Landscape and Urban Planning 141 (2015) 112–122

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research Paper

Protecting trees at an individual level provides insufficient safeguard for urban forests

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HIGHLIGHTS

- Trees were protected primarily for cultural rather than biodiversity reasons.
- Older suburbs and those with higher density housing had the most protected trees.
- There were few protected trees in areas with high socio-economic deprivation.
- Approximately 10% of the protected trees were recognised weed species.

ARTICLE INFO

Article history:
Received 12 October 2014
Received in revised form 8 May 2015
Accepted 11 May 2015
Available online 1 June 2015

Keywords:
Urban tree protection
Vegetation cover
Urban forest
Tree conservation
Socio-economic
Housing-density

ABSTRACT

As an increasing proportion of the global human population resides in urban areas, urban forests are becoming both more important and more threatened. In many cities urban tree cover conflicts with strategies for urban intensification, and is being reduced due to inadequate protection. Here, we assess the effectiveness of one type of tree protection policy used by a number of cities worldwide: the case-by-case protection of specific individual trees. We use Auckland, New Zealand as a case study, where the main form of urban tree protection is now through Auckland Council's Schedule of Notable Trees. We investigated: (1) the species composition of the listed trees, and (2) the relative contribution of geographical variables (suburb age, dwelling density, socio-economic deprivation, and tree cover) in explaining spatial variation in listed-tree density. Tree cover (>8 m) in central Auckland was 6% of the land area, 63.2% of which was on private land. Of these trees, approximately 15% were protected. The tree species protected reflected cultural heritage; popular species were protected in large numbers, whilst only a single individual of a threatened native species was protected. The highest numbers of listed trees were in older suburbs, those with higher density housing, and those with lower levels of socio-economic deprivation. A low correlation between vegetation cover and listed-tree density shows that the proportion of trees protected varies substantially in different areas. We conclude that this case-by-case tree protection strategy provides insufficient protection for Auckland's urban biodiversity, but better implementation would improve biodiversity and social outcomes.

1. Introduction

Global urban growth is occurring at unprecedented rates, placing greater strain on urban ecosystems but rendering them ever more valuable. Urban trees are increasingly important for biodiversity conservation (Goddard, Dougill, & Benton, 2010), ecosystem services (McPherson, Simpson, Peper, Maco, & Xiao, 2005; Roy, Byrne, & Pickering, 2012), and providing direct benefits to urban inhabitants (including psychological and physical health) (Roy et al., 2012; Tryväinen, Pauleit, Seeland, & de Vries, 2005). Globally, many city authorities recognise the importance of urban trees and are implementing planting programmes and tree cover targets. For example, a number of US cities, including New York, Los Angeles and Baltimore, have set tree canopy cover targets of up to 46% of land area and initiated planting strategies to improve city environments through larger tree populations (McPherson, Simpson, Xiao, & Wu, 2011; Morani, Nowak, Hirabayashi, & Calfapietra, 2011). However, increasing urban tree cover conflicts with strategies for increasing urban intensification, and this can lead to losses in tree

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http://dx.doi.org/10.1016/j.landurbplan.2015.05.006
0169-2046/

cover and green space where government policies favour higher intensity housing (Diaz-Porras, Gaston, & Evans, 2014; Nowak & Greenfield, 2012; Pauleit, Ennos, & Golding, 2005).

The cumulative and mounting pressure on urban trees due to housing intensification, climate change and the global spread of tree pathogens (Nowak & Greenfield, 2012; Pauleit et al., 2005; Tubby & Webber, 2010), emphasises the importance of policy and legislative mechanisms to protect and enhance urban tree cover. In a number of cities, such as Canberra (Australia), Hamburg (Germany) and Milan (Italy), protection policies involve the blanket protection of all trees above a certain height or trunk size (Schmied & Pillmann, 2003; Stagoll, Lindenmayer, Knight, Fischer, & Manning, 2012). Other cities only protect specific individual trees. This is done on a case-by-case basis and is usually accomplished through council selection or resident nomination of certain specimen trees of cultural, historical, or botanical significance. For example, in England 'Tree Protection Orders' can be placed on single trees or groups of trees with high amenity, historical or rarity values (Town and Country Planning [Tree Preservation][England] Regulations 2012), and exceptional individual trees are protected through lists of 'Heritage Trees' in cities such as Bangkok (Thailand), and Guangzhou (China) (Jim, 2005; Thaiutsa, Puangchit, Kjelgren, & Arunpraparut, 2008). Some cities, such as Sydney (Australia) use both blanket protection and specific tree protection policies (Kelly, 2013). This was also the case in Auckland, New Zealand, but changes in government legislation (Resource Management [Simplifying and Streamlining] Amendment Act 2009 [RMA]) implemented in January 2012 resulted in the removal of blanket protection based on tree size, retaining only a schedule of 'notable' trees (for further details, see Appendix A).

By global standards Auckland is a relatively young city (founded in 1840, Stone, 2001), dominated by an extensive and diverse urban forest (Wilcox, 2012). Since the city's foundation there has been a considerable shift in its floral composition; by 1985, 21% of native plant species recorded in 1871 ($n = 373$) were locally extinct (Duncan & Young, 2000), and 615 naturalised exotic species were recorded (Esler & Astridge, 1987). After the 2009 policy changes came into effect in 2012, the only legislation protecting Auckland's urban forest was through the Schedule of Notable Trees (hereafter SoNT), with the exception of protection of all vegetation within certain 'Significant Ecological Areas', and coastal and riparian margins (Appendix A). The original intention of the SoNT was to provide additional legislative protection (alongside the general tree protection rules) to only certain notable, significant or distinguished trees. These trees were those that were exceptional or unique examples of a species, were critical to the survival of other species (e.g. wildlife), were of cultural or historic value, or were of such age, stature, character or visibility that they were regarded as the best in Auckland (see Auckland Council (n.d.) for nomination details and assessment criteria). As a consequence of the policy changes mentioned above, we contend that the importance of the SoNT has increased beyond its original objectives by default. In the majority of urban Auckland it is now the only policy tool available to protect the urban forest and therefore implicitly has broader functions such as conserving biodiversity and ensuring that ecosystem services are provided by the urban forest. Although other cities employ similar specific tree protection, globally little is known about whether this method is an effective tool for protecting these functions.

Using Auckland as a case study, we examine the factors that determine which individual urban trees receive specific protection through the SoNT, both geographically and botanically. We also assess whether these scheduled trees are representative of the available tree resource that could be protected. We determine whether the case-by-case protection of individual trees is likely to maintain the environmental and conservation benefits provided by trees in the urban environment.

2. Methods

2.1. Identity of protected trees

Auckland Council's SoNT (as of 30 September 2013) was separated into two groups: (1) individual trees, where species identity and number were known for a specified location, and (2) groups of trees, where an unspecified number and species were listed together for a specified location. Groups were always defined on the SoNT as native, exotic, or mixed native and exotic trees. Species richness and abundance were assessed for all individual trees, and then separately for native and exotic species. The numbers of native, exotic, and mixed status tree groups were also assessed. Categorisation of scheduled tree species as environmental weeds was based on Howell's (2008) consolidated list and Auckland Council's Regional Pest Management Strategy (RPMS) 2007–2012, a legal notification of pest species for the region (Auckland Regional Council, 2007).

From the number of species on the SoNT we predicted the size of the species pools (native and exotic) available in the Auckland region using the Chao1 estimator (Chao, 1984; Gotelli & Colwell, 2011), and estimated the number of species currently not represented on the SoNT. We also compared the native tree species on the SoNT with the tree species on the most comprehensive species list available for Auckland (Wall & Cranwell, 1936). Trees were defined as species that reach at least 6 m in height (as in Poole & Adams, 1994): the minimum height above which most native trees were protected prior to the policy changes in Auckland (Appendix A). We used individual-based rarefaction (Gotelli & Colwell, 2011) using the rarefy() function from the Vegan package (Oksanen et al., 2011) in R v. 2.13.0 (R Development Core Team, 2011) to produce rarefaction curves for both native and exotic trees (based on Hurlbert, 1971).

2.2. Predictors of notable tree density on private, urban land

The land area under the jurisdiction of Auckland Council (5106 km^2) was divided into 379 census area units (mean area $13.5 \pm 2.9\ km^2$), as defined by Statistics New Zealand for the 2006 population census (http://www.stats.govt.nz/Census.aspx). For each census area unit, we obtained data for two variables we considered potential drivers for notable tree density: (1) dwelling density (dwellings km^{-2}), and (2) the percentage of the population made up by each of the four main ethnic groups (European, Māori, Pacific peoples, and Asian, which collectively encompass 90% of declared ethnic affiliations in Auckland as stated on the 2006 census). We determined the mean age of a census area unit (in terms of years since it was first developed) by the area-weighted mean of the historic urban area extent (data layer obtained from Auckland Council). We also calculated an index of socio-economic deprivation for each area unit based on the mean of the 2006 New Zealand deprivation indices (NZDep2006) for the census mesh blocks that together make up each census area unit. The socio-economic deprivation index uses nine variables that reflect a lack of: income, employment, communication, transport, support, qualifications, owned home, and living space (Salmond & Crampton, 2012; Salmond, Crampton, & Atkinson, 2007). LiDAR (Light Detection and Ranging) data of vegetation cover (collected in 2008) were only available for the area that was governed by the former Auckland City Council (Auckland Isthmus) (Fig. 1). This area is a subset of urban Auckland and contains the CBD and nearby suburbs. We used these LiDAR data to calculate the percentage of each area unit covered by vegetation above 8 m tall (the height above which all trees were protected under previous legislation).

We used the Proposed Unitary Plan for Auckland (http://unitaryplan.aucklandcouncil.govt.nz/) to define urban land within