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Urban climate change adaptation: Exploring the implications of future land cover scenarios

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ABSTRACT

Different land cover futures will have contrasting implications for cities working to adapt to the changing climate. This paper explores this issue, reporting on the application of a scenario-based land use modelling case study focused on Greater Manchester in North West England. It highlights that the interplay between varied drivers of change has the potential to generate contrasting land cover futures for the city-region, which will in turn influence climate change adaptation prospects. The case study pays specific attention to green infrastructure cover, as this can enhance the capacity of urban areas to adapt to climate change by providing functions such as evaporative cooling and rainwater infiltration. The two scenarios analysed within this paper connect, broadly, to the contrasting processes of expansion and shrinkage that are shaping cities worldwide. Where cities are expanding, stimulated by economic growth and increase in population, the danger is that associated land use change will pressure existing green infrastructure resources with a detrimental impact on adaptive capacity. Cities that are shrinking, or experiencing relative decline in comparison to other cities, face a different set of issues. Here, the emergence of vacant land provides an opportunity to secure adaptive capacity benefits associated with green infrastructure. With the processes of expansion and shrinkage projected to continue to influence the global landscape of cities, this research highlights that strategies are needed to protect and enhance green infrastructure in both contexts in order to maintain and build adaptive capacity and moderate climate-related risks.

1. Introduction

The adaptive capacity of cities and urban areas, which relates to their ability to anticipate, moderate and manage climate change impacts, is influenced by features and characteristics of their landscapes. Urban land cover also affects climate change impacts. For example, urbanisation can influence hydrological processes and in turn affect the frequency and intensity of flooding events (EEA, 2012; Sun, Li, Fu, Li, & Tang, 2013). This paper focuses on urban adaptive capacity in the context of the green infrastructure sites and networks that surround, permeate and exist within cities and urban areas. This includes woodlands, river valleys, parks and gardens, for example. The role of green infrastructure in adaptation to climate change, for example via the provision of urban cooling and flood risk management functions, is increasingly recognised within policy making and research communities (e.g. European Commission, 2013; Gill, Handley, Ennos, & Pauleit, 2007). However, less is understood about how urban land use change, specifically concerning the nature and extent of green infrastructure coverage, may influence the adaptive capacity of cities and urban areas over time. This paper is focused on exploring this issue.

Urban land cover and land use characteristics are complex and dynamic over multi-decadal timescales (Allen, 1997), with processes of urban development and decay continually reshaping cities. Globally, some cities are growing and expanding whereas others are experiencing shrinkage and decline (Martinez-Fernandez, Audirac, Fol, & Cunningham-Sabot, 2012; McKinsey and Company, 2016; Sassen, 2001), influenced by dynamic processes including globalisation, deindustrialisation and demographic change (Hall, 1993; Martinez-Fernandez et al., 2012). Ruth and Coelho (2007) recognise that this complexity adds to the challenges associated with responding to climate change in urban settings. In this context, they suggest that scenarios capturing "…a wide range of influences on the behaviour of urban systems…" can be developed with stakeholders, and subsequently analysed using computer models, to support institutional learning and action (Ruth & Coelho, 2007: 3325). When creating climate change adaptation strategies, scenario planning can support decision makers in understanding and responding to the implications of divergent development pathways and contrasting future land use patterns on urban adaptive capacity. Despite the potential value of this approach, little research has been undertaken on this topic to date, and this paper aims

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to address this gap and support activities linked to the reduction of urban climate risk.

This paper considers how land use change over the coming decades, with a specific focus on green infrastructure, may influence the capacity of urban areas to adapt to extreme weather and climate change hazards such as flooding and heatwaves. A case study focused on Greater Manchester in North West England is utilised to explore these issues. Established scenario development and land use modelling methods are integrated to create two different future land use scenarios for Greater Manchester. The two scenarios represent contrasting ways that the city-region's urban centres and surrounding landscapes may evolve over the period to 2050. The scenarios are analysed and discussed to build understanding of how changes in land use, particularly green infrastructure, may influence Greater Manchester's adaptive capacity. Broadly, one scenario presents a future driven by growth and expansion, whereas the second scenario is characterised by processes connected to shrinkage and decline. Building on the research outputs, transferable insights are developed into approaches that can help to secure the long-term contribution that green infrastructure can make to building capacity to adapt to climate change in urban areas.

2. Literature review

Given the severity of future climate change projections, and the increased risk of related impacts such as heatwaves and flooding (IPCC, 2013), greater emphasis must be placed on adapting urban areas to the changing climate. One aspect of adapting to climate change concerns maintaining and enhancing adaptive capacity. The Intergovernmental Panel on Climate Change (IPCC) positions adaptive capacity as one of the factors that determines the severity of climate-related risks, specifically as an element of vulnerability, which also incorporates the concept of sensitivity (or susceptibility to harm from) climate hazards (IPCC, 2014). Following the IPCC's approach, risk is therefore a function of climate hazards, the degree to which a receptor is exposed to a hazard and the vulnerability of the receptor to the hazard. Consequently, where adaptive capacity is high this acts to moderate the severity of climate-related risks by reducing vulnerability, although low adaptive capacity can therefore exacerbate risk.

Swart et al. (2012: 11) define adaptive capacity as "…the longer-term capacity to plan for preventing and/or managing the impacts of climate change". The European Environment Agency adds that adaptive capacity relates to "…a set of enabling conditions…" that support adaptation to climate change impacts (EEA 2012: 63). Adaptive capacity is determined by a wide range of interrelated issues, including societal characteristics (e.g. citizens' awareness of climate change), land use (e.g. the extent of green infrastructure coverage), and institutional factors (e.g. the existence of strategies and governance frameworks related to adaptation) (Haddad, 2005; Smit & Wandel, 2006; Swart et al., 2012; Yohe & Tol, 2002).

Although urban landscapes act to intensify climate change impacts such as flooding and heatwaves (EEA, 2012), they can also have a moderating influence. Green infrastructure is a particular feature of urban areas that performs this function (EEA, 2012; European Commission, 2012). The European Commission (2013: 7) defines green infrastructure as "…a strategically planned network of high quality natural and semi-natural areas with other environmental features". This can encompass, for example, vegetated areas, parks, gardens, wetlands, natural areas, green roofs and trees (EEA, 2012). Green infrastructure is associated with the concept of adaptive capacity. Swart et al. (2012) note that green infrastructure enhances capacity to respond to climate change impacts, including heat stress and flooding, by lowering surrounding air temperatures and providing water storage and infiltration capacity.

Studies on urban parks and green spaces indicate that they have a cooling effect on surrounding areas (Hamada & Ohta, 2010; Spronken-Smith & Oke, 1998). Akbari and Konopacki (2005) demonstrated that widespread tree planting can affect the energy balance of a whole city, highlighting the potential cumulative impact of a city's green infrastructure network on moderating air temperatures. Trees and green spaces also have the potential to reduce flood risk by capturing rainwater, increasing evapotranspiration and raising the infiltration capacity of urban landscapes (Armson, Stringer, & Ennos, 2013; Bartens, Day, Harris, Dove, & Wynn, 2008; Stovin, Jorgensen, & Clayden, 2008). Catchment scale modelling has demonstrated that changing the surface area of green infrastructure cover influences the volume of run-off produced following rainfall events (Carter, Handley, Butlin, & Gill, 2017). Taking these ideas forward in practice, building on work in European and American cities on sustainable urban drainage systems (SuDS) (Zhou, 2014), the concept of 'sponge cities' is taking hold. These approaches are receiving particular interest in China where cities are suffering from flooding and water shortages, and a number of sponge city pilots are underway drawing on government funding. Liu et al. (2017: 473) describe a sponge city as:

> …an urban environment that is devoted to finding ecologically suitable alternatives to transform urban infrastructures into green infrastructures so these could capture, control and reuse precipitation in a useful, ecologically sound way.

It is recognised that adaptive capacity is not static and changes over time (Alberini, Chiabai, & Muehlenbachs, 2006; IPCC, 2007). The connection between green infrastructure and adaptive capacity illustrates this point. As urban areas expand or conversely 'shrink', influenced by multiple local and global drivers, the nature and extent of green infrastructure coverage will also change. For example, green infrastructure may be protected and enhanced by spatial planning policies (Lennon & Scott, 2014), or conversely may be lost due to urban expansion, driven by pressures including population growth and economic development (Angel, Sheppard, & Civco, 2005). These changes can, over time, affect the capacity of cities and urban areas to address climate-related risks, both positively and negatively depending on how land use changes. However, it is difficult to predict the direction of drivers of urban land use change and, consequently, long-term urban planning exercises are confronted with challenges posed by uncertainty (Balducci, Boelens, Hillier, Nyseth, & Wilkinson, 2011). Scenario-based approaches can be applied in response to the uncertainty that characterises urban dynamics to strengthen understanding of the nature and implications of future urban land use change.

Scenarios have been used extensively across a range of sectors to support the process of bringing a futures perspective into planning and decision-making (Bezold, 2010; European Environment Agency, 2009). It is important to remember that scenarios are not intended to be true representations of alternative futures (Selin, 2005). Scenarios present plausible possible future visions, and are usually formed around a series of 'drivers of change'. Drivers of change incorporated within established scenario processes focus on different sectors include those concerning demographic, economic, environmental, policy, scientific, social, technological, cultural and values related issues (Nakicenovic et al., 2000; Natural England, 2009; Nelson et al., 2006). Scenarios are often developed in collaboration with stakeholders, and are intended to provoke discussion and support decision-making (EEA, 2009). Scenario outputs can also contribute to modelling exercises. For example, scenarios are developed to create different potential future greenhouse gas emissions trajectories, which subsequently feed into climate models to produce temperature and precipitation projections (IPCC, 2013). Although there is now broad consensus that climate change is occurring and looks set to intensify (IPCC, 2013), the need for scenarios in this context reflects our incomplete knowledge of key climate processes and inability to predict future greenhouse gas emissions trajectories (Dessai & Hulme, 2004).

Several studies have been published that apply scenario-based approaches to look at land use change in the context of urban climate change impacts. Storch and Downes (2011) assessed the implications of