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Population size and development history determine street tree distribution and composition within and between Eastern Cape towns, South Africa

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ABSTRACT

Street trees are a common feature of urban nature, providing ecological, economic and social benefits. These public functions are highly dependent on specific design principles, including the composition and diversity of tree species within the urban forest. Consequently, it is important to understand the patterns and correlates of street tree distribution and diversity to assess benefit flows. This requires sampling across and within towns. This paper reports on an assessment of the distribution, composition and diversity of street trees between and within multiple South African towns, and ascertains the correlations between tree density and composition with social contexts. Randomly selected streets were sampled in the affluent, township and low cost housing suburbs of ten Eastern Cape towns. Sixty-nine out of 300 sampled transects had street trees, with 888 trees enumerated, spanning 97 species. Alien tree species accounted for 71% of all the enumerated trees while indigenous trees species accounted for 12%. Tree density and composition were significantly lower in smaller towns and those marginalised during the previous racially-based political regime. Within towns, the poor areas had fewer street trees, with many streets having none. Collaboration and constant communication between the various government departments involved in suburb development is crucial to ensure a more rigorous incorporation of green infrastructure into the building and development plans of new housing developments.

1. Introduction

Urban forestry is poised to “go global” with the intent of using trees to mitigate several of the negative environmental and social effects of urbanisation, and to contribute to the long-term goal of creating more liveable and environmentally sustainable eco-cities (Carreiro, 2008). In promoting urban forestry, street trees have become the major strategy to fulfil this goal and to improve the livelihoods of dwellers in many cities worldwide (Churkina et al., 2015). Street trees are a widespread, common form of urban nature, often found in urban areas even in the absence of nearby parks and other green spaces (Grant, 2012). In the past, they have been planted for their aesthetic benefits such as beautifying the streetscapes but in recent years more of their tangible and intangible benefits; including ecological, economical, and social benefits (Mullaney et al., 2015), have been identified and advocated (Grant, 2012). Besides park trees and trees in private gardens, street trees play the biggest role in improving the climatic conditions for the urban population in arid cities (Breuste, 2013). Notwithstanding this, there have been many towns observed as having several treeless spaces but are biophysically suitable for the establishment of trees, which suggests that there are instances where social factors are actively preventing the establishment and planting of trees (Kirkpatrick et al., 2012). The composition of the urban forest is influenced by both the biophysical (Kirkpatrick et al., 2007) and socio-economic factors (Kendal et al., 2012b). Furthermore, species origin plays a role in the species composition of urban forests, with dispersal patterns between cities acting as immigration sources from which the alien species can disperse into the surrounding landscape (Alston and Richardson, 2006). The SANBI (2015) reported that there are approximately 1700 indigenous trees in the Southern Africa region, some of which have been used as urban trees, including *Acacia galpinii* and *Harpephyllum caffrum*. Similarly to other countries like Canada (Ordóñez and Duinker, 2013), the introduction of alien trees, such as *Jacaranda mimosifolia*, in the Southern Africa region can be attributed to the region's colonial history (Moran et al., 2013).

The public functions of street trees are highly dependent on specific design principles, which include the composition and diversity of tree species within the urban forest (Kendal et al., 2014). For example, Shackleton (2016) reported that birds in Grahamstown, South Africa favour indigenous street trees in their choice of habitat, compared to mistletoes, which favour alien street trees. The selection of the most appropriate trees is important for the success of any tree planting

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programme (Gerhold and Porter, 2007). In selecting the most appropriate species for street planting, it is important to define the purpose of the trees and the site conditions that will affect the choice (Gerhold and Porter, 2007). Simultaneously, an evaluation of diversity in the existing tree populations should be conducted before any new planting or replacement is undertaken (Subburayalu and Sydnor, 2012). The evaluation of diversity can be achieved through a variety of guidelines, as used by Sanders (1981), McPherson and Rowntree (1989), Santamour (1990), and Sun (1992). The two most commonly used guidelines for assessing street tree diversity are the target-based 10/20/30 heuristic (Santamour, 1990) and the non-target-based mathematically computed indices, such as the Simpson and Shannon-Weiner indices (Sanders, 1981). The "target-based 10/20/30 heuristic guideline", which was proposed for protecting urban forests from serious pest outbreaks (Shams, 2016), suggests that street tree populations should consist of not more than 10% of a single tree species, 20% of a single genus and 30% of a single family (Santamour, 1990). However, this guideline does not consider that most pests attack more than one tree species, genus or family at any given time (Raupp et al., 2006). To mitigate this, Raupp et al. (2006) then suggested that diversification takes place at the genus, family and possibly the ordinal levels. On the other hand, the Simpson and Shannon–Weiner indices use indices to calculate species diversity (Keylock, 2005).

Similarly to the "target-based 10/20/30 heuristic guideline", these indices are limited because they are based entirely on the number and relative abundance of all the taxa being evaluated (Subburayalu and Sydnor, 2012). Despite having a scientific basis, the use of these indices as an evaluation tool in the tree selection process is limited to the number and evenness of the taxonomic unit being evaluated (Subburayalu and Sydnor, 2012). To mitigate these limitations, Richards (1983) outlines guidelines for street tree diversity, correctly noting that such diversity should relate to the set of conditions and objectives for a given community. In addition to these guidelines, urban foresters and municipal officials responsible for urban greening may also consider factors like pest vulnerability, environmental benefits and tree adaptability, and limitations that are location and tree species specific during the planting of new trees or the replacement of old ones (Subburayalu and Sydnor, 2012).

In South Africa, the development history and legacy of apartheid has left visible disparities in the distribution, diversity and variation of street trees both between and within towns (Kuruneri-Chitepo and Shackleton, 2011; Shackleton et al., 2014), with low abundance or absence of street trees in many former homeland towns compared to the towns which were not part of the homelands during apartheid. Former homelands refer to those areas defined by the previously racially-based political dispensation as reserved for residency by black South Africans (Stull et al., 2016). These homelands received little economic development and remained mired in poverty and lack of opportunity (Stull et al., 2016). To this day, the towns in the former homelands are mostly characterised by poverty, limited employment and low socio-economic development compared to towns that never were in the homelands (Gwedla and Shackleton, 2015). These disparities are further exacerbated by limitations which most of the towns face, such as vandalism and limited funds for urban greening (Gwedla and Shackleton, 2015). There are also disparities in the distribution and variation of street trees between residential areas within towns. The affluent and in many instances, formerly white suburbs, are characterised by a greater distribution and abundance of street trees than both the townships and the post-1994 housing developments under the Reconstruction and Development Programme (RDP) (Kuruneri-Chitepo and Shackleton, 2011). The 'townships' are suburbs previously reserved for black South Africans who worked in cities during the apartheid period (Wilkinson, 1998). These suburbs were poorly serviced and dominated by relatively small, high-density 'erven' (lots), and high poverty levels due to restrictions on employment opportunities (Kuruneri-Chitepo and Shackleton, 2011). The low-cost housing suburbs, colloquially termed 'RDP suburbs' are a result of the post-1994 democratic government's initiative to address the severe backlogs of service provision and housing created during apartheid (Wilkinson, 1998) by delivering large numbers of low cost houses consisting of a single storey on a 40 m^2 foundation to the poor and previously homeless (Gilbert, 2004). Both these suburbs are characterised by a lower abundance, distribution and diversity in street trees, but the township suburbs have more street trees than the RDP suburbs (Kuruneri-Chitepo and Shackleton, 2011). While municipalities would prefer, despite the various socio-economic challenges faced in their towns, that suburbs are equally dense in street greenery (Gwedla and Shackleton, 2015), the goals related to dense and diverse urban forests, and major decisions regarding where trees should be situated are largely influenced by the availability of trees and funding, and the perceived threats to the trees, with the final decision for planting sites taken by the municipal officials themselves (Gwedla, 2016).

Several studies have been conducted on the patterns of urban green space and street tree distribution in South Africa (i.e. McConnachie et al., 2008; McConnachie and Shackleton, 2010; Kuruneri-Chitepo and Shackleton, 2011; Shackleton et al., 2014; Kaoma and Shackleton, 2014; Gwedla and Shackleton, 2015). Correlating to these studies, this paper seeks to examine and ascertain the macro-level correlates resulting in the density and distribution of street trees by examining the patterns of street tree distribution, composition and diversity between and within multiple South African towns, and how these relate to town socio-economic attributes.

2. Study sites

This study was conducted in 10 towns randomly selected from the 24 previously sampled by Gwedla and Shackleton (2015) in the Eastern Cape province of South Africa (Fig. 1). The province is situated in the south-eastern seaboard, bordering Kwa-Zulu Natal in the north-east, Free State and Lesotho in the north, and the Western and Northern Cape in the west. It is the second largest province in the country after the Northern Cape province and occupies an area of 169 580 km^2 (approximately 14% of the total area of South Africa) (Gwedla and Shackleton, 2015). The northern and north-western parts of the province are characterised by arid areas of the Great Karoo, the north-eastern parts by the Drakensburg Mountains, and the southern and eastern parts are bordered by the warm waters of the Indian Ocean (Gwedla and Shackleton, 2015). The north-eastern interior of the province experiences cold and clear days in winter but become hotter and drier towards the western parts of the province (Gwedla and Shackleton, 2015).

The province has 6.92 million people, of which 53% are females, representing 12.6% of the total population of South Africa (Stats SA, 2015). It is divided into six district municipalities, 37 local municipalities, and two metropolitan municipalities along the coast, with the smallest municipality having 36 002 people and the largest having 1.15 million people (Stats SA, 2015). The sizes of the municipalities range from 1291 km^2 to 11 668 km^2 (Stats SA, 2015). The province has 128 areas classified as urban areas, with the largest (Port Elizabeth) having 876 436 people, followed by East London (295 644 people) and Uitenhage (242 924 people), and the smallest (Hogsback) having 1029 people (City Populations Database, 2016). The province is the poorest in the country, with low adult education levels, high unemployment (> 35%) and poverty, with these being higher in the more rural municipalities and lower in the larger towns and cities (Gwedla and Shackleton, 2015).

2.1. Individual town characteristics

One-third of the sample towns are in the grassland biome (Table 1). Fifty percent of the towns were previously classified as having medium street tree density, while 30% were classified as having low density (Gwedla and Shackleton, 2015). The street tree densities had previously