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Adapting and applying evidence gathering techniques for planning and investment in street trees: A case study from Brisbane, Australia

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ABSTRACT

Trees along footpath zones (or verges) grow on the "front-line" of urban forest ecosystems, increasingly recognised as essential to the quality of human life in cities. Growing so close to where residents live, work and travel, these street trees require careful planning and active management in order to balance their benefits against risks, liabilities, impacts and costs. Securing support and investment for urban trees is tough and robust business cases begin with accurate information about the resource. Few studies have accounted for spatial heterogeneity within a single land-use type in analyses of structure and composition of street tree populations. Remotely sensed footpath tree canopy cover data was used as a basis for stratification of random sampling across residential suburbs in the study area of Brisbane, Australia. Analysis of field survey data collected in 2010 from 80 representative sample sites in 52 suburbs revealed street tree population (432,445 ± 26,293) and stocking level (78%) estimates with low (6.08%) sampling error. Results also suggest that this population was transitioning to low risk, small-medium sized species with unproven longevity that could limit the capacity of the Brisbane's Neighbourhood Shadeways planting program to expand from 35% footpath tree canopy cover in 2010, to a target of a 50% by 2031. This study advances the use of contemporary techniques for sampling extensive, unevenly distributed urban tree populations and the value of accurate resource knowledge to inform evidence-based planning and investment for urban forests.

1. Introduction

Urban forest ecosystems provide beneficial services that are increasingly recognized as essential to the quality of life in human settlements, including a range of economic, environmental and social services that have been widely reported (Planet Ark, 2014; Dwyer et al., 2003; McPherson, 1995; McPherson et al., 1997, 2005; Nowak et al., 2006; Roy et al., 2012; Tarran, 2009). Ely and Pitman (2012) summarise the various benefits, acknowledged disservices (Dobbs et al., 2014; Lyytimäki and Sipilä, 2009), costs (McPherson and Peper, 1996) and risks of the street tree component of urban forests (Table 1).

Although often a small subset of the urban forest, street trees within footpath zones (or verges), medians and other road reserve lands, grow close to where residents live, work, play and travel, requiring careful planning and active management in order to balance their benefits against the risks, liabilities, challenges and costs. In most cities, annual investment in street trees must also compete for limited local government funds with numerous other essential public assets, services, major projects and community priorities.

Emerging urban forest research has increasingly focused on helping communities and urban tree managers to build a stronger evidence base to assist with strategic planning and to promote adequate investment (McPherson, 1995; Nowak et al., 2008a). The combination of "data-driven planning", diverse funding sources, integrated within organisational priorities has also helped cities reorient tree planting towards broader green infrastructure goals (Young, 2011) including managing urban stormwater and reconnecting people with nature.

Sustaining net benefits of urban forests over time requires the right kind of human intervention and management across three components – (i) the composition, condition and structure of the resource itself; (ii) a strong community framework and (iii) appropriate management of the resource (Clark et al., 1997; Kenney et al., 2011; Mincey et al., 2013). Miller et al. (2015) similarly suggests appropriate planning begins with urban forest managers asking typical asset management questions like "what they have", "what they want to achieve" and "how to reach their goals". The evidence base for planning and investment must be accurate and

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Table 1
Environmental, economic and social benefits of street trees, adapted from Ely and Pitman (2012) and acknowledged disservices, costs and liabilities.

Environmental benefits
- Urban heat island effect mitigation
- Wind speed modification
- Carbon sequestration & storage
- Avoided emissions (energy conservation)
- Air quality improvement
- Stormwater quality & quantity management
- Soil stabilisation and nutrient recycling
- Habitat support

Social benefits
- Human health and well being – physical, mental, and social capital
- Cultural connections
- Visual and aesthetic quality
- Sense of place & time

Economic benefits
- Avoided costs of environmental regulatory and provisioning functions
- Commercial vitality
- Increased property values
- Monetary values of human health and well-being benefits
- Tourism
- Preferred locations for corporate centres

Disservices, liabilities and risks
- Costs of planting, maintenance and removal/replacement
- Damage to public infrastructure from tree roots, falling branches, canopy obstructions
- Risks to public safety
- Risks to adjacent private property
- Storm damage and disruption to services
- Obstruction of views and solar access
- Nuisance and litter

relevant to target an audience of decision makers, community and broader stakeholders/potential investors yet at the same time align with contemporary conservation and urban forest management (Jansson and Lindgren, 2012; Sutherland et al., 2004; Wolf et al., 2015).

Urban forest research, predominantly in the US, especially over the last three decades, has established quantifiable relationships between urban forest structure and ecosystem services functions and value. Tree canopy cover and stem density, species diversity, condition and distribution across urban landscapes not only affects the extent of ecosystem services, such as air and water cleaning and cooling services, but also determines the current and forecast levels of maintenance need, risk, resilience and capacity for enhancement (McPherson, 1995; Nowak et al., 1996). Software tools, also developed in the US, such as "i-Tree" (I-Tree, 2014), and tree canopy cover data from remotely sensed imagery are now available to assist cities around the world gather evidence for planning and managing urban trees.

Several studies and sampling techniques have identified and accounted for spatial heterogeneity of urban tree canopy cover across different land-uses and tenures (Dobbs et al., 2013; Escobedo and Nowak, 2009; Jaenson et al., 1992; Kirkpatrick et al., 2011; Maco and McPherson, 2003; Nowak et al., 2008a; Nowak et al., 2008b; Sanders, 1984). Others have explored the influence of biophysical, land-use change and socio-economic factors on this uneven distribution and consequent inequity in urban ecosystem services provision (Conway and Bourne, 2013; Gong et al., 2013; Heynen et al., 2006; Ives and Kendal, 2014; Kendal et al., 2012; Landry and Chakraborty, 2009; Pham et al., 2013; Wolch et al., 2014). Such unevenness has not been limited to tree cover on private property, but is also found in public streetscapes and park-

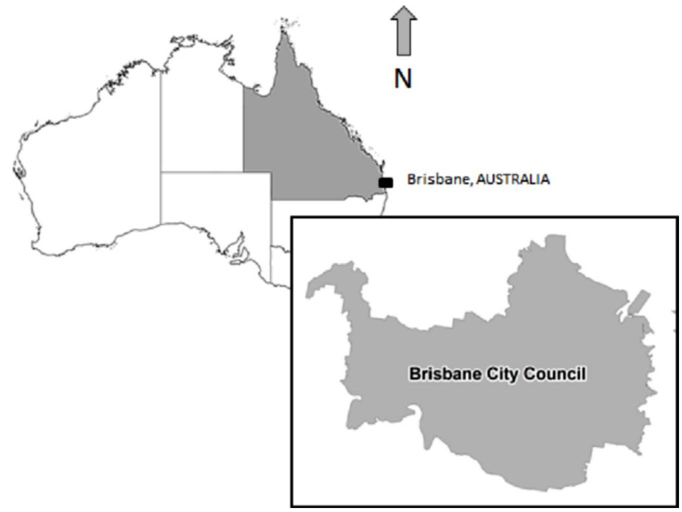

Fig. 1. Location of Brisbane study area in South East Queensland, Australia.

lands. However, few studies and tools have accounted for spatial heterogeneity when sampling street tree populations within a single land-use type (Nagendra and Gopal, 2010).

In large cities, 100% street tree inventories are often cost prohibitive or undertaken infrequently. Frequent monitoring of street tree assets, however, is especially important within areas of residential land use in rapidly growing cities where residential development can provide opportunities for improvements to public streetscapes as well as impacts on existing street trees. Such changes in street tree extent and structure, in turn, affect the flows of regulatory and cultural ecosystem services and disservices to the inhabitants of these populous land use zones (Berland and Hopton, 2014; Escobedo et al., 2015; McPherson et al., 2016; Sarkar et al., 2015; Tucker Lima et al., 2013; Dobbs et al., 2014). Sample surveys provide a cost effective alternative to monitor the street tree resource and inform forward planning (Nowak et al., 2008a). Given the importance of accurate evidence as the foundation to planning and investment in high value urban forest components like street trees, there are opportunities to improve contemporary evidence gathering techniques to ensure that sampling is representative of unevenly distributed tree cover. The aim of this study was to explore adaptations to evidence gathering techniques and demonstrate their usefulness for urban forest planning and policy review in the subtropical case study city of Brisbane, Australia.

1.1. Case study city: Brisbane, Australia

In 2010, an estimated 1.06 million people were living within the local government area (LGA) of subtropical Brisbane, located, on the east coast of Australia at latitude 27° 28′ S and longitude 153° 1′ E (Fig. 1). Brisbane is the third most populated and one of the fastest growing cities in Australia (Australian Bureau of Statistics, 2011). Around 20,000 new residents each year, in the ten years 2001–2010 years, were attracted by employment opportunities, affordable housing choices, access to major health and transport facilities and other lifestyle features.

Like most local councils in Australia, Brisbane City Council (BCC) has responsibility for the planning, planting, maintenance and protection of all trees on Council controlled land, including street trees. Brisbane's challenge is to continue to strategically expand street and park tree cover, while maintaining and managing existing tree assets with limited resources. However, unlike other Australian capital cities, Brisbane's area of jurisdiction extends well beyond the city centre to include 1340 square kilometres of residential, industrial, commercial centres, rural land uses and greenspace. To