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VOLUME EQUATIONS FOR *EUCALYPTUS REGNANS* IN YOUNG PLANTATIONS

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NOTE : Confidential to participants of the management of Eucalyptus species cooperative.

: This material is unpublished and must not be cited as a literature referance.

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EXECUTIVE SUMMARY

MANAGEMENT OF EUCALYPTS

VOLUME EQUATION FOR EUCALYPTUS REGNANS IN YOUNG PLANTATIONS

Estimation of tree volume is of vital importance to management. Advantage has been taken a Nelder spacing trial planted in *Eucalyptus regnans* to derive a volume table for trees in young unthinned stands. The Nelder design is efficient for determining effects due to changes in spacing, trees being planted in a series of concentric circles with the same number of trees in each circle. Those closest to the centre represent the closest spacings. Two hundred and sixteen trees were sectionally measured and their volumes calculated. The data were then used to derive a volume equation of the form $V = \pi \times D^2 \times H/4000 \times$ Form Factor.

The form factor is derived from a multiple linear regression equation of the form $FF = B_0 + B_1\ Ln(D) + B_2 + Ln\ (D^2 \times H \times S) + B_3 \times D \times S$.

where D = dbh (OB)
H = total height
S = stocking in stems/ha
and B_0, B_1, B_2 and B_3 are coefficients.

The inclusion of stocking rate in the equation to determine form factor means that the estimates of tree volume are sensitive to changes in initial stocking. The volume equation is both accurate and precise. The overall bias of total predicted volume minus actual total volume expressed as a percentage of predicted volume is + 0.04%. This is a trivial effect and means that as an estimator of stand volumes the equation can be expected to give very accurate results.

Precision is also good, individual tree volumes are predicted to within ± 13.4% with 95% certainty.

The volume equation is most useful in estimating the volume in young unthinned stands of the type that might be harvested for pulp or fuelwood. Because the data came from one locality, Kaingaroa forest near Murupara, the equations must be regarded as "local". Their use should also be restricted to unthinned stands.

ABSTRACT

A volume equation was calculated for young, unthinned Eucalyptus regnans F. Muell. growing in the Murupara subdivision of Kaingaroa Forest. The data were collected from 216 trees grown in a Nelder spacing trial at 7 years of age. The trees were sectionally measured at short intervals up to 5.5 m and then longer intervals up to the total height. Stepwise regression analysis was used to fit a nonlinear model for volume as a function of tree diameter, height and tree form factor. Tree form was found to be related to diameter, height and initial stocking.

INTRODUCTION

This paper describes the construction of local volume equations for Eucalyptus regnans. The trials sampled were untended but are representative of well grown stands of young age.

The source of data was two semicircular spacing trials planted in 1978 using a Nelder experimental design in Compartment 1209, Kaingaroa Forest.

The seedlings were bare rooted and raised in the Forest Research Institute nursery. The seedlot was HO 74/815; this originated in Franklin, Tasmania (altitude 304-365 m a.s.l.).

Each of the two semicircles, contains 23 radial spokes separated by 8 degree intervals to give spacings ranging from 1.5 m^2 to 10 m^2 per tree. More details are given in Appendix 1 (Table 1).

Nelder design spacing trials have been studied by tennent (1973) in the past and used to highlight the relationships between spacing and tree characteristics in P. radiata. The present study deals with the interaction of tree volume, DBH, height and initial stocking.

METHOD

In 1985 when the trees were 7 years old, six areas representing initial stockings of 2551, 1111, 480, 364, 209, 158 stems/ha were selected for taking sectional measurements. A sample of 216 trees were selected in groups of 21 or 43 trees of equal initial stocking to test the variation in tree form. This sample size was regarded as suitable because the Nelder design reduces the variation in tree form due to other causes (for example, site index) to a minimum.

The trees were chosen so that the whole diameter range was represented in the sample.

Because the selected trees are not spatially dispersed throughout a geographic range, but are instead representative of one locality (Murupara, Kaingaroa); the equations should be regarded as 'local'.

Each sample tree was first measured for DBH and total height. Then upper stem diameters of standing trees were assessed using a telescopic optical instrument, the Barr and Stroud optical dendrometer (Type FP12). The lower portion of the stem was measured by climbing each tree up to 5.5 m. Measurements of over bark diameter using a girth tape, and two bark thicknesses were taken at heights 0.5, 1.0, 1.4, 1.5, 2.5, 3.0, 3.5, 4.5, and 5.5 metres. Two or three measurements were made above 5.5 metres, usually at 2.0-3.0 metre intervals. Bark thicknesses at the points above 5.5 metres were estimated using an equation derived from the measured over-bark diameters and bark thicknesses below 5.5 m.

Stem volume was calculated by conceptually subdividing the bole into sections. The diameters measured were treated as the upper and lower end of each section (inside bark) and were used then to calculate the sectional volume using the Smalian's formula:

$$V = \pi * L/8 (D1^2 + D2^2)$$

Where V = Sectional volume in m^3.

D1 = Under bark diameter at top of the section in cm.

D2 = Under bark diameter at bottom of the section in cm.

L = length in m.

The volume of the uppermost segment was estimated using the formula for the volume of a cone and the volumes of the two sections below 1.4 metres were calculated using the formula for a truncated cone:

$$V = \pi * L/12 (D1^2 + D1*D2 + D2^2).$$

Total volume of the stem was obtained by summing the volume of all the sections.

Note, if a paraboidal shape (Smalians) had been assumed for these lower sections the volume would have been over-estimated as the stem shape tended toward a cone (or a neiloid in some cases) at the base.

The local volume prediction equation was developed by fitting nonlinear models to the data using stepwise regression analysis. The total volume obtained for each tree was correlated to DBH, total height and initial stocking.

RESULTS

The stepwise regression procedure gave the following equation for predicting total volume inside bark from stump height to the tip of the tree:

$$V = 3.14156*D^2*H/40000 * FF$$

$$FF = B0 + B1*\ln(D) + B2*\ln(D^2*H*S) + B3*D*S$$

Where D = DBH outside bark in cm.

H = Total height in m.

S = Initial stocking in stems/ha.

B0	=	0.136	S.E. =	0.0941
B1	=	-0.0932	S.E. =	0.0112
B2	=	0.03575	S.E. =	0.00859
B3	=	-1.826E-6	S.E. =	0.605E-6

Tests of accuracy show that when the difference between total estimated and total actual volume of sample trees was expressed as a percentage of total estimated volume the percentage bias was only +0.04%.

The test of precision showed that in 95% of all cases the volume of a single tree will be predicted to within 13.4% of the true volume.

There are two main advantages in fitting a model to predict form factor:

$$(FF, \text{form factor}) = k*V/D^2*H$$

Where k = $40000/\pi$.

1. The relationship between FF and diameter breast height usually has a fairly constant variance over the range of DBH, thus satisfying one of the assumptions of normal regression analysis.

2. The resulting equation can be quickly interpreted and easily compared with previous experience as it describes the change in the tree form factor with the independent variables.

A similar model has been used successfully for E. regnans by Opie (1976).

The shape of a stem, and consequently its total volume varies according to the site and management of the stand (density, age, site index, fertilisation, Paropsis spp. attack, thinning, pruning, etc.).

It would be impossible to account for all of these variations in the construction of a volume equation unless a very large and carefully designed data set was available. We chose the three most important causes of variation and believe that any statistical error resulting from the omission of the others is acceptable. DBH and total height explain much of the volume variation. However, the initial stocking was regarded as a good third choice because it is a variable often determined by management and its inclusion removed the greatest part of the residual variation. A sensitivity analysis showing change in volume when the three variables are altered is shown in Table 1.

TABLE 1: Sensitivity analysis for stem volume with change in size or initial stocking

DBH o.b. (cm)	T. height (m)	Total stem volume i.b. (m^3)		
		1800 sph	1000 sph	200 sph
9.5	11.5	0.03352	0.03294	0.02938
9.5	13.5	0.03990	0.03921	0.03504
10.5	13.5	0.04810	0.04744	0.04250
13.5	16.0	0.09212	0.09183	0.08316
15.5	17.0	0.12665	0.12718	0.11598

The table shows changes in stem volume for trees of the same diameter but different height (lines 1 and 2). The increases in volume when the height is increased are 19.0%, 19.0%, 19.26% for initial stocking of 1800, 1000, or 200 stems/ha respectively.

However, when the diameter is increased and the height remains constant (lines 2 and 3) the increases in volume are 20.56%, 20.97%, and 21.32%. this means that a 1 cm. increase in diameter results in bigger change in volume than a 1 m. increase in height.

It is also interesting to note that trees of equal diameter and equal height usually improve in stem form and consequently increase in volume when they are from stands of higher initial stocking. However, this is not true for stands of initial stocking higher than 1000 stems/ha and trees of DBH bigger than 15.5 cm and total height greater than 17 m. The effect of initial stocking is not always a simple increase in form factor, but interacts with tree size. This means that the volume equation can be used to predict volumes of dominant trees as well as trees of average size within a particular initial stocking class.

CONCLUSION

The volume equation developed for young plantations of Eucalyptus regnans performs very satisfactorily and is applicable to stands that have not been pruned or thinned. Because initial stocking is one of the dependent variables in the equation, any non-natural change in the actual stocking will cause bias on any predicted volumes.

It is also restricted to a local region around Murupara where the site index remains constant. As the data base of sectional measurements is enlarged, a more general equation could be derived together with a compatible taper equation.

ACKNOWLEDGEMENT

The data used in developing this volume equation were collected in part by R. Cairns and used independently by him in a dissertation submitted to the University of Canterbury in 1986.

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APPENDIX 1

TABLE 1: Nelder details

Arc no.	Radii of planting arcs (m)	Equivalent square spacing (m^2)	Initial stocking (stems/ha equiv.)
-	9.36	1.31 (not assessed)	-
1	10.75	1.50	4444
2	12.35	1.72	3380
3	14.20	1.98	2551
4	16.31	2.28	1924
5	18.75	2.62	1457
6	21.54	3.00	1111
7	24.75	3.46	835
8	28.44	3.97	634
9	32.68	4.56	480
10	37.56	5.24	364
11	43.16	6.03	275
12	49.59	6.92	209
13	56.99	7.95	158
14	65.48	9.14	120
15	75.25	10.50	91
-	86.47	12.06	-
-	99.34	13.86 (not assessed)	-

The above progression was derived from the general formulae:

$$Sn = 2rn*Sin\ 1/2\,\alpha$$

Where Sn = the distance between trees on an arc of radius rn such that $rn = p^n*ro$ where ro is the radius of the innermost arc and p is the constant factor used in deriving the successive radii of planting arcs such that the area occupied by each tree is the square of the spacing (Sn).

The value of P for this trial, with a between spoke angle of 8° (45 spokes per circle) was derived using the formula given by Beekhuis in his comments to G.S. Brown's Work Plan S 85/1/1, 1965.

Thus $$p^2 - \frac{4N}{\pi} * (\sin^2 \frac{180}{N}) * p - 1 = 0$$

$$p^2 = 0.27879\ p - 1 = 0$$

$$p = \frac{0.27879 + \sqrt{0.077723 + 4}}{2}$$

$$p = 1.1491$$