Urban Forestry & Urban Greening 14 (2015) 952–958

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Understanding the potential loss and inequities of green space distribution with urban densification

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ARTICLE INFO

Article history:
Received 30 December 2014
Received in revised form 1 September 2015
Accepted 4 September 2015

Keywords:
Urban planning
Urban trees
Remote sensing
Socio-economic indices
Environmental justice
Green infrastructure
Social inclusion

ABSTRACT

Urban population growth is leading to growing concerns about land use change, green infrastructure, and the loss of beneficial ecosystem services. Human and environmental health is supported by services such as climate regulation, air filtration, and flood mitigation. However, maintaining these services within cities requires the preservation and equitable distribution of green infrastructure near where people live. Sydney, Australia, where the population is expected to grow from 4.3 million to 5.6 million by 2031, is undergoing an urban transformation. This study investigates the spatial distribution of green infrastructure within Sydney to determine how patterns of green infrastructure vary according to land use, residential density, and socio-economic variation. More than half of urban Sydney is comprised of residential land use, representing the single largest contribution to Sydney's green infrastructure. Two types of green infrastructure are examined in this study, public green space represented by parkland area and tree canopy cover and private green space represented by residential area and tree canopy cover. Results show that with greater dwelling density, both types of green infrastructure decrease. Availability of private versus public green infrastructure, however, differs according to socio-economic advantage. Suburbs of higher socio-economic advantage have significantly more private green cover, but slightly less public green cover than suburbs of greater disadvantage. These findings highlight that urban densification can lead to a general loss of two important reservoirs of urban green infrastructure (public parkland and residential tree cover). Disadvantaged communities may have a greater reliance on public green infrastructure in the form of parkland due to a lack of private residential tree cover.

1. Introduction

Growing urban populations present a challenge to many cities around the world. More than half of the world's population now reside in urban areas, with cities expected to absorb most of the future growth in global population over the next four decades (United Nations, 2010). This has led to increasing focus by urban planners on the strategy of urban infill to increase population density and concentrate people closer to public transport, employment, and urban amenities (Zhou et al., 2013). At the same time, however, there are also growing concerns about the effects of increasing density on the maintenance of urban green infrastructure and the provision of ecosystem services that benefit urban populations (Eigenbrod et al., 2011).

There are a large range of ecosystem services that improve human and environmental health in cities. Urban green infrastructure provides microclimate regulation of the urban heat island through the cooling benefits of vegetation. This cooling effect can reduce heat-related health risks to humans and other organisms by creating more comfortable urban temperatures (Lehmann et al., 2014). Vegetation can also reduce the energy required for air conditioning in residential homes, through the provision of shade and shelter, thereby reducing peak loads and consumer costs (Xu et al., 2012). Green infrastructure also enhances urban quality of life by increasing the psychological well-being of citizens (Bolund and Hunhammar, 1999; Fuller et al., 2007) by providing opportunities to experience nature (Pyle, 2003; Miller, 2005). Other benefits include noise attenuation, where vegetation is used to buffer residential areas from urban noise pollution, and flood mitigation, where carefully designed planting regimes can reduce flood peaks by slowing runoff following intense rainfall, thus allowing greater levels of infiltration and recharge within the urban environment (Bolund and Hunhammar, 1999).

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http://dx.doi.org/10.1016/j.ufug.2015.09.003
1618-8667/

However, if urban citizens are to directly benefit from these ecosystem services, there must be green infrastructure available in and near the places where people live, work and play. Yet the pathways for increasing future green infrastructre remain unclear (Bowler et al., 2010) given the trend for more compact and dense urban form, where there may be less space for trees (McPherson et al., 2011). There are also concerns regarding the priorities for future green infrastructure and whether resources should be directed towards public versus private land and what this might mean for the equitable distribution of the benefits from nature. While green infrastructure on private land is heavily reliant on homeowner preferences and is therefore difficult for governments to manage or incentivise (Andersson et al., 2007), it comprises the large majority of green infrastructure in many cities (Loram et al., 2007; Mathieu et al., 2007; van Heezik et al., 2012). There is a widely held view that as urban densities are increased, any subsequent loss of private green infrastructure can be offset by increased access to or provision of public green infrastructure (Maat and de Vries, 2006), but there is little evidence this offset is actually occurring (Byrne et al., 2010). Additionally, it becomes increasingly difficult to retrofit public green infrastructure into dense urban areas to make up for lost private green infrastructure, leading to a reduction in the overall ecosystem benefits to a city. Thus, it is both the amount of future green infrastructure as well as the patterns of distribution and access that are crucial for determining how ecosystem services are allocated across a city.

Few studies have examined the socio-spatial inequities associated with the distribution of green infrastructure in cities. One study in Pheonix, Arizona, demonstrated a strong relationship between neighbourhood income, vegetation cover and cooling benefits (Jenerette et al., 2011). Another study in Tampa, Florida, that examined the environmental equity of street trees, showed a significantly lower proportion of trees in neighbourhoods containing a higher percentage of minorities, low income residents, and renters (Landry and Chakraborty, 2009). A handful of studies have also focused on the distribution of green space as an environmental justice issue because of differences in tree cover related to the ethnicity of neighbourhoods, and the subsequent reduction in ecosystem service provision (Flocks et al., 2011; Heynen et al., 2006). Such findings have important implications for the equity and fairness of future public investment in green infrastructure and associated urban policy development and strategies. For example, there may be tensions between an equitable distribution of green infrastructure across neighbourhoods versus targeted investment in selected neighbourhoods that are deemed to be most in need, according to various criteria.

In Sydney, Australia, where the population is expected to grow from 4.3 million to 5.6 million people by 2031 (NSW Government, 2013), the majority of this growth is expected to occur within existing urban areas through urban consolidation (Bunker et al., 2005; Gray et al., 2010; Holloway and Bunker, 2006). Although both state and local governments are developing guidelines and strategies to ensure that green cover is maintained through this land use change process (NSW Government, 2013), there is still a need for a consistent, reliable, city-wide understanding of the current patterns of distribution and access to green cover. Recent green cover audits using i-Tree (an urban forestry assessment tool developed by the US Forest Service) within the City of Sydney (City of Sydney, 2013) and in the North Sydney local government area (North Sydney Council, 2011) reveal that most public spaces already have green cover. Thus, in these two cases there may be little to gain by targeting future green infrastructure in public land, with the greatest opportunity residing in private spaces.

Here, we present an analysis undertaken in Sydney, Australia, where decision-makers are grappling with rapid population growth while trying to achieve urban green cover targets through smart urban planning. Understanding patterns of change in green infrastructure with increasing urban consolidation will assist decision-makers in assessing the trade-offs between urban consolidation and the provisioning of public and private green infrastructure to deliver important ecosystem services. This paper provides; (1) a broader understanding of the patterns of distribution of green infrastructure across Sydney; (2) explores the relationship between urban population density and green infrastructure; and (3) identifies potential social justice issues associated with inequitable distribution that may help target future investment.

2. Methods

2.1. Study area

Sydney is the capital of New South Wales (NSW) and is the largest and most densely populated city in Australia. It is located on the east coast at latitude 34°S and experiences a temperate oceanic climate with generally mild winters and warm summers (Vaneckova et al., 2010). The study area was defined by the Urban Centre and Locality (UCL) boundary identified within the Australian Statistical Geography Standard (ABS, 2012). This definition restricts the boundary of Sydney to the contiguous, built up areas of the city, thereby excluding the surrounding peri-urban areas and National Parks that make up the Greater Sydney Region. The Sydney UCL comprises a land area of 2037 km^2 that extends 70 km from the coastline in the east to the Blue Mountains in the west (Fig. 1).

Sydney's urban development has proceeded rapidly since 1945 (post-World War II), primarily through extensive suburbanisation, largely in the form of single detached housing on large blocks of land (Bunker et al., 2005). With a growing emphasis on urban consolidation from the early 1980s (Bunker and Searle, 2009; Gray et al., 2010), the population and dwelling densities of Sydney's existing suburbs are now increasing. This has led to debates over the transformation that is occurring in Australia's suburbs (Newton, 2013) and the loss of private green infrastructure associated with shrinking backyards (Hall, 2010).

The Sydney UCL has a complex policy environment that is made up of 41 individual local councils. Although the state government has developed recommended guidelines to help the local councils develop policies and strategies for managing their green infrastructure, there are no specific targets identified (NSW Government, 2015). As a consequence, the level of green infrastructure policy development across Sydney is highly variable, with some local governments already developing and applying urban forest strategies, while others have done very little (Wang and Merrick, 2013).

2.2. Distribution patterns of green cover across Sydney

A vegetation assessment of Sydney was undertaken to determine how patterns of green infrastructure vary according to land use and residential dwelling density. Green infrastructure represents the range of tree cover and vegetation within the city. Two different types of specific green infrastructure are examined in this study, public green space represented by parkland area and tree canopy cover and private green cover represented by residential area and tree canopy cover. Canopy cover was determined using Foliage Projection Cover (FPC), a measure of the percentage of ground area that is covered by the vertical projection of foliage from tall woody vegetation (Walker and Hopkins, 1990). The FPC estimates were provided by the NSW Department of Premier and Cabinet, Office of Environment and Heritage, and were derived from SPOT 5 satellite imagery captured for Sydney at 10 m spatial resolution on the 12th May 2012.

Land use within the Sydney study area was determined using the land use classification of Mesh Blocks (ABS, 2010) identified in