A COMPARISON OF METHODS OF DETERMINING THE CUBIC VOLULE OF STANDING KAURI.

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1. Introduction.

Absolute accuracy is seldom possible in the determination of volume of standing timber. Nevertheless the objective should be to keep the error of estimate within certain known limits, the permissible percentage error to be small (say $\pm$ 5%) in the case of estimates for sale purposes, moderate (say $\pm$ 10%) in the case of estimates for working plans, and the maximum (say $\pm$ 15% to 20%) in the case of extensive surveys and preliminary reconnaissances. Further, cruising practices should be directed towards securing a lower percentage error of estimate in high value timbers such as kauri (*Agathis australis*) as compared with lower valued species such as miro (*Podocarpus ferrugineus*) or rimu (*Dacrydium cupressinum*).

According to current cruising practice the volume estimate of standing kauri is based on the measurement of G.B.H. (girth over bark at breast height) and merchantable height, and an estimate of girth at the centre of the merchantable length (centre-girth over bark or C.G.). The volume in cubic feet corresponding to C.G. and merchantable length is then obtained from the New Zealand State Forest Service Log Scale (a cylinder table).

As far as can be ascertained no check has been made of the relative accuracy of this method.

During the course of departmental logging operations to procure kauri for shipbuilding purposes during Word War II measurements were made of felled trees, the points of measurement being at intervals along the merchantable length. Complete data relating to 164 trees were obtained and form the basis of this paper.

2. Nature and Scope of Investigation.

(a) The determination of the merchantable cubic volume of 164 kauri trees by the centre-girth method, C.G. being measured, not estimated.

(b) The preparation of a local volume table based on the measurements of the above 164 trees.

(c) An assessment of the accuracy of the centre-girth and volume table methods of determining the merchantable cubic volume of 164 standing kauri trees relative to the volumes of the same trees estimated in short sections after falling.

3. Description of Material Investigated.

The material used consisted of 164 kauri trees of normal form felled at Omahuta and Waipoua State Forests, ranging in G.B.H. from 8 ft. 8 in. to 19 ft. 11 in., and in merchantable height from 22 ft. to 70 ft.

TABLE I.

Number of Trees by G.B.H. and Merchantable Height Classes.

G.B.H. Class—Feet	Merchantable Height Class—Feet						Totals
	20	30	40	50	60	70	
8—10	1	5	3	1	1	—	11
10—12	2	12	6	7	1	2	30
12—14	4	19	15	8	3	2	51
14—16	5	17	14	2	2	—	40
16—18	3	10	8	4	—	—	25
18—20	—	4	2	—	1	—	7
Totals	15	67	48	22	8	4	164

4. Methods of Investigation.

(a) Determination of True Merchantable Volume.

(i) **Measurement.**—Measurements were made of G.O.B. (girth over bark) at butt, B.H. (breast height), top, and at intervals along merchantable length. It was not possible to secure measurements at fixed and uniform points. The intervals between points of measurement ranged between 3 ft. and 22 ft., averaging 9.4 ft. Measurements were made with a metallic tape, girth in feet and inches to the nearest inch, length in feet to the nearest foot.

(ii) **Calculation of Volume.**—The mean of lower and upper girths of each short log was determined. The volume corresponding to the relevant mean girth and length was read, for each short section, from the State Forest Service Log Scale and expressed in cubic feet to the nearest cubic foot. The sum of short section volumes of each tree gave the total overbark volume of the merchantable bole.

(b) Determination of Merchantable Volume by Centre-girth Method.

(i) **Measurement.**—Measurements were made of G.O.B. at B.H. and wherever possible at centre of merchantable length. Where measurement at centre was not possible, centre girth was determined by proportion from short section measurements above and below the centre point.

(ii) **Calculation of Volume.**—Overbark merchantable volumes corresponding to the relevant C.G. and merchantable length of each tree were read from the State Forest Service Log Scale, expressed in cubic feet to the nearest cubic foot.

(c) Determination of Merchantable Volume by Local Volume Table Method.

A local volume table was prepared from the data in (a) above by the volume curve method, the table being based on G.B.H. and merchantable height classes, girths being expressed in 2 inch classes and merchantable heights in 2 foot classes, overbark volumes being expressed in cubic feet to the nearest cubic foot.

The volume table was checked against the basic data for aggregate difference and average deviation.

(d) **Comparison of Methods.**

Class volumes, by G.B.H. and merchantable height classes, were determined for true volume, C.G. volume, and volume table volume, and the percentage difference of each from true volume found.

The percentage differences from the true volumes of individual trees by the two methods were grouped into frequency tables, and the mean and standard deviation calculated.

5. **Results of Investigation.**

TABLE II.

Percentage Difference from True Volume by G.B.H. Classes.

G.B.H. Class Feet	No. of Trees	Volume O.B. in Cubic Feet				
		True Volume	C. G. Volume		Volume Table	
			Volume	% Diff.	Volume	% Diff.
8—10	11	2,175	1,953	—10.3	2,304	—5.9
10—12	30	9,019	8,341	—7.9	8,951	—0.8
12—14	51	20,930	19,238	—8.5	21,238	+1.4
14—16	40	20,252	18,749	—7.7	20,346	+0.5
16—18	25	16,905	16,086	—4.8	16,710	—1.2
18—20	7	5,990	5,531	—7.4	5,934	—0.9
Totals	164	75,271	69,898	—7.1	75,483	+0.3

TABLE III.

Percentage Difference from True Volume by Merchantable Height Classes.

Merch. Height Class—Ft.	No. of Trees	Volume O.B. in Cubic Feet.				
		True Volume	C.G. Volume		Volume Table	
			Volume	% Diff.	Volume	% Diff.
20	15	5,041	4,460	—11.3	5,318	+5.5
30	67	27,644	25,576	—7.5	27,750	+0.4
40	48	24,625	23,104	—6.2	24,293	—1.3
50	22	10,942	10,275	—6.1	10,884	—0.5
60	8	4,748	4,297	—9.5	4,977	+4.8
70	4	2,271	2,186	—3.7	2,261	—0.4
Totals	164	75,271	69,898	—7.1	75,483	+0.3

TABLE IV.

Aggregate Percentage Difference and Mean Percentage Difference.

Quantity	Centre-girth Method	Volume Table Method
Aggregate percentage difference	—7.1%	+0.3%
Mean percentage difference	—7.85%	±6.93%
Standard deviation	±4.30	±5.52

6. Discussion of Results.

(a) Centre Girth Method.

(i) Of the 164 trees examined, C.G. volume exceeded true volume in one case only (by +1.4%). In all other cases C.G. volume was less than true volume by amounts varying from 0 to —21.9%.

(ii) The aggregate difference from true volume was —7.1%.

(iii) The mean percentage difference from true volume was —7.85%.

(iv) The standard deviation of mean percentage difference was ±4.30. Thus for a similar sample of 164 trees one could expect that 67% of the individual deviations will have a value within ±4.30 of the average deviation of —7.85%.

(v) The percentage difference from true volume showed a tendency to decrease with both increasing G.B.H. and merchantable height. The explanation of this is that taper is regular from butt to merchantable top in trees of small girth (young trees); in trees of average size taper is rapid in the lower bole and less rapid in the middle and upper bole; but in trees of large girth (old trees), taper is rapid in the lower bole, less rapid in the mid-bole, while in the upper bole absence of taper, or reverse taper is frequent.

(b) Volume Table Method.

(i) The aggregate difference between true volume and the volume obtained from the local volume table was +0.3%.

(ii) The mean percentage difference was ±6.93%.

(iii) The standard deviation of mean percentage difference was ±5.52. Thus a similar sample of 164 trees, one could expect that 67% of the individual deviations will have a value within ±5.52 of the average deviation of ±6.93%.

(c) Comparison of Methods.

(i) **Total Sample.**—The volume table gave an aggregate result +0.3% higher than true volume, whereas the C.G. aggregate was 7.1% less than true volume. Moreover, in addition to giving a smaller mean percentage difference (±6.93% for volume table compared with —7.85% for C.G. method), percentage differences in the case of the volume table were compensating, whereas those by the C.G. method were consistently negative.

(ii) **Individual Trees:**

	C.G. Method	Volume Table
Actual range of percentage difference from true volume	+1.4% to —21.9%	—16.5% to +29.3%

(iii) **Individual G.B.H. or Height Classes:**

	C.G. Method	Volume Table
Actual range of percentage difference from true volume		
G.B.H. classes	—4.8% to —10.3%	+1.4% to —5.9%
Height classes	—3.7% to —11.3%	—1.3% to +5.5.%

7. Conclusions.

(a) The centre-girth method does not give an accurate estimate of volume when applied to kauri. The mean deviation from true volume in a sample of 164 trees was —7.85%. The deviations in all except one case were negative.

(b) In this investigation centre-girths were measured whereas in current practice they are estimated, this practice introducing a further source of error of unknown magnitude.

(c) A local kauri volume table has been prepared based on 164 trees. Compared with the basic date this volume table showed an aggregate difference of +0.3% and a mean percentage difference of $\pm$6.93%.

(d) Errors in the case of the volume table are compensating and could be expected to give more accurage results than the C.G. method.

(e) The centre-girth method should be abandoned, except where approximate results only are required, and replaced by either the volume table method or log scaling.

8. Summary.

The relative accuracy of the current method of measuring standing kauri (the centre-girth method) was examined. A sample of 164 trees, ranging in G.B.H. from 8 ft. 8 in. to 19 ft. 11 in. and in merchantable height from 22 ft. to 70 ft., showed a negative aggregate difference of —7.1% by the centre-girth method, as compared with true volume determined by measuring each tree in short sections. With one exception all trees showed a negative percentage difference from true volume, the difference decreasing with increasing height and G.B.H., the mean percentage difference being—7.85%.

A local kauri volume table was prepared from these same trees which, checked against the basic data, showed an aggregate difference of +0.3% and a mean deviation of $\pm$6.93%.

The recommendation is made that the centre-girth method be abandoned and be replaced by either volume table or log scaling.