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Short communication

The comparative growth rates of indigenous street and garden trees in Grahamstown, South Africa

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ABSTRACT

Urban forestry is advocated worldwide as a means of enhancing the liveability of towns and cities, and mitigating some of the anticipated impacts of climate change. Optimisation of the benefits of trees in urban areas is dependent upon knowledge of tree form, growth, and the products and benefits that trees provide. Growth rates are a vital variable for modelling benefits, yet there is a significant gap in knowledge pertaining to growth rates of trees in urban areas, especially indigenous species in developing world countries. Here we report on growth rates of indigenous street and garden trees in Grahamstown, South Africa, using two approaches; tree ring counts on increment cores and mean rates from trees of known planting age. Growth equations for both street and garden trees were derived. There was no significant difference in mean growth rates determined via the two methods. For both methods street trees grew approximately 30% slower than trees in gardens.

1. Introduction

Urban forestry has been encouraged worldwide as a means of mitigating some of the ecological and social problems associated with urbanisation (Nowak and Crane, 2002; Guevara-Escobar et al., 2007; Georgi and Dimitriou, 2010; Viswanathan et al., 2011). Urban trees have also been advocated as an important strategy to mitigate some of the anticipated impacts of global climate change (Stoffberg et al., 2010; O'Donoghue and Shackleton, 2013). The magnitude of benefits provided by urban trees depends on their abundance, size and growth in the urban landscape which in many places can be constraining on tree survival and growth. On the one hand, growth rates may be lower in some urban areas due to urban pollution and the restriction of aboveground and belowground space (Gregg et al., 2003). Root growth may be constrained by soil compaction during building processes and adverse soil conditions due to reduced aeration, water infiltration and input of organic matter because of paving of the soil surface (Viswanathan et al., 2011; Lawrence et al., 2012). Aboveground growth may be constantly trimmed to prevent trees interfering with utilities and signage (Consolloy, 2007). On the other hand, tree growth may be enhanced in some urban environments through greater care via fertilisers, irrigation, thinning and reduced browsing; there may also be reduced canopy competition due to wide spacing and elimination of new recruits (Rhodes and Stipes, 1999; Quigley, 2004). Thus, the relative magnitude of enhancing or constraining factors on tree growth will vary between climatic zones and between and within cities, and requires greater understanding to ensure that city-wide models of tree growth are adequately parameterised. This is particularly important in determination of carbon offsets and credits (Stoffberg et al., 2010). However, there is a general dearth of growth rate information for indigenous trees in most urban settings of the developing world where monitoring records of planting and maintenance programmes of urban trees are frequently limited (Shackleton, 2012). Here we report on the growth rate of a selection of indigenous urban street trees relative to garden trees in Grahamstown, South Africa.

2. Methods and materials

2.1. Study location

Grahamstown (33°18′S; 26°32′E) is located 60 km inland between the two major cities Port Elizabeth and East London, in the Eastern Cape province, South Africa. It has a population of approximately 65 000 (Kuruneri-Chitepo and Shackleton, 2011). Grahamstown has seasonal fluctuations of mean temperature, ranging from 5 °C in winter (Jun–Sept) up to 35 °C in summer (Nov–Apr). Mean annual rainfall is 669 mm (State of the Environment in South Africa, 2004), with bimodal peaks in October–November and again in March–April.

2.2. Species selection

Phase 1 determined which trees species were suitable for study. Of the 22 sufficiently abundant indigenous species in the town in both street and

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garden environments, stem cores were taken at breast height (1.3 m) using a 5.15 mm diameter increment borer. Cores were placed in a container, which was then sealed and labelled. In the laboratory each core was viewed using a dissecting microscope at 4.5× magnification to determine if clear growth rings were present. As suggested by Lilly (1977) various combinations of sanding, wetting, varnishing or no 'treatment' of the cores before inspection were attempted, but did not markedly increase the clarity of rings in those species with clear rings. The species for which clear rings could be discerned were used in the next phase.

2.3. Determination of growth rates from tree rings

Using suitable species identified in Phase 1, stem cores (at breast height, to a depth of 7 cm or greater) were taken from both street and garden environments for a range of sizes for each species. Tree circumference was recorded. The cores were air dried for 24 h and then glued onto mounting blocks. Each was then observed under a dissecting microscope as described above, and the number of discernible rings recorded over a given length of core (at least 4 cm). The mean ring width was determined by dividing the distance measured by the number of rings counted. The mean ring width was doubled to derive the mean diameter increment of the sampled tree.

2.4. Determination of growth rates from known planting dates

Trees of known age were sampled as an independent check on the growth rates determined from ring counts because of the well-known drawbacks of ring counts, such as false or missing rings (Lilly, 1977; Gutsell and Johnson, 2002; Therrell et al., 2007). For these trees, we noted the planting year and diameter of the tree. The diameter of each tree was divided by the known age to determine mean annual diameter increment.

2.5. Analysis

As the data per location and method were not always normally distributed, we deployed Mann–Whitney U tests to assess differences in mean annual diameter increment between sites and methods separately. The growth rate of trees in both environments relative to their age was then determined by regression analysis.

3. Results

Although several indigenous species provided clear rings, only a few species were in sufficient abundance in the street environment to be used in subsequent phases. Because sufficient numbers of the same species could not be found in both street and garden environments, a mix of species was obtained from both environments to provide a reasonable sample size. This precluded analyses based on single species. Data were collected from 11 indigenous species in the street environment and 17 in gardens. Of the species with a sample of three or greater discernable rings were found in ≥90% of the samples for *Combretum erythrophyllum* (Burch.) Sond., *Podocarpus latifolius* (thumb.) R.Br ex mirb., *Podocarpus henkelii* Stapf ex Dallim & Jacks and *Zanthoxylum capense* (Thunb.) Harv. Those with between 50% and 90% usable cores were *Celtis africana* Burm. F., *Ekebergia capensis* Sparrm., *Podocarpus falcatus* (Thumb.) R. Br ex Mirb. and *Trichilia emetica* Vahl. Those with less than 50% usability included *Erythrina caffra* Thunb., *Harpephyllum caffrum* Bernh. and *Vepris lanceolata* (Lam.) G.Don.

Both methods to determine growth rates indicated a significantly higher mean diameter increment rate for garden trees than street trees (Table 1). From ring counts, street trees had a mean diameter increment of 0.71 cm/yr, which was 26% less than the 0.96 cm/yr for garden trees. Assessing mean growth rates via the known age method indicated that growth of street trees was 36% less than that of garden trees. There was no statistical difference in growth rates determined by the two methods (Table 1). None of the owners of gardens in which we sampled claimed to have given special attention or care to the sampled garden trees beyond the first growing season after planting.

Table 1
Mean annual diameter increment of indigenous street and garden trees determined from known planting dates and tree ring counts.

Method	Mean annual diameter increment (cm/yr)		Statistics
	Street trees	Garden trees	
Known age	0.83 (n = 45)	1.25 (n = 56)	z = 3.95; p < 0.0001
Ring count	0.71 (n = 38)	0.96 (n = 30)	z = 3.00; p < 0.005
Statistics	z = 0.62 p > 0.05	z = 1.38 p > 0.05	

The growth rate of trees in street and garden environments was significantly and negatively correlated to tree age (Street trees $r^2 = -0.136$, $p < 0.0001$; Garden trees $r^2 = -0.184$, $p < 0.05$), and more so for the garden environment than the street environment (Fig. 1). The growth rate equation for garden trees was $y = 1.5926e^{-0.022x}$ and for street trees it was $y = 0.9719e^{-0.011x}$.

4. Discussion

This study made two findings pertaining to the determination of growth rates in the urban environment. Firstly, that for only eight of the 22 indigenous species examined, were three-quarters or more of the cores useable. Secondly, the growth rates of urban trees vary significantly in relation to the environment in which they are found. In particular, using two different approaches, the mean annual diameter increment of street trees was approximately 26–36% less than that of trees in gardens. This is presumably because of the adverse environment for urban streets, particularly the increased soil compaction and low aeration, rainfall infiltration and organic matter inputs (Viswanathan et al., 2011; Lawrence et al., 2012). The growth rates and equations produced may be used by researchers as well as city managers to plan the placement and use of trees in different areas (Nagendra and Gopal, 2010).

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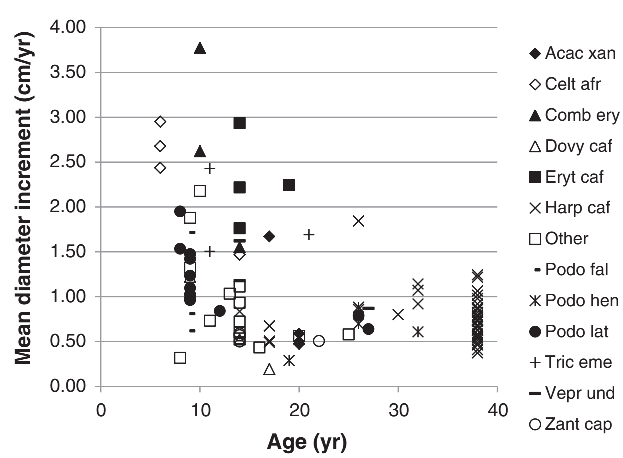

Fig. 1. Mean annual diameter increment (cm/yr) of indigenous street (n = 45) and garden (n = 56) trees relative to their age (Species abbreviations are genus and species (4 and 3 letters, respectively; the species 'other' refers to nine species for which the sample was less than three stems per species).

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