49.5%
<i>Education</i>		
University degree holders		53.3%
Non-degree holders		46.7%
<i>Tenure</i>		
Owned the house / unit currently occupied		75.8%
Renting		24.2%
<i>Children</i>		
Have children under 18 years		31.5%
Otherwise		68.5%



Table 2 Descriptive statistics for model variables (n = 289)

<b>Item</b>	<b>Observed range</b>	<b>Mean</b>	<b>S.D.</b>	<b>Alpha</b>
<i>Dependent variable</i>				
Perceived Benefits of Urban Trees	0-5	3.31	1.39	.69
<i>Independent variables</i>				
Awareness (heard of climate change)	0-1	.95	.22	-
Concern (worry about climate change)	0-1	.82	.38	-
Expected climate change impacts				
Weather Changes	0-5	2.45	1.39	.64
Economic Disruptions	0-6	2.88	1.96	.78
Confidence (people can stop climate change impacts)	0-1	.63	.48	-
Effective Actions	0-7	4.83	1.96	.74
Park Use	0-13	3.58	2.42	.68
Park Visit Frequency (times / month)	1-60	14.05	11.67	-

Table 3 Correlation coefficients for the dependent and independent variables

	Awareness	Concern	Weather Changes	Economic Disruptions	Confidence	Effective Actions	Park Use
Perceived Benefits of Urban Trees	.098	.006	.243**	.391**	.141**	.441**	.235**
Awareness		.301**	.222**	.113	.047	.187**	.031
Concern			.103	.120*	.209**	.186**	.037
Weather Changes				.480**	.025	.320**	.212**
Economic Disruptions					.095	.369**	.294**
Confidence Effective Actions						.196**	.094 .359**

\* denotes significance at 0.05 level and \*\* at 0.01 level

Table 4 Regression model for perceived benefits of urban trees

	Beta	Std. Error	Sig.	Collinearity Statistics	
				Tolerance	VIF
(Constant)		.397	.022		
Awareness	.053	.348	.332	.839	1.192
Concern	-.100	.198	.072	.825	1.213
Expected Impacts: Weather Changes	.019	.059	.752	.710	1.409
Expected Impacts: Economic Disruptions	.223	.043	.000 **	.662	1.511
Confidence	.078	.151	.139	.897	1.114
Effective Actions	.313	.043	.000 **	.684	1.462
Park Use	-.006	.032	.921	.814	1.228
Age	.207	.005	.001 **	.636	1.573
Gender	.011	.149	.838	.861	1.161
Education	-.058	.151	.287	.843	1.186
Tenure	.019	.206	.764	.628	1.593
Children	-.018	.165	.751	.809	1.236
Adj. R <sup>2</sup>	.29				
F Statistic	10.764				
Std. Error	1.16				
Total df	281				

Dependent variable: Perceived Benefits of Urban Trees

\*\* denotes significance at 0.01 level

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Figure 1  
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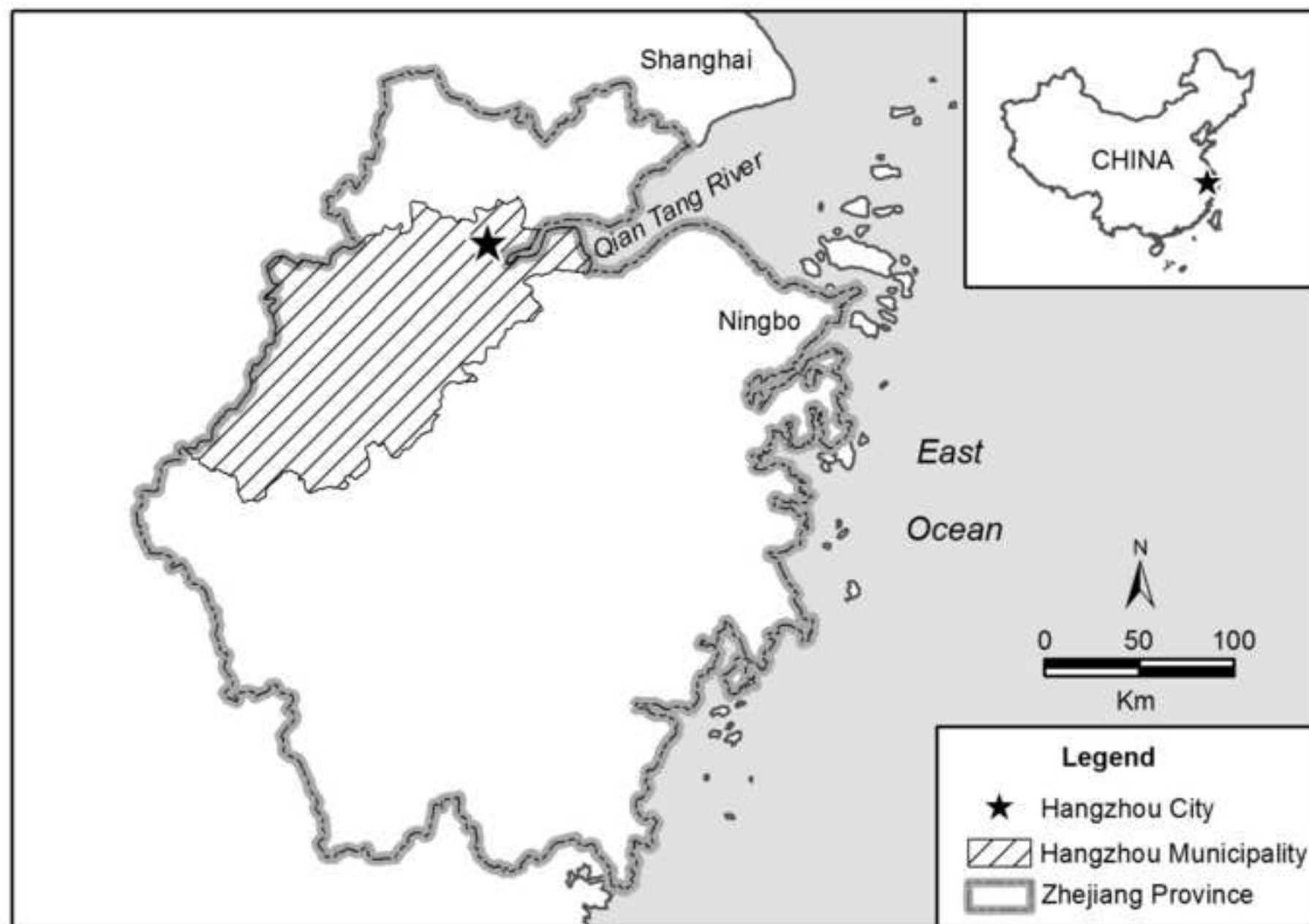


Figure 2  
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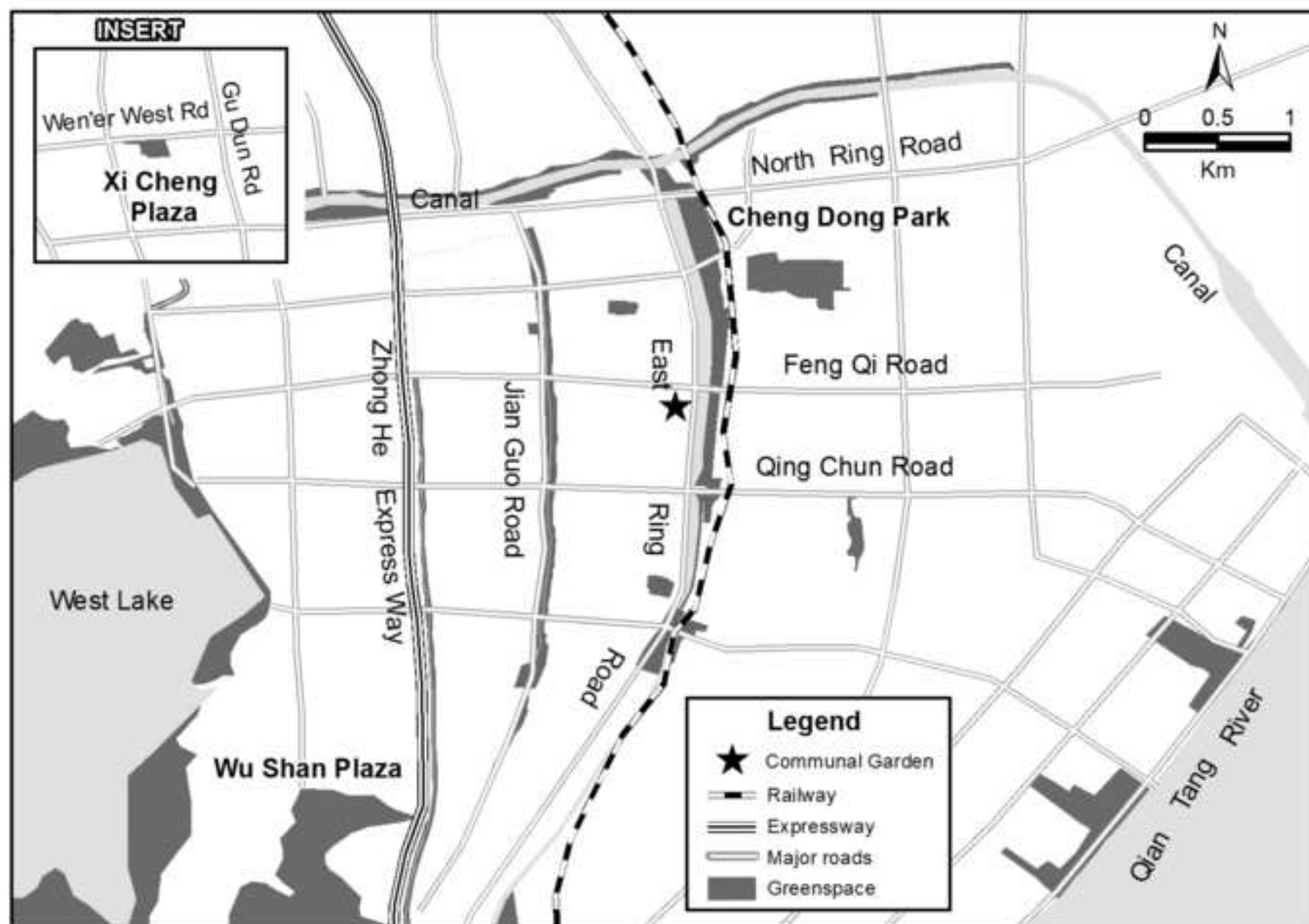


Figure 3a  
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**Figure 3b**  
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Figure 4a  
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Figure 4b  
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Figure 5b  
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Figure 5a  
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### Acknowledgements

We would like to thank the anonymous reviewers for their assistance with this paper. Their suggestions and feedback have greatly improved the paper. We would also like to thank Griffith University and Zhejiang University for funding this research, and Zhejiang University for generously providing office space for the first author during his research leave. Thanks are also due to Daniela Guitart (Griffith University) for her assistance in cleaning the data for analysis, and to Hong Yi Dan, Jiang Yan, Zhang Bin, and Zheng Wen Wen (Zhejiang University) for their assistance in collecting the park user data and helping to identify suitable green-spaces for the research. We also thank Mrs Huang Juying for assisting us in providing the participation vouchers for survey respondents and for acting as an intermediary in securing the permission of the community managers for undertaking the survey in Feng Qi Gardens. Finally we owe a debt of gratitude to Dr Christina Qi Li, spatial analyst with the Gold Coast City Council, for generously giving up her own free time to prepare the maps for this paper. All errors and omissions remain those of the authors.