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Research Paper

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

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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.

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ABSTRACT

Hangzhou is a rapidly growing Chinese coastal metropolis that is facing climate change impacts, including intense heat waves, flooding and increased severity of storms (e.g. typhoons and thunderstorms). This paper examines whether green infrastructure (GI), specifically increased tree planting, could help Hangzhou City adapt to some of these impacts. The paper reports the results of a survey of Hangzhou green-space users and their disposition toward tree planting in public and communal green-spaces as a climate change adaptive response. Results show that surveyed green-space users tended to favor tree planting as an adaptive strategy if they were older, believed that individual actions could reduce climate change impacts, and believed that future climate change impacts would be economically disruptive. Few respondents reported tree costs (disservices). While the perceived benefits of urban trees were unrelated to support for urban greening, results suggest that under some conditions, residents may be willing to support increased tree cover within urban public and communal open spaces. Findings suggest land use planners and environmental managers in China would do well to cultivate support for green infrastructure interventions among older green-space users and residents who perceive personal costs associated with climate change. Additional research across a range of Chinese cities, and internationally, could further assist in evaluating the efficacy of green infrastructure for climate change adaptation from a green-space user perspective. Particular attention will need to be given to the potential costs of large-scale tree planting (e.g. health impacts) and to the utility of GI for macro-scale climate change response.

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 (Norton et al., 2015). 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 toward adaptation initiatives, such as urban greening (Brown, 2011; Bulkeley, 2013; Emmanuel & Loconsole, 2015; Klemm, Heusinkveld, Lenzholzer, & Van Hove, 2015; Mees & Driessen, 2011). Much recent planning and urban design research have investigated how best to adapt urban environments to expected climate change impacts, including better understanding the barriers and enablers to adaptive responses (e.g.

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Castán Broto & Bulkeley, 2012; Matthews, Lo, & Byrne, 2015). Using 'green infrastructure' for climate adaptation such as green walls, green roofs, urban trees and designed wetlands (Abreu-Harbich, Labaki, & Matzarakis, 2015; Byrne & Yang, 2009; Gill, Handley, Ennos, & Pauleit, 2007; 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, Byrne, & Pickering, 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, Vanos, Kenny, & Lenzholzer, 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, Gleeson, Howes, & Steele, 2009; Howes et al., 2010). This paper reports the results of research investigating citizens' dispositions toward 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 toward 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 toward 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, Verspecht, Vermeire, Van Huylenbroeck, & Gellynck, 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 & 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, Henneberry, Hehl-Lange, and Keskin (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, Allen, & Meurk, 2011).

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

We recognize that this conception of green infrastructure challenges some established definitions, which include what might be called 'natural' areas. Our intent is not to perpetuate a schism about human-nature duality, we recognize that cities are social and ecological entities (Byrne, 2011), and we see green infrastructure as a socio-natural assemblage. Two reasons inform our alternative