*Journal of Tropical Forest Science* 11(3):657–660 (1999)

# BASAL AREA INCREMENT IN A MIXED DIPTEROCARP AND HEATH FOREST OF BRUNEI DARUSSALAM

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Heath forests, also known as kerangas forests in north Borneo, occur on soils thought to be characterised by low fertility and a propensity to waterlogging or irregular drought (Whitmore 1984). Accurate timber growth data from mature natural heath forest in Borneo are available from only three plots. It has nevertheless been concluded that growth rates on average are considerably lower in heath forest than in mixed dipterocarp forest, although growth rates for the best sites in heath forest may approach the average for dipterocarp forest (Bruenig 1996). Here we compare basal area increment of trees sampled and measured in comparable fashion from a heath forest and a mixed dipterocarp forest in Brunei.

All trees ≥ 0.05 m dbh (diameter at breast height) were tagged, mapped and identified in a 0.96-ha plot established in dipterocarp forest at Andulau F. R. (Forest Reserve) and another in heath forest at Badas F. R. (Davies & Becker 1996). After removing loose bark and moss, diameter was measured to 1 mm at marked points (nominally 1.3 m above ground or 0.2 m above the apex of the tallest buttress) with a fabric tape during 7–31 July and 1–15 August 1992 at Badas and Andulau respectively (Davies & Becker 1996).

Trees were selected for remeasurement five years later in July 1997 by a stratified random method to ensure an even distribution across the plots and diameter classes. Trees were placed in four diameter classes: ≥ 0.05 to < 0.1 m, ≥ 0.1 to < 0.2 m, ≥ 0.2 to < 0.4 m, and ≥ 0.4 m dbh. For each of the 24 contiguous 20 × 20 m quadrats within the plots, one tree was randomly selected from each diameter class. For the two largest diameter classes, there was no or only one available tree in ten quadrats at Andulau and five quadrats at Badas. Duplicate diameter measurements of selected trees during both measurement periods agreed to within 2 mm. Two trees at Andulau had a diameter in 1997 (confirmed by remeasurement) less than that recorded in 1992, and these were excluded from the analyses. Basal area was calculated from diameter using the formula for a circle, which slightly overestimates the sectional area of trees that are not truly circular (Philip 1994). To test for effects on growth rate, crown exposure was scored in two classes by noting whether the projected crown area exposed to open sky was < 50% or ≥ 50%. All statistical analyses were performed with Systat 5.03 (Wilkinson 1990).

Our sample design was chosen to facilitate regression analysis so that size effects on growth could be examined, albeit with possible confounding effects of plant density and exposure. Basal area increment over five years was linearly related to basal area in 1992, and square-root transformation of both variables helped to normalise the residuals and to homogenise the variance about the regression line at both sites (Figure 1). The strongly dominant *Agathis borneensis* (Araucariaceae) at Badas accounted for 0, 25, 52, and 87% respectively, of the remeasured trees in the four diameter classes listed above. Following Sokal and Rohlf (1995 : 498), however, there was no significant difference ($p > 0.05$) between *A. borneensis* and other species in the regression of basal area increment on their overlapping 1992 basal area (≤ 0.25 $m^2$, data not shown). Therefore, the combined data set was used in further analyses.

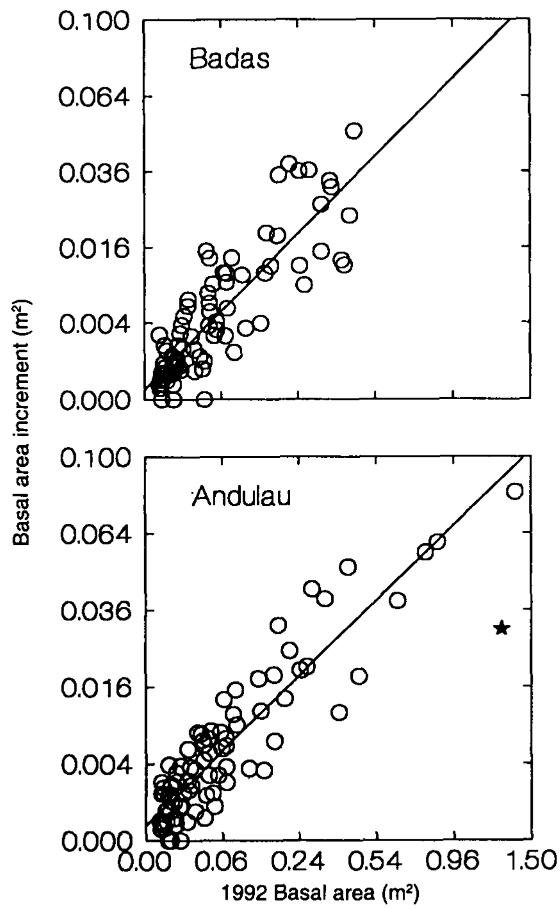


**Figure 1.** Basal area increment (1992–97) versus 1992 basal area in mixed dipterocarp forest at Andulau and heath forest at Badas, with square-root scales on both axes. The tree represented by a star at Andulau was excluded from all analyses reported here because its 1992 diameter was incorrectly measured over a huge scarred wound. Lines fitted by linear least squares regression to square-root transformed data–Andulau: $Y = 0.012 + 0.252X$, $r^2 = 0.84$, $p < 0.01$ for regression slope; Badas: $Y = 0.0085 + 0.264X$, $r^2 = 0.74$, $p < 0.001$ for regression slope.

For both their full and overlapping size ranges (1992 basal area $\leq 0.5$ m$^2$), there was no significant difference ($p > 0.05$) between Andulau and Badas in the slopes of the regression of basal area increment on 1992 basal area after square-root transformation of both variables. Qualitatively identical results were obtained whether or not these regressions were forced through the origin, as justified by a non-significant Y-intercept (Badas only) and biological expectation. Residuals (deviations of observed from predicted growth rates) of trees with $\geq 50\%$ crown exposure were significantly larger than those of less exposed trees at Badas (separate variances *t*-test; $n = 28$ and 41 respectively; $p = 0.008$), but not at Andulau (pooled variances *t*-test; n = 12 and 53 respectively; p = 0.07) for regressions over the size range of less exposed trees (1992 basal area ≤ 0.1 $m^2$ and 0.15 $m^2$ at Andulau and Badas respectively).

Although size-specific growth rates at Andulau and Badas did not differ, growth could still vary at the stand level depending on inter-site differences in tree density and size-class distribution. The number of trees in the plot at Andulau (1484) was 11% higher than at Badas (1341), but their size-class distributions were quite similar (Figure 6 in Davies & Becker 1996). Applying the regressions fitted to the data in Figure 1 to the 1992 basal areas of trees ≥ 0.05 m dbh, the basal area increment at Andulau (0.74 $m^2$ $y^1$) was 12% greater than that at Badas (0.66 $m^2$ $y^1$). For regressions forced through the origins, this difference disappeared but the estimated increments were 10–20% lower—0.60 and 0.59 $m^2$ $y^1$ for Andulau and Badas respectively. An unforced regression is probably preferable for predictive purposes, but the differences illustrate the difficulty of scaling up from tree to stand level and caution against estimates of basal area increment based on lumped diameter classes. Neither calculation accounts for basal area increase due to ingrowth or loss due to mortality. There was, however, no significant difference (*G*-test, p = 0.97) in five-year mortality rates at Andulau and Badas, where 6 out of 96 and 94 trees respectively, died—distributed evenly between the lower and highest diameter classes.

**Table 1.** Mean annual diameter increment (mm $y^1$) of trees in unlogged mixed dipterocarp and heath forests of north Borneo. Data for Andulau and Badas from this study; those for KBFSC (Kuala Belalong Field Studies Centre, Brunei) from C. Maycock (pers. comm.); all other data from Bruenig (1996).

| | Diameter at breast height (m) | | | |
|---|---|---|---|---|
| | 0.1–0.2 | 0.2–0.4 | 0.2–0.9 | ≥ 0.4 |
| Dipterocarp | | | | |
| Andulau | 1.9 | 2.5 | | 5.2 |
| Mulu R.P 142 | 1.0 | 1.6 | | 2.7 |
| KBFSC Plot 1 | 1.9 | 3.2 | | 3.8 |
| KBFSC Plot 2 | 1.5 | 3.1 | | 4.5 |
| Heath | | | | |
| Badas | 1.6 | 2.9 | | 4.7 |
| Mulu R.P. 142 | 1.1 | 1.7 | | 3.3 |
| Similajau - Nyabau | - | | 4 | |
| Anduki R.P. 21 | - | | 5–9 | |

Available diameter increment data show substantial site variation with no indication of lower growth rates in heath compared to dipterocarp forests (Table 1). Both this and the preceeding comparison of basal area increment are limited in failing to account for tree height and increment and wood density, all of which are likely to differ between these forest types (Bruenig 1996). Nevertheless, it remains true that there is no quantitative empirical support for the claim that heath forests are less productive or have slower timber growth rates than dipterocarp forests. Neither stand structure (density and size class distribution) nor propensity to regenerate following severe disturbance such as fire is necessarily correlated with productivity. Given the significance of the purported lower productivity of heath forests to ecological theory (Janzen 1974) and the economics of forest management

(Bruenig 1996), it is highly desirable to obtain information on volume increment of heath forests from the full spectrum of site favourability.

## Acknowledgements

We thank the Forestry Department of Brunei Darussalam for permission to work in forest reserves, the Universiti Brunei Darussalam for logistical support, and Colin Maycock for unpublished data. Eberhard Bruenig, Stuart Davies and Tim Whitmore kindly commented on a previous draft.

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