No adverse signs of the effect of environmental change on tree biomass in the Knysna forest during the 1990s

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We analysed the growth of all trees greater than 10 cm diameter at breast height in 108 plots of 0.04 ha each in an unharvested nature reserve in the Knysna forest for the period 1991–2001. Gross growth rates (in-growth plus growth of survivors) of trees were extremely slow (<1%) and thus the forest is extremely sensitive to changes in mortality of large trees. Over the 10-year study period, total basal area and biomass increased by 2%, in part because overall stem density increased by 1.2%. Rainfall in the 1990s was slightly below the long-term mean for the study area. At this stage, therefore, the Knysna forest biomass is not showing a negative response to environmental change.

Introduction

The present and predicted future impacts of global environmental change on intact forests are both alarming and contentious. For example, some local models have predicted the demise of South Africa's only significant extent of indigenous forest, the Knysna forest, by 2050.[1] Globally, although there are models which predict a drastic decline in tropical forest biomass, this is apparently contradicted by data which suggest the opposite.[2,3] There is thus a need for a local perspective on this debate, which we aim to provide here by an analysis of a decade of growth of the Knysna forest.

Methods

In the Lilyvlei Nature Reserve (33.56°S, 23.02°E), an unharvested section of the Knysna forest, 108 plots of 0.04 ha each were laid using a grid system which provided a 5% sample area. Midgley *et al.*[4,5] reported that the Knysna forest is comprised mainly of shade-tolerant species with abundant regeneration and has a mild disturbance regime (most trees die standing, creating small gaps). The Lilyvlei Nature Reserve can therefore be considered old-growth forest and changes in growth and biomass are not a result of successional responses. All trees greater than 10 cm in diameter at breast height (dbh) and rooted in the plots were individually tagged and painted with a white circle at a height of 1.3 m, and their diameter measured in 1991 and re-measured in 2001. To convert dbh to above-ground biomass (AGB), we used Equation 2.1 from Baker *et al.*,[6] where

$$\text{AGB} = \text{sum}(\exp[0.33(\ln \text{dbh}) + 0.933(\ln \text{dbh})^2 - 0.122(\ln \text{dbh})^3 - 0.37]).$$

This allometric equation has not been verified for the Knysna forest and therefore the analysis reported here is preliminary, because wood density significantly affects AGB estimates.[6] Using data in von Breitenbach,[7] we obtained a mean relative wood density of 0.78 g cm^{-3} for the 10 most abundant species in the forest (they represented >95% of basal area in our plots) and a weighted mean of 0.71 g cm^{-3}. The local mean wood density is greater than that in 55 of the 56 plot averages reported by Baker *et al.*[6] This suggests that for comparative purposes, our assumption of AGB is probably an under-estimate. Because many analyses of forests are, for practical purposes, undertaken at the level of basal area (BA), we analysed patterns at both the AGB and BA levels. Net growth is the difference between final and initial total values, whereas gross growth is the amount of growth of those initial stems still alive at second census plus the new stems in the 10 cm dbh size-class (= net growth + mortality).

Results

Net BA and AGB increased over the 10-year study period by 2% and there was a 1.2% increase in stem numbers (Tables 1, 2), distributed almost equally amongst all size-classes. Compositional changes were minor with only *Ocotea bullata* (9 stems, 11.4% increase) and *Cassine papillosa* (14 stems, 16.3% increase) changing by more than 10%. Gross growth rates were slightly less than 1% (Table 2).

Discussion

Gross growth rates of 1% imply a residence time of over a century for the average individual. This extremely slow turnover rate also equates to the total annual growth per hectare of the basal area of only a single tree of 71.5 cm dbh (= 0.4 m^2). In other words, the annual mortality of a single tree this large per hectare (of which there are 11.6 stems ha^{-1}, Table 1) would correspond to zero net growth. This means that over relatively short periods such as our decade, the AGB of this forest is more sensitive to negative/stressful conditions that would increase mortality, than to factors which may increase growth. Despite this, net biomass increased slightly. This may mean either reduced mortality rates or increased growth rates, but we do not have earlier growth or mortality data with which to compare the present findings. Changes in these rates may have been the effect of the increase in global atmospheric carbon dioxide, rather than to enhanced local precipitation because precipitation was average. According to rainfall data provided by the South African Weather Service, precipitation over the period 1991–2001 was some 5% less than the long-term average. At nearby Knysna (34.05°S, 23.05°E), mean annual rainfall was 735.7 mm compared with the long-term average of 778 mm. The

Table 1. Demographic changes over the 10-year study period in 108 plots of 0.04 ha each in the Knysna forest.

Size-class (dbh) (cm)	Mortality (%) [*n*]*	Original:Final number of stems
10–20	7.1 [106]	1494:1495
20–30	5.9 [30]	512:533
30–40	6.5 [17]	261:263
40–50	6.8 [11]	162:168
50–60	3.0 [3]	101:107
60–70	17.3 [9]	52:43
70–80	7.1 [2]	28:32
80–90	11.8 [2]	17:18

*(Number of stems that died (= *n*) divided by number of original stems) × 100.

Table 2. Estimates of growth and biomass for the Knysna forest for the period 1991–2001.

	Initial	Final	Gross growth (yr^{-1}) (%)	Net growth (yr^{-1}) (%)
AGB (Mg ha^{-1})	489.5	498.7	4.7 (1)	0.92 (0.2)
BA (m^2 ha^{-1})	41.4	42.1	0.4 (1)	0.07 (0.2)

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$0.9\ Mg\ ha^{-1}\ yr^{-1}$ net increase in biomass we recorded is fairly close to the mean increase of $1.22\ Mg\ ha^{-1}\ yr^{-1}$ reported by Lewis *et al.*[2] for the Amazonian rainforest. At this stage, therefore, there appears to be no sign of the effect of environmental change on the above-ground biomass of the Knysna forest.

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