Chapter 8

An international perspective on growth rate and carbon sequestration of urban trees

Introduction

In this chapter comparisons are made between the growth rates of sixteen non-indigenous street tree species growing in the coastal area of southern California, USA and that of the three street tree species *Combretum erythrophyllum*, *Rhus lancea* and *Rhus pendulina* investigated in this study. Comparisons are also made of the sequestration rate and capacity of the three species investigated in this study and that of the urban trees on other continents.

Growth rate discussion

Peper *et al.* (2001) compared the growth of sixteen street tree species growing in southern California. These species were compared in terms of stem diameter at breast height (DBH), tree height and crown diameter growth. Their study was similar to that presented in Chapter 3 and 4 in this thesis in that predictive equations were derived and the comparisons made in Tables 8-1, 8-2 and 8-3 are based on predicted or modelled dimensions for both the local and the Californian species.

Table 8-1. Predicted stem diameter at breast height sizes for coastal southern California street tree species investigated by Peper *et al.* (2001) as well as for those investigated in this thesis. The stem diameter of *Combretum erythrophyllum*, *Rhus lancea* and *Rhus pendulina* street tree species investigated in this thesis was measured at ground level or just above the basal swelling.

	DBH (cm) 15 years		DBH (cm) 30 years
*Combretum erythrophyllum**	40.42	*Combretum erythrophyllum**	68.13
Pinus canariensis	36.92	*Cedrus deodora*	57.85
Ficus macrocarpa	32.74	*Pinus canariensis*	53.43
Cedrus deodora	32.69	*Ficus macrocarpa*	47.33
*Rhus pendulina**	29.13	*Melaleuca quinquenervia*	46.30
*Rhus lancea**	26.83	*Cinnamomum camphora*	44.93
Shinus terebinthifolius	26.50	*Eucalyptus ficifolia*	42.48
Cinnamomum camphora	24.00	*Rhus lancea**	39.00
Cupaniopsis anacardioides	22.70	*Shinus terebinthifolius*	38.52
Metrosideros excelsus	22.58	*Metrosideros excelsus*	36.99
Jacaranda mimosifolia	19.72	*Ceratonia siliqua*	36.39
Liquidambar styracifolia	18.93	*Magnolia grandiflora*	32.78
Melaleuca quinquenervia	18.65	*Cupaniopsis anacardioides*	32.61
Tristania conferta	18.45	*Liquidambar styracifolia*	27.55
Podocarpus macrophyllus	15.76	*Jacaranda mimosifolia*	26.35
Magnolia grandiflora	15.72	*Tristania conferta*	24.96
Ceratonia siliqua	15.32	*Podocarpus macrophyllus*	21.45
Callistemon citrinus	13.29	*Callistemon citrinus*	20.56
Eucalyptus ficifolia	12.05	*Rhus pendulina**	#
Mean	23.28	Mean	38.76

* Diameter was taken at ground level
# No data

Table 8-2. Predicted tree height sizes for coastal southern California street tree species investigated by Peper *et al*. (2001) as well as for *Combretum erythrophyllum*, *Rhus lancea* and *Rhus pendulina* indigenous street trees investigated in this thesis

	Height (m)		Height (m)
	15 years		30 years
Pinus canariensis	16.21	*Pinus canariensis*	19.24
Cedrus deodora	11.77	*Cedrus deodora*	16.09
Liquidambar styracifolia	9.57	*Combretum erythrophyllum*	11.47
Combretum erythrophyllum	8.47	*Liquidambar styracifolia*	11.37
Rhus pendulina	8.39	*Melaleuca quinquenervia*	10.43
Cinnamomum camphora	7.74	*Cinnamomum camphora*	10.02
Cupaniopsis anacardioides	7.36	*Metrosideros excelsus*	10.00
Tristania conferta	7.22	*Magnolia grandiflora*	9.04
Melaleuca quinquenervia	6.90	*Ficus macrocarpa*	8.95
Ficus macrocarpa	6.86	*Eucalyptus ficifolia*	8.54
Magnolia grandiflora	6.59	*Cupaniopsis anacardioides*	8.24
Metrosideros excelsus	6.26	*Tristania conferta*	7.92
Shinus terebinthifolius	6.23	*Shinus terebinthifolius*	7.59
Jacaranda mimosifolia	5.95	*Ceratonia siliqua*	7.55
Podocarpus macrophyllus	5.73	*Jacaranda mimosifolia*	7.23
Rhus lancea	5.43	*Podocarpus macrophyllus*	6.75
Ceratonia siliqua	4.79	*Rhus lancea*	6.36
Callistemon citrinus	4.48	*Callistemon citrinus*	5.78
Eucalyptus ficifolia	4.11	*Rhus pendulina*	#
Mean	7.37	Mean	9.59

[#] No data

Table 8-3. Predicted crown diameter sizes for coastal southern California street tree species investigated by Peper *et al*. (2001) as well as for *Combretum erythrophyllum*, *Rhus lancea* and *Rhus pendulina* indigenous street trees investigated in this thesis

	Crown diameter (m)		Crown diameter (m)
	15 years		30 years
Combretum erythrophyllum	10.37	*Combretum erythrophyllum*	17.56
Cedrus deodora	8.04	*Cedrus deodora*	11.70
Rhus pendulina	7.80	*Cinnamomum camphora*	10.44
Pinus canariensis	6.90	*Metrosideros excelsus*	10.01
Cinnamomum camphora	6.79	*Rhus lancea*	8.79
Cupaniopsis anacardioides	6.63	*Ficus macrocarpa*	8.73
Podocarpus macrophyllus	6.58	*Magnolia grandiflora*	8.56
Shinus terebinthifolius	6.53	*Pinus canariensis*	8.25
Rhus lancea	6.35	*Cupaniopsis anacardioides*	8.12
Ficus macrocarpa	5.97	*Shinus terebinthifolius*	8.08
Jacaranda mimosifolia	5.49	*Jacaranda mimosifolia*	8.04
Magnolia grandiflora	5.41	*Ceratonia siliqua*	7.98
Liquidambar styracifolia	5.33	*Podocarpus macrophyllus*	7.90
Tristania conferta	5.10	*Eucalyptus ficifolia*	7.66
Metrosideros excelsus	4.70	*Liquidambar styracifolia*	6.48
Ceratonia siliqua	4.47	*Tristania conferta*	6.22
Melaleuca quinquenervia	4.27	*Melaleuca quinquenervia*	6.16
Callistemon citrinus	3.74	*Callistemon citrinus*	4.85
Eucalyptus ficifolia	2.73	*Rhus pendulina*	#
Mean	5.96	Mean	8.64

No data

In Table 8-1 it is shown that *Combretum erythrophyllum* has the largest stem diameter at an age of 15 years and 30 years. It is also shown that *Rhus pendulina* and *Rhus lancea* has the fifth and sixth largest stem diameters at age 15 years respectively. These stem diameters are inflated due to it being taken at ground level (see Chapters 2, 3 and 4) and is therefore a less accurate comparison. But it may, however, be conjectured that the diameter at breast height of these three species will be within the range of the diameter at breast height of the other sixteen species.

Combretum erythrophyllum, *Rhus lancea* and *Rhus pendulina* is positioned fourth, fifth and sixteenth respectively, when considering tree height at an age of 15 years (Table 8-2). However, both *Combretum erythrophyllum* and *Rhus pendulina* have a tree height of approximately half that of *Pinus canariensis* at an age of 15 years. At age 30 years *Combretum erythrophyllum*'s tree height is approximately 7 m less than that of the tallest tree measured namely *Pinus canariensis*.

Regarding crown diameter one observes that *Combretum erythrophyllum* has the largest crown diameter at both 15 years and 30 years. This may be attributable to the cultural practices such as pruning.

When comparing the species at an age of 15 years then both *Combretum erythrophyllum* and *Rhus lancea* show relatively high growth rates compared to the southern Californian street trees. A comparison at age 30 years indicates that *Combretum erythrophyllum* has a competitive growth rate also at this age which suggests that this species could be considered a fast growing tree when compared to those investigated by Peper *et al.* (2001).

Carbon sequestration discussion

The carbon sequestration rates of *Combretum erythrophyllum*, *Rhus lancea* and *Rhus pendulina* street tree species investigated in this thesis are compared with those of other studies in Italy, United States of America and China. Even though comparisons are made they should be interpreted with caution due to a number of variables differing in each study. *Combretum erythrophyllum* does, however, sequestrate carbon at a similar rate to *Quercus ilex* and *Quercus pubescens* growing in Rome, Italy.

Table 8-4. Comparison of carbon sequestration rate (kg C / yr) for various cities and species

Author	City / state and country	Species	Tree size or age	kg C / year
Current study	City of Tshwane, South Africa	*Combretum erythrophyllum*	Mean over 46 years	29
Current study	City of Tshwane, South Africa	*Rhus lancea*	Mean over 32 years	8
Current study	City of Tshwane, South Africa	*Rhus pendulina*	Mean over 15 years	8
Gratani *et al.* (2006)	Rome, Italy	*Quercus ilex*	Tree height 12 m	22
Gratani *et al.* (2006)	Rome, Italy	*Quercus pubescens*	Tree height 12 m	30
McPherson *et al.* (1999)	California, USA	*Populus 'Robusta'*	Mean over 30 years	82
McPherson *et al.* (1999)	Twin Cities, St Paul, USA	*Acer saccharum*	Mean over 60 years	53
McPherson *et al.* (1994)	Chicago, USA	Mean for study	< 80 mm DBH	1
McPherson *et al.* (1994)	Chicago, USA	Mean for study	>760 mm DBH	93
Yang *et al.* (2005)	Beijing, China	11 main species	Mean for estimated 2.3 million trees	5

Methodologies used to calculate carbon sequestration rates varied and differed in the studies presented in Table 8-4. Further to the application of the different methodologies, variation in carbon sequestration rates are due to amongst others different species, tree ages and sizes along with some of the factors mentioned below. Due to the above and amongst others the factors mentioned below, the comparisons in Table 8-4 are done with some degree of incongruence. Yet limited information exists and therefore these incongruent comparisons are inevitable.

Factors that need consideration for growth and carbon sequestration comparisons

Caution needs to be applied when considering Tables 8-1 to 8-4 for comparative purposes. This is due to the numerous different growth conditions of trees in urban areas. The growth of trees in natural environments is the result of mainly species, genotype, climate (including rainfall), available water, geographic region, soil conditions and type as well as growth inhibitors like herbivory, pests and diseases. It should also be appreciated that trees in natural environments differ in some instances largely between species and geographic regions along with the other factors mentioned above. Urban trees share the same variables as trees in natural environments. There are, however, numerous additional factors influencing urban tree growth. Some of these factors will be discussed here to illustrate that care needs to be applied when making inter-geographic species as well as inter-species, inter-city and even intra-city growth and carbon sequestration comparisons.

The following are some factors that influence tree growth and carbon sequestration rates in urban areas which in turn influence growth prediction modelling:

1. Pruning practices differ depending on city ordinances, utilities and urban foresters' training. Pruning training also differs between training facilities.
2. Tree curb distances, tree-curb-paving distances and underground utility composition, structure and layout influence the rooting space available to trees and vary even in the same city between land uses within such a city.
3. Tree grids are often found in high density commercial areas. Often the sizes of these grids are limited. It there is no alternative direct source of water, then the

size of the tree grid as well as its position as a catchment basin is crucial to tree growth. These grids and water catchment issues vary across landuse, manufacturer specifications, cities and countries.

4. Irrigation varies greatly between landuse, for example, inner city and residential as well as between climatic zones such as for instance, arid versus mediterranean within a country. It may also differ according to income status of land owners in different landuses or suburbs.
5. Method of tree planting differs regarding, for example, the size and geometry of the planting hole, as well as the added supplements like compost or fertilisers during planting.
6. Soil compaction practices during road, pavement and lawn construction influence root penetration in these zones.
7. Soil type, texture, structure and acidity or alkalinity vary greatly even in the same city, as well as country. Tree growth may differ markedly, for instance due to differing soil pH, all other factors being equal.
8. Soil texture, structure and soil acidity or alkalinity alteration due to building, road and pavement rubble dumped in tree planting zones are problematic in South Africa and will differ in other countries and cities.
9. Municipal street tree fertilization practices as well as that in adjacent landuse for example lawn fertilization practices influence tree growth. Fertilization may also be influenced by cultural practices derived from, for example, education and income of land owners.
10. Street microclimate differs between landuses as well as within each landuse and influences tree growth.
11. Macro and local climate differs in each city and country.

12. Annual rainfall is an important factor regarding tree growth and may cause large variations in growth rates within the same and other species.
13. Number of frost free days influences the growth season of trees.
14. The number of photosynthetic sunny days and the length of photosynthetic time in those days varies.
15. There may be growth rate differences between cultivars within species.

Conclusion

The above growth influencing factors vary in most cities across the world and also vary with time in each city. It is noteworthy that the species compared above mostly do comply within reasonable growth bounds. Large variation is, however, apparent regarding carbon sequestration rates which lead to the question as to the appropriateness of such inter-geographic and inter-city comparisons.

There are limited urban growth and carbon sequestration data and equations available. It is thus suggested that those equations and data that do exist be used in a generic manner, yet with the proviso that their original context be noted and taken into consideration during their application. These factors also need to be communicated in literature and commercial publications in which they are applied in order to remain transparent and provide results that may be judged objectively.

References

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