AN ASSESSMENT OF FIVE METHODS OF ESTIMATING LEAF AREA IN JARRAH (*Eucalyptus marginata Donn ex Sm.)*

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1986

LE 513

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In October 1985 a trial was undertaken to determine the efficacy of a variety of leaf area measurement techniques. Five methods of assessing the leaf area of a jarrah pole stand were examined.

These were:

1) The relationship of sapwood cross-sectional area to leaf area,
2) The relationship of DBHOB to leaf area,
3) The relationship of functional sieve tube width (or area) to leaf area,
4) The relationship of various combined morphometric variables to leaf area,
5) The use of the light interception technique developed by Dr A.R.G. Lang (Lang, 1984).

TECHNIQUE

General Technique

The site chosen was a healthy pole stand of 1421m² area. The plot basal area was 30.71m²/ha. The average DBHOB was 23.8cm and the average tree height was 17.8m. The site location was 100m east of Banksiadale Road near Dwellingup, F.D. map reference CS64 2,9 (for descriptive site statistics see Appendix 1). Diameter, canopy depth, height and seeding status were measured for all trees on the plot. The seeding status was subjectively assessed into one of four categories. These were:

1) heavily seeding,
2) seeding,
3) light seeding
4) not seeding.

80% of the trees in the plot were classed as light seeding or seeding.

From this data a sample of seeding and light seeding trees were selected to cover the range of diameters from 6.7 to 43cm. These trees were individually studied to develop relationships that could be applied to determine the whole plot leaf area.

The selected trees were fallen into an open space to minimize leaf loss. Limbs were removed and leaves were stripped into plastic bags. The bags were then sealed to halt water loss. The total leaf mass for each tree was determined to $\pm$0.1gm. A sample of between 61gms (186 leaves) and 136gms (321 leaves) was removed from each bag and assessed to determine the mean specific area for that bag, i.e. the ratio of area to live weight. A LiCor optical planimeter was used to determine the sample area. The total bagged leaf area could then be determined to better than $\pm$1.4% (see Appendix 2).

Stem disks were removed at 1.3m and from below the first fork for assessment of functional sieve tube width and sapwood area.

1. **Sapwood area assessment technique**

Sapwood area was determined using two different methods to highlight any bias in this measurement. These two techniques will be called the "functional" and "visual" methods.

Method a) *The Functional Method*

The prevailing justification for the use of sapwood leaf area relationships is that the sapwoods contains open vessels which conduct water and hence limit leaf area (Kaufman, 1981). This first method follows this logic by assessing the area of sapwood containing functional vessels. This was determined on the basis of the presence or absence of tyloses in the vessels. Stem disks were examined under a binocular microscope and the sapwood boundary delineated on this basis.

It should be noted that all vessels are not clearly functional or non functional. Tyloses partly obstruct but do not block some vessels. Partly obstructd vessels could still conduct water. Such vessels occur at the sapwood-heartwood interface. The width of this uncertain area varies, with some stems showing open vessels in the heartwood coloured section, and others showing intrusions of blocked vessels well into the sapwood coloured material. Hence a measure of discretion enters into this visual assessment. However, this method more correctly follows the initial premise that sapwood is related to leaf area via water conducting area.

Method b) *The Visual Method*

This second assessment of sapwood area was based on the sapwood-heartwood colour change. This method was used by Colquhoun (unpublished) in similar work on jarrah.

Clearly different sapwood areas are sometimes produced by these two methods. In both assessments the stem disk was photocopied and the area defined as sapwood was cut out and determined with an optical planimeter. The figure used being the average of 5 readings.

Examination of the distortion produced by photocopying showed that any error this produced was much smaller than errors from the delineation of the sapwood heartwood boundary in either technique.

TECHNIQUE

2. **Functional sieve tube width technique**

Contact J. Tippett

3. DBHOB technique

Diameter over bark was measured at approximately 1.3m on the stem. Bark depths were also measured at this point

4. Canopy relationships technique

Canopy depth and two widths were measured. A subjective assessment of the canopies occupation of this defined volume was made. Tree heights were measured with a clinometer. A modified version of the Grimes crown assessment was also used.

5. The sunlight penetration method

The theoretical basis for this technique is presented in Crop Structure and the Penetration of Direct Sunlight (Lang 1985). For this trial the selected plot was defined so that the boundaries of a rectangular area ran north-south and east-west. This was an area of relatively uniform canopy height, depth and density. All jarrah coppice, banksias and persoonia were removed from this and the surrounding area to ensure that only the tree canopy leaf area was measured by the light interception technique.

The mean canopy height for the plot was found, and this along with sun angle, was used to determine the projection of the canopy onto the ground, over the period from sunrise to noon, on the day of measurement.

Sixty four, one minute, random walk light meter readings were taken within the relevant projected canopy boundary throughout the morning.

The readings covered a sun (probe) angle range of 77° to 33° from the zenith. The instrument used was a DLM-1 model light integrator which correctly follows the circuit diagrams supplied by Dick Lang. The instrument circuit has been checked as correct and functioning properly. It is unclear if the instrument was correctly functioning at the time when these light readings were taken. The treatment of the readings collected with the light meter followed that prescribed by Lang (1985).

RESULTS AND DISCUSSION

1. Sapwood Leaf Area Correlation

Least sum of squares regression fits were obtained for upper (below first fork) and lower (at 1.3m) functional sapwood areas and lower visual sapwood area.

Regression Statistics for Leaf Area, Sapwood Area Relationships

Leaf Area Related to Functional Sapwood Area

	r^2	s.e.e.	Slope	Intercept	N
Upper Sapwood Area (first fork)	0.763	16.404	0.543	-7.392	18
Lower Sapwood Area (1.3m)	0.751	16.814	0.553	-16.019	18

Leaf Area Related to Visual Sapwood Area

	r^2	s.e.e.	Slope	Intercept	N
Lower (Sapwood Area (1.3m)	0.751	15.244	0.398	-8.573	17
Colquhouns Lower Sapwood Area (1.3m)	0.89		0.24	+3.70	15

Statistics for these sapwood based relationships appear promising and could lead to the conclusion that sapwood is a good predictor of leaf area. Examination of the scattergrams shows the spread of this data associated with seeding. Generally, for a given sapwood area, seeding trees show reduced leaf area. ~~Trees 70 and 73 are an extreme example of this effect.~~ Trees classed as heavily seeding or not seeding were not considered for this work as they were a minority of all the trees on the plot. It was proposed that for determining the plot leaf area, seeding and light seeding trees would produce a better predictive regression. On sites having a greater number of seeding & not seeding trees a less robust ~~is generally heavy, a poor~~ relationship between leaf area and sapwood area could be expected.

Seeding status of trees on the plot.

Number of each seeding class	Not Seeding	to	Light Seeding	to	Seeding	to	Heavily Seeding	Total number of trees
~~Whole~~ Total plot	15	1	20	2	38		1	77
Sampled trees	1	1	7	1	8			18

The sampled trees can be grouped on the basis of seeding and separate regression lines fitted to the seeding and light seeding groups. T-tests of these 2 regression lines show that they have the same slope but different intercepts (Appendix 3).

Flowering and later seeding of jarrah causes a reduction in shoot development (Loneragan, 1971 and Jacobs, 1955). It appears that no corresponding reduction in sapwood area or restriction of sapwood growth occurs. If sapwood area does not respond to the leaf loss associated with seeding, it would then seem unlikely that sapwood area could effectively respond to leaf loss caused by the external environment e.g. storms or bird defoliation.

The justification for sapwood leaf area relationship is probably correct in that sapwood area should limit the upper extent of leaf area development but, it cannot reflect the extent to which leaf area can diminish in response to flowering or environmental factors. Because of this, sapwood area alone is not a good predictor of current leaf area. in jarrah.

When determining the sapwood heartwood transition it was noted that vessel density and to a lesser extent vessel diameter varied between trees. It was speculated that this actual conducting area (the total cross-sectional vessel area) could be more closely related to leaf area than sapwood area.

Examination of trees paired for common sapwood area but different leaf area did not clearly show this to be true. For example, the vessel area of tree 58 was estimated as greater than tree 73. For some of these paired trees weighting sapwood area for relative vessel density and/or area would improve the relationship to leaf area, while in other trees this factor would reduce the relationship. It was concluded that because of the difficulty in using and developing this technique and its apparent lack of promise it did not warrant further investigation. Whitehead et al (1984) found that "In a particular climate the area of foliage on disimilar trees is more closely related to the product of sapwood area and permeability than it is to sapwood area alone".

The "visual" determination of the sapwood-heartwood boundary was undertaken to resolve a difference in results between this work and similar work undertaken by Ian Colquhoun. The latter work produced a regression line fit with a markedly lower slope. Colquhoun used a "visual" assessment of sapwood area.

Colqhoun (unpublished)	$LA = 0.24SA + 3.70$	$n=15$	$r^2 = 0.89$
This work found	$LA = 0.40SA - 8.57$	$n=17$	$r^2 = 0.75$

T-testing of the regression slope confirms that these data points came from different populations. The data from both trials covers similar ranges and the experimental technique appears to be comparable. Site type and possibly season (i.e. position on the seeding and annual leaf cycles) are the most likely differences.

Colquhouns data shows little scatter and no obvious influence of seeding. Colquhoun made no assessment of seeding status in his work.

2. DBHOB and DBHUB Relationships Results and Discussion

A regression was also produced for DBHOB against leaf area.

LA = 2.860(DBHOB) - 38.613 n=18 $r^2 = 0.739$ s.e.e = 17.192

The correlation coefficient here is only slightly less than for sapwood area. As would be expected there is a high correlation between DBHOB and S.A.

DBHOB = 0.194(SA) + 8.092 n=15 $r^2 = 0.915$ s.e.e. = 2.985

DBHUB = 0.177 (SA) + 27.996 n=17 $r^2 = 0.901$

Relationship between DBHUB and SA

The DBHOB, leaf area relationship showed a similar distribution of points as the sapwood area relationship. Within a site DBHOB would appear to be a surrogate for sapwood area. It has been proposed that sapwood area is superior to DBHOB as a predictor of leaf area as it is less affected by variations in site fertility (Whitehead, 1978). However, this has not been supported by Albrektson (1984).

DBHOB is much easier to measure than sapwood area & therefore more useful as a predictor of LA. Unfortunately as with sapwood area

At this point in the discussion it is appropriate to consider the effects of leaf area dynamics. Leaf area relationships like DBH and sapwood area attempt to freeze the picture of leaf area in time and consider only variations in space. It is clear, from both casual observation and from work such as Loneragan's (1971), that jarrah follows an annual and a seeding cycle of leaf area, in which seeding has a major effect. Factors such as rainfall, fire, wind and bird defoliation also affect leaf area and can do so without affecting other possibly related tree parameters such as DBH and S.A. ~~Clearly~~ factors that can affect leaf area alone will confound any attempt to measure leaf area through a related tree parameter. These relational measures can only define the range over which leaf area may vary in the preceeding and following months or years.

Reference to Loneragan's diagram of floral-seeding (Figure 1) and foliage-vigour cycles will show that leaf area and girth increment do not follow parallel cycles. While girth increment largely expands through autumn and winter, the major leaf flush occurs in early summer. Girth expansion should be indicative of sapwood area expansion. This is not to say that sapwood area necessarily follows girth increment, but it seems highly unlikely that the sapwood area reduction could so thoroughly counteract girth expansion that sapwood area cycle could mimick the leaf area cycle.

It would be reasonable then to assume that both DBHOB and S.A. were out of phase with leaf area. Hence, sapwood or DBH based relationships should consider both annual and seeding cycle in a multiple regression. This would be difficult and impractical to develop as the entire 7 year seeding cycle should be considered.

Any attempt to consider the relationship of leaf area to other DBH ~~tree parameters~~ cannot account for weekly or seasonal changes unless ~~it considers~~ some measurement of the canopy existing at the time of measurement is considered. It would seem logical that an attempt to describe the canopy volume and leaf density within that volume, would produce good descriptions of the current leaf area.

4. Morphometric Correlations Results and Discussions

With this concept of canopy assessment in mind, several other measurements of tree parameters were made and related to leaf area. A variety of linear and multiple regressions were determined. These are shown in Appendix 4.

The linear regressions show the power of DBHOB & DBHUB in predicting leaf area. The "plane area" and width of the canopy are similarly good predictors. Squaring DBH improves relationships. DBH^2 is equivalent to basal area which is a better description of tree size than DBH alone. These DBH^2 regressions should be treated with caution as they heavily weight the information gathered from the few larger trees.

Hierarchial and stepwise multiple regressions were determined for basic tree dimensions and leaf area. All of these regressions relate tree size and canopy dimensions to leaf area. They are effective in showing that such descriptions of tree size are as good as sapwood area in predicting leaf area. Unlike sapwood area these actual canopy measures should be better able to account for change in canopy leaf area. Unfortunately no assessment of canopy leaf density was made for the trees in this study. It is likely that such an assessment would improve the predictive ability of canopy and tree dimensional relationships. A measure of leaf density within the canopy volume would allow for variations such as that which occurs with seeding, where the canopy volume changes only slightly but the leaf area declines significantly.

RESULTS AND DISCUSSION - LIGHT METER TECHNIQUE

The multiple regression for leaf area and the DBH based linear regression were applied to all the stems on the site to determine the total plot leaf area. From the plot area and these calculated leaf areas the Leaf Area Indices (LAI) were calculated.

		Multiple regression	DBH regression
Total Leaf Area		2599.99m^2	2496.66m^2
Measured Plot Area	=	1421m^2	
LAI		1.829	1.757

The light meter cannot distinguish between wood and leaf. Following the advice of Dr Lang, projected plane wood area was also determined for the sampled trees. This was related to DBH and tree height and these relationships used to determine projected wood area over the entire plot. From the plot area the Wood Area Index (WAI) could then be calculated.

	Multiple regression	DBH regression
Total wood area	446.13m^2	426.08m^2
Wood area index	0.3139	0.2998

From these values the total area index, i.e. the value determined by the light meter, was found.

TAI = WAI + LAI

Total Area Index = Wood Area + Leaf Area Index

	Multiple regression	DBH regression
TAI	2.14	2.06

The processed readings from the light meter yield a total area index of 1.52.

Source	Total area index	LAI
DBH linear regressions	2.06	1.76
Multiple regressions	2.14	1.83
Light meter	1.52	

The light meter estimate is 26% less than the estimate from the linear regressions and 29% less than the multiple regression estimate.

The predictive accuracy of the DBH relationship is about ±20% (see Appendix 5). The multiple regressions should have similar accuracy. This indicates that the light meter under-estimates total area index in a canopy of this density and structural type.

It is interesting to note that if no allowance is made for the wood area of the canopy, the light meter produced an acceptable value for LAI i.e. the light meter assessment of TAI was equivalent to the LAI calculated from the regressions.

APPENDIX 1

SITE DESCRIPTION

Location: Banksiadale Road, Dwellingup
Map reference CS64 2.9

Area: 1421m²
82 trees total
77 Jarrah and 5 Marri

Site Basal Area: 30.71m²/ha

Site Type:

Site Statistics From the 82 Trees

Variable	Mean	Std.Dev.	Sum	Max.	Min.	Range
DBHOB (cm)	23.82	10.58	1953.20	53.50	5.20	48.30
Height (m)	17.82	5.85	1461.50	27.00	6.00	21.00
Tree height to Canopy Base (m)	11.52	3.84	944.64	19.00	4.00	15.00
Basal Area (cm^2)	532.25	429.93	43644.44	2246.87	21.23	2225.64

APPENDIX 2

DETERMINING THE SAMPLE SIZE, AND ACCURACY, OF BAGGED LEAF AREA CALCULATIONS

For n = 200 leaves as used at Banksiadale Road

from Zar

$$n = \frac{s^2 t^2_{(2),(n1)} \, F_{(1),(n1,V)}}{d^2}$$

$$\text{the error size } d = \frac{s^2 t^2_{(2),(n1)} \, F_{(1),(n1,V)}}{n}$$

for leaves from trial data

Std.Dev. S = 3.277 $s^2 = 10.737$ with $\nu = 262$

$$t_{0.01(2)200} = 2.601$$

$$F_{0.01(1),(200,262)} = 1.35$$

$$d = \frac{10.737 \times 2.6 \times 1.35}{200} = 0.434$$

for a specific area of 30.7cm^2/gm (average specific areas from 18 trees) this is an error of 1.4% i.e. with a sample of this size (n=200) we can be 99% sure that the 99% confidence intervals for the specific areas are no wider than 1.4%.

The total bagged leaf weight was determined to 0.1gm. Hence, errors in calculating the bagged leaf area are due to any error in the specific area used in this calculation. The determination of bag leaf area is accurate to 1.4%.

APPENDIX 3

T-TESTS OF 2 REGRESSION LINES FITTED TO SAPWOODLEAF AREA DATA ON THE BASIS OF SEEDING STATUS. SAPWOOD AREA WAS ASSESSED USING THE FUNCTIONAL METHOD.

Test 1 (follows Zar pp 295)

H_0: The slope of line 1 (B_1) is the same as the slope of line 2. $B_1 = B_2$

H_A: B_1 is not $= B_2$

Light seeding class

$\sum x^2 = 36595.7$
$\sum xy = 20645.5$
$\sum y^2 = 13322.1$
$n_1 = 10$

Seeding class

$\sum x^2 = 7527.7$
$\sum xy = 3062.5$
$\sum y^2 = 2779.1$
$n_2 = 8$

$$b_1 = \frac{\sum xy}{\sum x^2} = \frac{20645.5}{36595.7} = 0.564 \qquad b_2 = \frac{\sum xy}{\sum x^2} = \frac{3062.5}{7527.7} = 0.407$$

$$\longrightarrow \quad t = \frac{b_1 - b_2}{S_{b1-b2}} = 0.821 \quad \longrightarrow$$

$$D.F. = (n_1 - 2) + (n_2 - 2) = 14$$

from t-tables (Zar) $t_{0.05(2)14} = 2.145$

therefore accept H_0 $B_1 = B_2$

T test of y intercepts (follows Zar pp 297)

H_0: The two population regression lines have the same y intercept.

H_A: $\text{Intercept}_1 = \text{Intercept}_2$

$$t = \frac{(Y_1 - Y_2) - b_c(X_1 - X_2)}{\sqrt{(S^2_{Y.X})_c \left[\frac{1}{n_1} + \frac{1}{n_2} + \frac{(\bar{X}_1 - \bar{X}_2)^2}{A_c}\right]}}$$

$t = 2.275$ $\qquad$ $D.F. = n_1 + n_2 - 3 = 15$

from t-tables $t_{0.05(2)15} = 2.131$

therefore reject H_0 intercept_1 not $= \text{intercept}_2$

APPENDIX 4

LINEAR REGRESSIONS FOR LEAF AREA (M^2) FROM MORPHOMETRIC VARIABLES

Predictor	r^2	S.E.E.	significance	N	slope	intercept
Candepth	0.381	26.515	0.00317	16	6.703	-10.936
Avwidth	0.604	22.344	0.00020	16	12.381	-20.859
CA	0.636	21.424	0.00011	16	0.979	1.337
CA1	0.574	23.157	0.00034	16	0.139	13.015
CA2	0.574	23.157	0.00034	16	0.109	13.015
CA3	0.526	24.448	0.00074	16	0.104	15.342
DBHHT	0.718	17.912	0.000	18	0.099	-17.745
DBHDEPTH	0.748	16.935	0.000	18	0.215	-8.224
DBHCA2	0.646	21.119	0.00009	16	0.003	14.899
DBH2CA3	0.638	21.357	0.00010	16	0.00007	18.371
DBH2HT	0.838	13.579	0.000	18	0.00238	-3.853
DBH2HT1	0.855	12.847	0.000	18	0.00534	1.454
DBH2	0.849	13.093	0.000	18	0.0596	-10.196
AVWIDTH2	0.529	24.351	0.0007	16	1.104	8.417
DBH2CA2	0.680	20.067	0.00004	16	0.00008	16.803

Variables used:

```
Candepth = canopy depth (m)
W1 & W2  = canopy widths (m)
Tophite  = tree height (m)
DBH      = DBHOB (cm)
AVWIDTH  = (W1+W2)/2.0
CA       = CANDEPTH*AVWIDTH
CA1      = ((AVWIDTH*0.5)**2)*3.142*CANDEPTH
CA2      =  (AVWIDTH**2)*CANDEPTH
CA3      =  CANDEPTH*W1*W2
DBHHT    = DBH*TOPHITE
DBHDEPTH = DBH * CANDEPTH
DBHCA2   = DBH * CA2
DBH2CA3  = CA3 * (DBH**2.0)
DBH2HT   = (DBH**2)*TOPHITE
DBH2HT1  = (DBH**2)*CANDEPTH
DBH2     = DBH**2
AVWID2   = AVWIDTH**2
DBH2CA2  = CA2*DBH2
BA       = ((DBH*0.5)**2)*3.142
```

APPENDIX 4

MULTIPLE REGRESSION FOR LEAF AREA (m^2)

Two multiple regressions were determined one stepwise and one hierarchical.

<u>Hierarchical regression</u>

LA = 4.455DHB + 0.242AVWIDTH - 5.1467HEIGHT + 2.444 Canopydepth + 1.2547

Multiple R^2 = 0.85
DBH = DBHOB (cm)
AVWIDTH = Average of 2 canopy width measurements (m)
HEIGHT = Tree height in metres
Canopy Depth = distance from top to base of the canopy (m)
LA = leaf area in m^2

<u>Stepwise regression</u>

LA = 4.502DBH - 5.179HEIGHT + 2.483 Canopy depth + 1.52

Multiple r^2 = 0.85

This stepwise regression did not include AVWIDTH as it added little to the regression r^2. This is because AVWIDTH is highly correlated with DBH (r^2=0.699). Because of this there is little reason for considering AVWIDTH or using the first equation.

APPENDIX 5

BANKSIADALE ROAD DBH LEAFAREA RELATIONSHIP CONFIDENCE INTERVALS ABOUT REGRESSION (follows Zar page 273)

Confidence Intervals for an estimated Y.

Y is y estimated from X_i using a regression equation.

The std error of the estimated value:

$$S_{Yi} = \sqrt{S^2_{Y.X}\left[\frac{1}{n} + \frac{(X_i - X)^2}{\sum x^2}\right]}$$

X_i is an individual data point

X is the sample mean of data points

$S^2_{Y.X}$ is the residual mean square

$$S^2_{Y.X} = \frac{\text{residual SS}}{\text{residual DF}} \qquad DF = n - 2$$

residual sum of squares = total SS - regression SS

$$\text{total SS} = \sum y^2$$

$$\text{linear regression SS} = \frac{(\sum xy)^2}{\sum x^2}$$

<u>95% confidence interval for predicted values</u>

DBH range = 6.7cm to 43cm.

$$S_{Yi} = \sqrt{S^2_{Y.X}\left[\frac{1}{n} + \frac{(X_i - X)^2}{\sum x^2}\right]}$$

$S^2_{Y.X}$ = 295.55 n = 18 X = 26.7

$\sum x^2$ = 1643.75

for X_i = X

$$S_{Y1} = \sqrt{295.55\left[\frac{1}{18} + \frac{(26.7 - 26.7)^2}{1643.75}\right]} = 4.05$$

for X_i = 43cm

$$S_{Yi} = \sqrt{295.55 \left[\frac{1}{18} + \frac{(43 - 26.7)^2}{1643.75}\right]}$$

$= 8.01$

for X_i = 6.7

$$S_{Yi} = \sqrt{295.55 \left[\frac{1}{18} + \frac{(6.7 - 26.7)^2}{1643.75}\right]}$$

$= 9.398$

LA = 2.86 DBH - 38.61

95% confidence interval

$= (t_{0.05(2)}) \ (S_{Yi})$

$= (2.12) \ (S_{Yi})$

i.e. for $X_1 = 6.7$

95% confidence interval = - 19.5 $\pm$ 19.9 i.e. 100%

for X_i = 26.7

95% confidence interval = 37.75 $\pm$ 8.58 i.e. + 22.7%

for X_i = 43

95% confidence interval

for predicted Y = 84.37 is 16.98 i.e. $\pm$ 20%

i.e. my calculation of the site leaf area is only good to about $\pm$20% if it is based on the linear regression using DBH.

Note that the confidence intervals vary over the range of X

X ranged from 6.7 to 43cm.

Predicted Variable	Predictor	r^2	S.E.E.	Significance	N	Slope	Intercept
Jarrah LEAF AREA (m^2)	Functional Sapwood area at 1.3m (cm^2)	0.751	16.814	0.00	18	0.553	16.019
	Visual Sapwood area at 1.3m (cm^2)	0.751	15.244	0.00	17	0.398	8.573
	Colquhoun's Visual Sapwood at 1.3m (cm^2)	0.89			15	0.24	3.70
	Functional Sapwood area at first fork	0.763	16.404	0.00	18	0.543	7.392
	DBHOB (cm)	0.739	17.192	0.00	18	2.860	38.613
DBHOB	Functional Sapwood at 1.3m (cm^2)	0.915	2.985	0.00	15	0.194	8.092
	Average Canopy width (m)	0.699	5.908	0.00003	16	4.051	7.022
Projected wood area (m^2) stems viewed as planes	DBHOB	0.883	1.584	0.00	15	0.425	4.928
	Tree height (m)	0.575	3.015	0.00052	15	0.690	7.376

APPENDIX

SUMMARY OF LEAF AND TWIG STATISTICS FROM FIRST TRIAL PRIOR TO BANKSIADALE ROAD

n = 263 leaves

Variable	Mean	Std Dev.	Max.	Min.	Range
Leaf Area (cm^2)	11.286	4.377	24.90	0.68	24.22
Leaf Weight (gms)	0.345	0.134	0.81	0.02	0.79
Specific Area (cm^2/gm)	32.70	3.277	42.62	13.56	29.06

n = 29 Twigs

Variable	Mean	Std Dev.	Max.	Min.	Range
Twig Area (cm^2)	102.356	51.103	252.85	14.11	238.74
Twig Weight (gms)	3.80	1.879	8.33	0.61	7.72
Specific Area (cm^2/gm)	26.975	2.397	31.15	21.83	9.32

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