Urban Forestry & Urban Greening 15 (2016) 45–52

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

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

Spatiotemporal patterns of tree canopy cover and socioeconomics in Melbourne

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ARTICLE INFO

Article history:
Received 16 June 2014
Received in revised form
15 December 2014
Accepted 21 October 2015
Available online 1 December 2015

Keywords:
Income
i-Tree
Planning
Policy
Time-related
Urban forest

ABSTRACT

This paper introduces a method to study the temporal relationship between the distribution of trees in cities and the residents' income, rate of home ownership and level of education. Through photo-interpretation methods, it documents tree cover percentages in five inner city Local Government Areas in Melbourne. A 10-year time frame (2001–2011) is examined. Prior socioeconomic indicators are juxtaposed against future tree cover levels to investigate relationships. This study demonstrates that tree cover inequity is increasing over time in Melbourne. The study indicates that prior income level is a fair precursor to future canopy cover. By comparing different tree policy approaches of the five adjacent local government areas in Melbourne, it is identified that progressive policy helps generate positive outcomes for the urban forest.

1. Introduction

Extreme heat is the number one cause of weather-related deaths in heavily urbanised Australia (Karoly et al., 2013). Cities exhibit an Urban Heat Island (UHI) effect. Impervious surfaces absorb and retain more solar radiation than natural environments (Akbari et al., 2001). An extended heat wave is amplified by the UHI, and can be fatal to the sick, elderly and socially or physically vulnerable (Semenza et al., 1996; Kovats and Hajat, 2008). Accelerated urbanisation means a larger group of people will be at risk since global climate change is expected to escalate the frequency and intensity of heat waves (Kovats and Hajat, 2008).

Large canopy trees help mitigate the UHI effect by shielding asphalt from the sun's rays and through evapotranspiration (Taha, 1997; Akbari et al., 2001). Trees generate a range of additional benefits for the metropolis. They help regulate microclimates (Akbari, 2002; Donovan and Butry, 2009), reduce stormwater runoff (Pataki et al., 2011), increase property values (Sander et al., 2010; Tyrvainen, 1997; Mansfield et al., 2005), produce a profitable investment (McPherson et al., 2005), improve the public's physical and mental health (Dwyer et al., 1992), and may improve air quality (Pataki et al., 2011) and reduce crime (Donovan and Prestemon, 2012); consumers prefer heavily treed precincts (Wolf, 2005). Alternatively, trees can damage pavements, footpaths and pipes (Nicoll and Armstrong, 1997), block transit signs and lighting (McPherson and Muchnick, 2005) and emit volatile organic compounds (Pataki et al., 2011). In general, however, the benefits are expected to outweigh the costs.

Wealthier communities tend to have larger amounts of canopy cover (Escobedo et al., 2006; Heynen, 2006; Landry and Chakraborty, 2009) than those poorer. Rates of home ownership might contribute to this disparity (Perkins et al., 2004). Wealthy home-owners may campaign for urban forestry action more vigorously (Conway et al., 2011). Tree cover is lower for minorities, who tend to rent their homes (Landry and Chakraborty, 2009; Heynen et al., 2006). The temporal study by Kirkpatrick et al. (2011) of six Australian cities differs regarding levels of home ownership and canopy cover. However, this may be explained by the gentrification of inner suburbs. In Australia, education has been shown to be a better indicator of canopy cover than income (Kendal et al., 2012; Luck et al., 2009)—though the two are closely related. Kendal et al. (2012) suggest that educated individuals value trees and elect to live in densely treed districts. Jones et al. (2012) contend it is much deeper; tree knowledge is important, but so is landscape experience, environmental concern, viewpoints on the perceived positive

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http://dx.doi.org/10.1016/j.ufug.2015.10.011
1618-8667/

and negative social impacts of trees, gender and political affiliation. The abstract concept of beauty has been the most influential factor elsewhere (Kirkpatrick et al., 2012).

Urban managers need a better understanding of temporal trends. In one study, income measurements in a given year held a more stable relationship to vegetation cover in future years (Luck et al., 2009). Few time based studies of tree cover and socioeconomics exist (Heynen, 2006; Luck et al., 2009; Kirkpatrick et al., 2011). Only one has analysed contiguous areas in a city (Heynen, 2006). With the exceptions of Heynen (2006), Landry and Chakraborty (2009) and Kendal et al. (2012), research has focused solely on urban trees on either private or public properties. No study has estimated both public and private tree cover to compare with socioeconomic indicators, in adjacent areas over time, with respect to varied policy frameworks. This study aims to fill this gap. It chronicles the recent (2001–2011) canopy cover, income level, homeownership rate and educated resident trends in five adjoining areas in inner Melbourne, and juxtaposes prior socioeconomic indicators against future per cent tree cover. Further, this study aims to analyse if planning policies have influenced changes in urban tree canopy cover from 2001 to 2011.

2. Methods

Melbourne is located in south-eastern Australia, on the northernmost point of Port Phillip Bay. It is the capital and most populous city of the Australian state of Victoria. Melbourne has a temperate climate, with a 30-year mean annual temperature of 15.9 °C and rainfall of 602.6 mm (Bureau of Meteorology, 2013). Five Local Government Areas (LGAs) in inner Melbourne are analysed. An LGA is a "spatial unit which represents the whole geographical area of responsibility of an incorporated Local Government Council" (Australian Bureau of Statistics, 2011). In 2011, the ABS introduced Mesh Blocks as a new unit for micro-level statistics. These units did not exist in 2001 and thus could not be used in this study. The LGAs are Maribyrnong, Melbourne, Port Phillip, Stonnington and Yarra. These LGAs represent a transection of wealth within inner Melbourne. They are also contiguous to one another and thus have similar natural environments and comparable amounts of rainfall. The LGAs comprise different sizes of land areas ranging from 19.5 km^2 in Yarra to 37.4 km^2 in Melbourne. The total land area examined is 134.4 km^2.

Maribyrnong was traditionally dominated by the defence and manufacturing industries. These sites have been redeveloped as housing and mixed use districts. Melbourne is the capital city and seat of the central business district and major municipal ports. Moving eastward, Port Phillip, Stonnington and Yarra are predominantly medium to high density residential districts with mixed use corridors.

Blends of native and exotic trees comprise Melbourne's urban forest. The trees, however, are increasingly under pressure due to old age, pests and disease, increasing population density, the Millennium Drought (1998–2007) and climate change. The City of Melbourne alone expects to lose 27% of its trees in 10 years, and 44% in 20 years, unless action is taken (City of Melbourne, 2012).

2.1. Canopy cover

Canopy cover is selected as an indicator of urban tree spatial distribution and calculated through digital photo-interpretation. Aerial photography analysis is one of the most often used methods to calculate canopy cover (Escobedo et al., 2006; Perkins et al., 2004; Heynen, 2006; Heynen et al., 2006; Kirkpatrick et al., 2011; Kendal et al., 2012). Using i-Tree methods (USDA, 2011), randomly generated points are cast over aerial images and classified into a previously defined class; the method generates a statistically valid estimate of the per cent cover in each class as well as a known standard error of estimation (USDA, 2011). Aerial photographs for 2001 and 2011 were acquired from the University of Melbourne Library's Map Collection. Metadata records state the custodian for 2001 imagery is the Victorian State Department of Infrastructure and image resolution was 35 cm. Correspondingly, the Department of Sustainability and Environment is the custodian for 2011 imagery; resolution was 10 cm. These aerial images were uploaded to ArcGIS. A polygon/vector layer delineating the five Local Government Areas' (LGA) boundaries was overlaid and then sample points were generated within these boundaries using the *Create Random Points* tool in ArcToolbox. This tool randomly distributes the classification points within an LGA's boundary with a minimum distance from any other point assigned by the user (1 metre buffer in this instance). The points' classification was recorded in the layer's attribute table and then exported to Microsoft Excel where canopy cover estimates were calculated as number of canopy points divided by total points. Five thousand randomly generated points were classified for this analysis. This number was based upon i-Tree's recommended range of 500–1000 points per area and the fact the scope of analysis is limited to five LGAs. A larger number of points interpreted produce a more precise measurement. Since the analysis was temporal, 5000 points were classified for 2001 imagery and the same 5000 points were classified for 2011 imagery; identical spatial points classified over two, temporally-separated images. The 5000 randomly generated points, differentiated by colour and LGA, are shown in Fig. 1.

Consistent analysis across each LGA required the number of sample points be appropriately apportioned relative to the size of each LGA. A larger LGA received more random points than a smaller one. The number was calculated by ArcGIS and ranged from 1315 points (Melbourne) to 773 (Yarra).

Each point was classified into one of five categories: (1) tree, (2) shrub/green space, (3) impervious building, (4) impervious groundcover or (5) water. Shrub/Green space refers to low lying vegetation such as bushes, grasses, gardens and open space such as beaches and rocky riverbanks. Impervious building denotes man-made structures such as offices, warehouses, accommodated dwellings, mature construction sites and shopping centres. Impervious groundcover represents paved roads and footpaths, train tracks, premature construction sites and cemeteries. This multi-pronged approach provides a more detailed estimate of land cover than a binary approach and might help explain the core findings. For example, a significant increase in impervious surfaces may influence a decrease in canopy cover. A binary approach explains whether canopy cover increases or decreases, but provides no additional information for explaining why.

2.2. Socioeconomic indicators

Median household income, home ownership and the number of university graduates are selected as socioeconomic indicators in the five councils.

Median household income is a measurement of wealth. It is the main socioeconomic variable to which canopy cover is analysed in the literature and most often argued to have the greatest influence on the spatial distribution of the urban forest (Escobedo et al., 2006; Perkins et al., 2004; Heynen, 2006; Heynen et al., 2006; Landry and Chakraborty, 2009).

The second variable is home ownership. Multiple authors have included rates of home ownership in their studies. Those who own their homes tend to be financially incentivised to invest in their properties through tree planting and maintenance (Perkins e al., 2004) or are perceived to campaign more vigorously for local governmental action (Conway et al., 2011). Conversely, those who rent have little economic motivation to finance home