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Research paper

Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences?

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HIGHLIGHTS

- Novel socio-cultural valuation framework for green infrastructure and climate impacts.
- People are more aware of present-day heat waves but more alarmed by future flooding.
- People tend to prefer diverse, familiar and visually attractive adaptation measures.
- Environmental education can increase support for effective adaptation measures.
- Results help planners prioritize effective and desired green infrastructure designs.

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ABSTRACT

Cities are particularly prone to the effects of climate change. One way for cities to adapt is by enhancing their green infrastructure (GI) to mitigate the impacts of heat waves and flooding. While alternative GI design options exist, there are many unknowns regarding public support for the various options. This study aims to fill this gap by performing a socio-cultural valuation of urban GI for climate adaptation that encompasses multiple dimensions: people's notion of and concerns about climate impacts, the degree to which people acknowledge the benefits of GI to alleviate such impacts, and people's preferences for different GI measures, including their willingness to pay (WTP). Data were collected through photo-assisted face-to-face surveys (n = 200) with residents in Rotterdam, the Netherlands, and linked to GI GIS data. Respondents had a notion of and concerns about climate impacts, but did not necessarily acknowledge that GI may help tackle these issues. Yet, when residents were informed about the adaptation capacity of different GI measures, their preferences shifted towards the most effective options. There was no information effect, however, on people's WTP for GI, which was mostly related to income and ethnicity. Our study shows that economic valuation alone would miss nuances that socio-cultural valuation as applied in this paper can reveal. The method revealed preferences for particular adaptation designs, and assists in detecting why policy for climate adaptation may be hampered. Understanding people's views on climate impacts and adaptation options is crucial for prioritizing effective policy responses in the face of climate change.

1. Introduction

Climate change impacts in cities have received increasing attention (EEA, 2012; UN-Habitat, 2011). It is becoming increasingly apparent that the combination of large populations, densely built structures and sealed surfaces seen in cities do not represent ideal conditions for tackling a changing climate. A climate in which weather events become more extreme may lead to an increase in flooding, droughts and heat stress, causing not only financial damage but also threats to public health and safety (Gao et al., 2015; IPCC, 2014).

Because many cities are already facing climate-related challenges, city administrations are developing climate adaptation strategies – often ahead of national plans (Carter et al., 2015). Nature-based adaptation options such as vegetated drainage

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ditches and stormwater retention ponds (Church, 2015) are increasingly recognized as alternatives to technical solutions for flood protection. To reduce the urban heat island effect, city governments have started embedding green space within streetscape design to create more comfortable urban environments (Norton et al., 2015). Green infrastructure (hereafter referred to as GI) is the "infrastructure of green spaces, water and built systems, e.g. forests, wetlands, parks, green roofs and walls that together can contribute to ecosystem resilience and human benefits through ecosystem services" (adapted from Demuzere et al., 2014). It is increasingly recognized that careful design and implementation of GI can contribute to climate adaptation (Matthews, Lo, & Byrne, 2015).

GI studies with a climate adaptation perspective typically focus on the two most challenging issues that cities encounter in the face of more frequent weather extremes: heat and flooding. The impacts of heatwaves and heavy rainfall events are magnified in urban areas because of the clustering of people and socioeconomic activity (EEA, 2012). GI can reduce urban heat and flooding by its shading, evaporative, interception and infiltration capacities (Demuzere et al., 2014; Derkzen, van Teeffelen, & Verburg, 2015). GI is also valuable for climate mitigation through its carbon storage function, for example in lawn-dotted (sub)urban USA (Visscher, Nassauer, Brown, Currie, & Parker, 2014). In the context of compact and low-lying Dutch cities, however, its main functionality lies in climate adaptation.

Beyond its role in climate adaptation and mitigation GI provides a range of other ecosystem services (TEEB, 2011). The ecosystem services framework is continuously developing and, although it has evoked a fair bit of criticism in the past decade (e.g. Silvertown, 2015), a majority of publications stresses the diversity of benefits provided by GI (Andersson et al., 2014; Hansen & Pauleit, 2014). Shortcomings of multiple benefit approaches are that such approaches do not always consider synergies and trade-offs among GI benefits or fail to assess GI values for different urban contexts (Sussams, Sheate, & Eales, 2015). As a result, prioritization of GI designs and their respective benefits becomes complicated, but is urgent given climate change impacts. At least two efforts can help GI prioritization: (i) empirical studies on GI synergies and trade-offs that transcend different scale levels and can be repeated in other localities (Demuzere et al., 2014); and (ii) studies that address people's needs and beliefs regarding GI benefits (Madureira, Nunes, Oliveira, Cormier, & Madureira, 2015). The latter is especially important for a successful implementation of GI-based climate adaptation strategies that provide benefits to the entire city and its residents.

To be able to address people's needs and beliefs regarding GI benefits, it is important to understand how citizens think about climate-related problems and the implementation of new GI. With such knowledge and the engagement of citizens, feasible and legitimate adaptation strategies that fit the local context can be developed (Anguelovski, Chu, & Carmin, 2014; Broto, Boyd, & Ensor, 2015). Moreover, involving people in the planning process can increase people's understanding of climate impacts and the need for adaptation can increase public support and inspire behavioural change (Baptiste, Foley, & Smardon, 2015; Demuzere et al., 2014). The difficulty lies in the existence of many unknowns: regarding people's notion of and concerns about climate impacts (i.e. the need to adapt), regarding the degree to which people acknowledge the benefits of GI to alleviate such impacts, and regarding people's preferences for the different GI measures, including their willingness to pay (WTP) for such measures (Byrne, Lo, & Jianjun, 2015; Madureira et al., 2015) (Fig. 1). Successful design of adaptation measures requires an understanding of these different unknowns, and how they relate to one another.

Existing socio-cultural valuation studies address different dimensions of climate impacts and GI benefits. In this context, multiple terms are used somewhat interchangeably, like awareness, perception, understanding and perceived importance (e.g. Burger, 2014; Byrne et al., 2015; Klemm, Heusinkveld, Lenzholzer, Jacobs, & Van Hove, 2015; Shackleton, Chinyimba, Hebinck, Shackleton, & Kaoma, 2015). More importantly however, these and other studies generally address only one dimension of the socio-cultural value. For example, Klemm, Heusinkveld, Lenzholzer, Jacobs et al. (2015) assessed citizens' perceptions of GI for thermal comfort but did not relate this to people's notion of or concern about heat. Likewise, Shackleton et al. (2015) studied how residents value tree benefits but did not extend to preferences for GI. Some studies tackle multiple dimensions, e.g., assessing perceptions of GI benefits and awareness and concerns about climate change (Byrne et al., 2015), but still refrain from looking into GI design preferences – which are more regularly captured by WTP exercises (Ng, Chau, Powell, & Leung, 2014). For urban planning, there is a need to couple public values with climate change strategies (Ordóñez Barona, 2015).

This study aims to fill this gap by performing a socio-cultural valuation of urban GI for climate adaptation that combines insights from the various dimensions listed in Fig. 1. Specifically, we address the following research question: *How do residents' views on climate impacts and GI benefits shape preferences for GI adaptation measures?* For the city of Rotterdam, the Netherlands, we conducted a survey among residents to assess the five dimensions and their relations. We assess the generality of our findings by (i) assessing the dimensions at three spatial scales associated with different types of urban GI (home, neighbourhood, city), (ii) comparing two neighbourhoods with a different demographic and GI character, and (iii) assessing how the dimensions are related to the current presence of GI in the respondents' neighbourhood. As such, the proposed method can generate improved understanding of people's views on climate impacts and the use of GI for adaptation, and can help detect why policy support for adaptation strategies may be hampered.

2. Methods

We designed a method addressing the five dimensions of analysis stated in Fig. 1. Each dimension was explored through a survey undertaken with residents in two neighbourhoods in Rotterdam, the Netherlands. To understand variation in responses and choices we have not only related the responses to socioeconomic characteristics of respondents but also to the presence of GI in the neighbourhood. The following paragraphs describe the case study and the different elements of the method in more detail.

2.1. Study area

Rotterdam is a major port, international commercial hub and the second city of the Netherlands with a diverse population of 620,000 people. The city is densely built, surrounded by water and with 90% of its surface below sea level. Two neighbourhoods are used as case studies (Fig. 2).

Tarwewijk and *Kralingen-West* represent typical Rotterdam neighbourhoods: one south of the river Meuse and one north; one in the lower socioeconomic strata and one middle-class. The two neighbourhoods were selected because they feature similar housing types but different character in terms of GI. The GI differs in abundance and diversity (Table 1) and provides diverse ecosystem services bundles in each neighbourhood: *Tarwewijk's* GI provides, as compared to other neighbourhoods in the city, a very small bundle of services whereas *Kralingen-West* is in the middle band (see Derkzen et al., 2015). Together with information about neigh-