A SAMPLING APPROACH TO NEW ZEALAND TIMBER CRUISING PROBLEMS.

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1. Introduction.

New Zealand indigenous forest associations are extremely variable both in distribution and in composition. Whatever the reasons may be there is a diversity in plant association unlike anything to be found in Northern temperate climates. This ecological fact has important mensurational significance and it is well to keep it in mind when considering a sampling approach to New Zealand's timber cruising problems. Homogeneous populations lend themselves readily to sampling methods, heterogeneous populations less so. The latter, however, can be sampled with only a small increase in the necessary intensity, if certain conditions exist; namely, if the population is stratified, if the sampling is systematic in nature, and if it is designed to take into account this stratification. Thus, in normal cruising practice the direction of strips is customarily taken at right angles to the prevailing topography; the regular stratification arising from ridges and valleys is recognised and the sampling pattern is designed accordingly. In most countries this method has given accurate results. In N.Z. it has not always done so. The reason is simply that the stratification in N.Z. forests is not sufficiently regular and that factors other than topography contribute to the marked heterogeneity which undoubtedly exists.

It is pertinent to analyse further the sources of such errors as have arisen. In strip cruising the total volume figure is obtained by multiplying the area in acres by the average volume per acre. If no typing is done, the area figure is known exactly, and subject to the limitations imposed by instrumental field work, it is without error. With typing, and when type areas are got directly from lineal proportions, a purely sampling error is introduced. Volume per acre is itself made up of two variables, density, or number of trees per acre and mean volume per tree, and both of these are subject to sampling errors. Thus, in strip cruising using separate area figures for separate types, there are three variables to be sampled, and hence three distinct sources of sampling error. In each case the extent of the error is a function of the degree of variation. The problem therefore is to decide which of these three factors is likely to be abnormally variable under N.Z. conditions. There is no reason why mean tree volume should be. There is every reason to suppose, on account of the heterogeneity already noted, that both density and type-distribution will be variable to an extraordinary degree.

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The greater part of the total sampling error can therefore be attribted to the individual errors arising from the abnormal variation in density and type-distribution. It is immediately apparent that if these sources of error could be eliminated, it would be possible to adopt a safe and efficient sampling method. The simple and obvious way would be to make a 100% tally of all merchantable trees on every area to be measured and by so doing to limit the sampling error to the one variable of mean tree volume.

The investigation described here was suggested by these considerations and in particular by an unpublished paper from the Southern Forest Experiment Station, U.S. Forest Service, entitled *Sampling Tree Volume on Tree Measurement Sales.* Designed for use in the Texas National Forest, it aimed to produce total cubic foot volume figures, to a given degree of accuracy and with a small amount of field work, by the application of a simple sampling procedure. The plan briefly was :—

(a) To make a 100% tally of all trees to be sold, keeping the tally separate by ocularly estimated 4 in. diameter classes.

(b) From a prior knowledge of the variation of volume within each diameter class to compute the number of trees which should be measured for any given degree of accuracy.

(c) By dividing the number so computed into the total number of trees in each class, to work out a sampling interval, such as every 5th tree or every 10th tree.

(d) To measure carefully every 5th or 10th tree as the case may be, and to compute the total results pro rata.

The success of this plan depended on accurate information being available concerning the *variation in volume within a diameter class.* Such information could be got either from prior knowledge or from an analysis of the figures for each individual sale. The information can be expressed mathematically by a figure which is termed the *Co-efficient of Variation.* Its derivation involves one of the simpler processes of statistical analysis and it can be computed by straightforward arithmetical processes. The present investigation was undertaken therefore to obtain similar information for N.Z. tree species, and using the results to test the possibility of applying a sampling procedure to N.Z. timber cruising problems.

2. **Objectives.**

More specifically the objectives of the project were :—

(a) For individual cruises, to work out the Co-efficients of Variation in net volume, per species, and per gross diameter classes.

(b) For individual cruises, to work out Co-efficients of Variation, per species, but irrespective of diameter classes.

(c) From the figures so obtained, to determine the intensity of sampling needed for different degrees of accuracy and for different probabilities of accuracy.

(d) To test the results by applying a sampling method to previous cruises and comparing the figures obtained with the 100% cruise totals.

3. Formulae and Basic Theory.†

(a) The best known measure of variation is termed the *Standard Deviation* (S.D.). It is an expression of the degree to which all values of a population deviate from their arithmetical mean. In terms of this project it is a measure of the dispersal of tree volumes about their average.

The basic formula is :—

$$S.D. = \sqrt{\frac{\Sigma(X-\bar{X})^2}{N}} \qquad (1)$$

Where X = Mean Volume.
$\bar{X}$ = Volume of each individual tree.
Σ = Sum of.
N = Total number of trees.

The arithmetic required to calculate the Standard Deviation by this formula is extremely laborious. In practice a short cut method is used, employing a grouped frequency distribution table.

(b) The Standard Deviation is a relative measure and its use is confined to the population (cruise) to which it refers. For comparative purposes, it is necessary to express it as a percentage of the mean. It then becomes the Coefficient of Variation and is an absolute, and not a relative figure.

The formula is simply :—

$$V = \frac{100 \text{ S.D.}}{X} \qquad (2)$$

Where X = Mean.
S.D. = Standard Deviation.
V = Coefficient of Variation, as a percentage.

(c) In any sampling method there is a probability of error inherent in the fact that only a small portion of the population is measured. This error has nothing to do with errors in field work, in instruments, in volume tables, or in compilation and it merely arises from the use of the sampling procedure. It is termed the *Standard Error*. A very definite relationship

† This section need not be read by anyone conversant with elementary statistical method.

exists between the Standard Deviation (or the Coefficient of Variation) and the Standard Error. It is expressed by this formula :—

$$a = \frac{V}{\sqrt{n}} \qquad (3)$$

Where a = Standard Error expressed as a percentage.
V = Coefficient of Variation.
n = Number of samples.

The same formula expressed another way, becomes :—

$$n = \frac{V^2}{a^2} \qquad (4)$$

Thus if a is predetermined, and V is known, it is possible to compute the number of samples needed, and it is this fact which enables the accuracy to be controlled. In other words, assuming V is known, it is possible either to ascertain the number of samples needed for a given degree of accuracy, or, for a given number of samples, to work out what sampling error has been introduced.

(d) In the above paragraph there is the term *probability of error.* This probability itself can be measured and it is the fact that the figures for probability obey certain mathematical laws which makes the whole of statistical method possible. Without going further into theory it can be stated that the the use of formula (3) or (4) involves a probability of 67%. In other words there are two chances out of three that the accuracy will come within the prescribed limits. For cruising work such odds are not nearly good enough and it is necessary to modify the formula so that the probability is much greater. This is done by halving the Standard Error (a) or more conveniently by multiplying the Coefficient of Variation by a statistic t, in this case given the value of 2. With such modification, the probability is raised to 95%, and there are 19 chances out of 20 that any results got will be within the limit of accuracy set by the Standard Error. Using the value of 2 for t the Standard Error is then said to be at the .05 *level of significance.* These odds (of 19 to 1) are generally considered to be reasonable and permissible in most forest mensuration work.

(e) All the foregoing is based on the assumption that the population is unlimited. In timber cruises, however, the exact number of trees is known and the population is therefore strictly limited. This fact means that a fewer number of samples are needed and the formula must be modified to take into account the factor of limited population. The final formula therefore is :—(‡)

$$n = \frac{Nt^2V^2}{Na^2 + t^2V^2} \qquad (5)$$

Where n =Number of samples needed.
N =Total number of trees.
V =Coefficient of Variation, *expressed as a decimal*.
a =Standard Error, also *expressed as a decimal.*
t =Safety factor to raise probability of accuracy.

As an example, if the Coefficient of Variation for 1,000 trees is 60% and the results are wanted to an accuracy of $\pm$5% at the .05 level of significance, the number of samples needed would be :—

$$n = \frac{1000 \times (2)^2 \times (.6)^2}{1000 \times (.05)^2 + (2^2 \times .6^2)} = \frac{1440}{394} = 365$$

(f) Unless otherwise stated, all the following calculations are based on the factors *a* and *t* being constant. They are given the values of .05 and 2 respectively. As stated above, this means that there are 19 chances out of 20 that the use of the sample will produce results within 5% of those got from 100% measurement. It should be pointed out that with these figures, two other results can be expected.

(i) There are 2 chances out of 3 that the results will be within $\pm 2\frac{1}{2}$%.

(ii) There are 369 chances out of 370 that the results will be within $\pm$ $7\frac{1}{2}$%.

The latter one is important since it means that if by the 1 chance in 20 the results are more than 5% out, there is an overwhelming probability that they will not be more than $7\frac{1}{2}$% out.

(g) It will be seen that the key to the use of the above formula and hence to the applications of a sampling method is the factor *V*, the Coefficient of Variation. An accurate knowledge of its value is thus of fundamental importance.

‡ Girard, J. W. and Gevorkiantz, S. R., "*Timber Cruising*," U.S. Forest Service.

4. **Methods and Results.**

(a) As a preliminary, Conservancies were asked to send in the original field books of some recent, reasonably typical cruises. Efforts were made to get a wide range both of species and of forest types within the major species rimu (*Dacrydium cupressinum*).

(b) Work commenced on determining the Coefficients of Variation on net volume per gross diameter classes. The use of net volume and gross diameter classes meant that defect was treated as a variable factor which could be sampled in the same way as volume. The work was done on a tree and not a log basis and hence one value was given for both or all logs of a branched tree. For this reason there was always a slight discrepancy in numbers when compared with the cruise tally sheets.

A difficulty arose through the fact that some diameters were estimated and not measured. It was not possible to allot these to their correct diameter groups and they were therefore left out of the original calculations. In the later analyses, which embraced all trees irrespective of diameter classes, they were, correctly, incorporated.

(c) The first cruise to be analysed came from the Wellington Conservancy and was a large one of good sized timber south of Lake Taupo. It consisted of approximately 45% matai (*Podocarpus spicatus*), 30% miro (*P. ferruginens*), 20% kahikatea (*P. dacrydioides*) and 5% rimu and totata (*P. totara*) by numbers. As with all subsequent cruises, only the major species were dealt with, the assumption being made that minor species would have to be cruised 100%. Taking matai as an example, it was found that by using 4 in. diameter classes, the Coefficients of Variation were uniformly between 20% and 30%. The numbers of samples needed were correspondingly small but as the total number of trees in each class itself tended to be small, the proportion needed to be measured was comparatively large. The figures were re-grouped therefore into 8 in. diameter classes and further computations made. As was expected, the Coefficients of Variation went up, though not by much. The total number of samples needed, however, was considerably reduced. A further computation was made using 12 in. diameter classes and the results showed a similar tendency, i.e. a slight increase in Coefficient of Variation and a considerable decrease in n. Finally the Coefficient of Variation was computed for all trees irrespective of diameter classes and although the figure was now up to 50%, the total number of samples needed was reduced by more than half. The following table shows the results.

TABLE I.

	Diam. Class	Total No.	V	No. of Samples
By : **4″ Groups**	16″—20″	18	20.36%	18
	20″—24″	150	25.74%	62
	24″—28″	314	25.40%	78
	28″—32″	465	29.12%	95
	32″—36″	513	28.21%	102
	36″—40″	460	30.42%	112
	40″—44″	292	30.80%	110
	44″—48″	181	32.80%	88
	48″+	233	30.97%	93
		2626		758
By : **8″ Groups**	16″—24″	168	28.33%	73
	24″—32″	779	30.93%	128
	32″—40″	973	30.34%	122
	40″—48″	473	30.96%	116
	48″+	233	30.97%	93
		2626		532
By : **12″ Groups**	16″—24″	168	28.33%	73
	24″—36″	1292	35.50%	175
	36″—48″	933	32.48%	144
	48″+	233	30.97%	93
		2626		485
All Diameters:		2626	50.00%	347

It will be seen that the interval comes down from every 3rd tree, using 4 in. classes, to every 7th tree irrespective of classes. This was a most gratifying result for obviously the application in the field would be much simplified if no diameter class differentiation need be made.

(d) The other two species in this cruise were dealt with similarly and several other cruises likewise, until it became apparent that in most cases it was neither necessary nor profitable to subdivide into diameter classes. Thereafter, the analyses were continued without making such subdivisions.

Further results, however, showed that in some cases a much lesser number of samples would suffice if diameter groupings were made. Details are shown in the following table :—

TABLE II.

Analysis No.	Total No. of Trees	V	Number of Samples Needed	
			With Diam. Classes	Without Diam. Classes
1	1552	37%	217	190
2	939	56%	367	325
3	2183	59%	357	450
4	2626	50%	485	347
5	1223	56%	422	358
6	1673	53%	348	355
7	1624	66%	362	488
13	2499	59%	429	442
20	609	69%	264	335
21	882	50%	299	273

It will be seen that the occasions where the grouping method is more efficient tend to correspond with the higher Coefficients of Variation. As will be demonstrated later, the Coefficients of Variation tend to be higher for small trees than for large. Thus, the grouping method tends to be more efficient for small timber, a fact which in the future may prove to have some significance. Immediately, however, the advantages of keeping the sampling method simple are so obvious that they would outweigh any slight saving in field work got by diameter class differentiation. The results shown below therefore are concerned solely with Coefficients of Variation for all trees in a cruise, irrespective of diameters.

(e) In all some 22 specific analyses were done, representing the figures from 19 cruises and ranging in numbers from 300 to 2,626 trees each. Species were represented as follows :—

Rimu	15 analyses	
Southland Beech	3	,,
Tawa	1	,,
Matai	1	,,
Kahikatea	1	,,
Miro	1	,,

The Conservancy distribution was :—

Rotorua	5 analyses	
Wellington	3	,,
Westland	4	,,
Nelson	3	,,
Southland	7	,,

The results are set out in the following table :—

TABLE III.

Analysis No.	Species	Conservancy	Total No. of Trees	Average Size	V	No. Samples Needed	Interval
1	Rimu	Rotorua	1552	Large	37%	190	1 in 7
2	,,	,,	939	,,	56%	325	2 in 5
3	Tawa	,,	2183	Small	60%	450	1 in 4
4	Matai	Wellington	2625	Large	50%	347	1 in 7
5	Kahikatea	,,	1223	,,	56%	358	1 in 3
6	Miro	,,	1673	Medium	53%	355	1 in 4
7	Rimu	Nelson	1624	Small	66%	488	1 in 3
8	Beech	Southland	952	,,	51%	288	1 in 3
9	Rimu	,,	500	,,	69%	302	3 in 5
10	,,	,,	300	Medium	63%	203	2 in 3
11	,,	,,	545	Small	68%	315	3 in 5
12	Beech	,,	338	Medium	45%	167	1 in 2
13	Rimu	Westland	2499	Small	59%	442	1 in 5
14	,,	,,	1496	,,	68%	491	1 in 3
15	,,	,,	775	,,	47%	240	1 in 3
16	,,	Southland	1224	,,	61%	398	1 in 3
17	Beech	,,	881	,,	64%	377	1 in 2
18	Rimu	Westland	2407	Medium	59%	481	1 in 5
19	,,	Nelson	500	Small	65%	286	3 in 5
20	,,	,,	607	Medium	69%	339	3 in 5
21	,,	Rotorua	869	Large	50%	273	1 in 3
22	,,	,,	1100	,,	42%	224	1 in 4

Average Coefficient of Variation=57.2%

(f) For the above table the following points can be noted :—

(i). The Coefficients of Variation are mostly in the order of 50%—60% but they range from 37%—69%, a very considerable difference.

(ii). Although the data are inadequate to draw definite conclusions, there are indications that the range of Coefficients of Variation cannot be attributed to specific differences. The averages for species are :—

Rimu	=	58%
Beech	=	53%
Tawa	=	60%
Miro	=	53%
Matai	=	50%
Kahikatea	=	56%

(iii). It is more likely that the explanation of the marked differences is to be found in the average size of the trees. It is noticeable that the very high figures refer to small diameter trees only and the lower ones to large diameter trees. This tendency is demonstrated by averaging the Coefficients of Variation for broad volume class groups, as follows :—

Group	Number of Analyses	Mean V.
Large	6	48.5%
Medium	5	58%
Small	11	62%

Again more data are needed before final conclusions can be drawn. Proof of a definite correlation would be very valuable, for the most important problem involved in the practical application of any sampling procedure is that of assessing the Coefficient of Variation in advance. A correlation such as this may provide the means.

(iv). It is immediately evident that a sampling system would save most field work in large cruises; conversely it is doubtful whether the amount of saving would justify its use for very small cruises. As an example of the effect of the size of cruise on interval, the results of Analyses Nos. 4 and 8 may be compared. The Coefficient of Variation is much the same for both. No. 8 has a total of 952 trees and the interval is 1 in 3 ; No. 4 on the other hand, with 2,625 trees needs an interval of only 1 in 7.

5. **Checks.**

(a) *Cubic Feet* :

It was considered desirable to check the conclusions shown in Table III. This was done by accepting the interval shown for each analysis, going back to the field books, taking the volumes of the trees at the intervals shown, and multiplying up to give total cubic foot volumes. The results got were compared with the volumes taken from the 100% cruise tally sheets. The check was done to demonstrate that the two figures would be within 5% of each other. Fifteen cruises were dealt with this way and the results are shown in the following table :—

TABLE IV.

No.	Total Cubic Foot Volume		Difference	
	By 100% Cruise	By Sample	Cubic Feet	Per Cent.
1	473,619	487,616	13,977	+ 2.96
2	242,086	234,385	7,701	— 3.18
3	118,070	120,558	2,488	+ 2.10
7	92,803	90,504	2,229	— 2.48
8	69,859	65,759	4,100	— 5.80
10	32,560	32,712	152	+ 0.45
11	45,425	48,054	2,629	+ 5.80
12	30,509	31,330	821	+ 2.68
13	217,711	216,994	283	+ 0.11
14	113,864	109,031	4,831	— 4.24
15	41,646	41,517	129	— 0.31
16	86,321	89,032	2,711	+ 3.14
17	57,814	56,112	1,702	— 2.94
18	209.240	201,269	7,971	— 3.80
19	29,350	28,934	956	— 1.44
22	340,191	322,497	17,694	— 5.20
Totals :	2,461,168	2,449,046	12,122	— 0.49

The following points arise :—

(i) It is clearly demonstrated that the sampling errors will tend to be compensating.

(ii) It will be seen that three results are not within the 5% allowed. Two of these, Nos. 8 and 11, refer to very small cruises and the cubic foot differences are small. Further, it was found for one of them that an insufficient number of samples had been taken, a fact which will most likely explain why the 5% was exceeded. (It should be remembered that in any case there is always one chance in 20 of the error being more than 5%).
Analysis No. 22 shows both large percentage and cubic foot differences and was hence subjected to a further investigation. The answer was thought to lie in the method of computation. As for all other analyses, the sample volume was worked up by totalling the individual volumes of each tree. The cruise figures on the other hand were arrived at by the usual method of averaging height per 2 in. diameter classes. The sample

figures were therefore recomputed using the average height method, with these results :—

100% Cruise figures	340,191 cubic feet.
Revised sample figures	329,606 ,, ,,
Difference	—3.11%

The difference between the two methods of computation was thus 2.16%. The average height method will give slightly incorrect figures in nearly all cases, and the errors will tend to be plus rather than minus. This fact should be noted when examining the results shown in Table I, which makes comparisons between figures which are not themselves strictly comparable. For practical purposes, however, the differences should be too small to be significant and should not affect the validity of the comparisons made.

(b) *Board Feet* :

The above figures are all in cubic feet. There is no reason why the samples taken should not reflect the proportion of volume in conversion factor groupings or that the board foot volumes should not be exactly comparable. Three tests were done, with these results :—

TABLE V.

No.	Cubic Foot Volume			Board Foot Volume		
	100% Cruise	Sample	Difference	100% Cruise	Sample	Difference
1	473,619	487,616	+2.96%	3,293,560	3,396,337	+3.12%
2	242,086	234,385	—3.18%	1,667,470	1,611,489	—3.36%
22	340.191	322,497	—5.20%	2,368,752	2,243,451	—5.25%

6. Pre-assessment of V.

(a) The project cannot be said to have succeeded completely since there is as yet insufficient information available to prophesy Coefficients of Variation, even for broad forest types. Work is proceeding in an attempt to isolate the factor which has the most effect in causing differences in V. A graphical expression of height, diameter, and volume frequencies is showing some promise.

(b) The alternative to having standard figures for species and for districts is to compute V for each cruise. This would introduce an assumption that V for the sample would be the same as for the whole population. Such an assumption is reasonably justifiable. It was checked, however, by working out both figures for three cruises. The results were as expected, and are shown in Table VI below.

TABLE VI.

Cruise No.	No. of Trees	V from Total	No. of Samples	V from Sample
2	939	55.64%	313	58.62%
21	869	49.92%	289	50.86%
22	1100	41.93%	275	43.28%

(c) A different approach has been tried, and one which is made possible by the fact that in a normal distribution the Standard Deviation should equal 1/6th of the range in volume from the lowest to the highest. A test gave the following results :—

TABLE VII.

No.	Using S.D. from Analysis			Using S.D. from 1/6 th. Range		
	V	No.	Interval	V	No.	Interval
2	55.6%	325	2:5	50.2%	282	1:3
4	50.0%	347	1:7	54.9%	408	1:6
5	56.3%	358	1:3	50.2%	303	1:4
6	53.1%	355	1:4	62.1%	453	1:3
7	66.0%	488	1:3	68.0%	509	1:3
8	50.8%	288	1:3	46.5%	254	1:3
9	69.1%	302	3:5	53.0%	238	1:2
10	62.6%	203	2:3	62.1%	203	2:3
11	68.3%	315	3:5	66.3%	308	3:5
12	45.3%	167	1:2	48.2%	179	3:5
13	58.7%	442	1:5	56.3%	423	1:5
14	67.6%	491	1:3	65.6%	472	1:3
15	46.6%	240	1:3	48.3%	252	1:2
16	60.7%	398	1:3	52.7%	327	1:4
17	64.1%	377	1:2	62.6%	350	1:2
18	58.9%	481	1:5	65.3%	532	1:4
19	65.0%	286	3:5	61.7%	273	3:5
20	69.4%	339	3:5	64.4%	317	3:5
22	41.9%	224	1:4	41.6%	222	1:4

The agreement is thus fairly close and as a short cut method to determine an approximate value for *V*, it shows some promise. It demands a reasonably accurate knowledge of both mean volume and range. In practice, they should be relatively easy to predetermine.

(d) Various alternatives suggest themselves :—

(i) To use the highest value of *V* for all cruises. This is 70% and its use would mean that in most cases the intensity of sampling would be unnecessarily high. It would be very safe but it would reduce field work to an appreciable extent only on the largest of cruises.
The following table shows the intervals which should be taken for various sized cruises and for different Coefficients of Variation.

TABLE VIII.

	Coefficient of Variation				Interval
	40%	50%	60%	70%	
No. of Trees	300-400	300-800	500-1200	800-1600	1 in 2
	400-800	800-1200	1200-1700	1600-2400	1 in 3
	800-1100	1200-1600	1700-2300	2400-3200	1 in 4
	1100-1400	1600-2000	2300-2900	3200-4000	1 in 5
	1400-1600	2000-2400	2900-3500	4000-4800	1 in 6
	1600-1800	2400-2800	3500-4000	4800+	1 in 7
	1800-2000	2800-3200	4000-4500		1 in 8
	2000-2300	3200-3600	4500+		1 in 9
	2300+	3600+			1 in 10

(ii) To use the average value of V for all cruises. This method would run considerable risks for in 50% of the cases V and hence the sampling intensity, would be too low.

(iii) To use an arbitrary value for V and from the sample taken to compute the actual V. This would seem to be the most satisfactory solution. If the figure chosen were low, say 40%, it would be necessary in most cases to take further samples, a procedure which would save unnecessary field work but which might have practical difficulties. If the figure were high, say 60%, it would entail some extra field work but in most cases there would be no need for further sampling.

(iv) To use an arbitrary value for V, chosen as a result of the cruising officer's judgment as to the uniformity or otherwise of the area in question, or alternatively, by comparison with figures for nearby and similar areas. This method seems to be the ideal but it could only be successfully applied by someone who had had past experience in estimating Coefficients of Variation. It is therefore a method for possible future, rather than for present use.

(v) To pre-assess V by making preliminrary estimate of mean volume and range.

7. Practical Application.

The practical application of the sampling procedure would be somewhat as follows :—

(a) A preliminary reconnaissance would be done. This reconnaissance would determine :—

(i) Which species were present in sufficient numbers to merit sampling ;

(ii) The approximate number of trees of every species to be sampled ; and, in the event of the 1/6th range method being used, to assess V,

(iii) The approximate mean and the approximate range.

(b) Having decided the figure for V, the interval would be determined, either from Formula (5) or Table VIII.

(c) Every tree would be examined to determine whether it was merchantable or not. Each merchantable tree would be given a field book number and branded.

(d) Sample trees would be measured at the correct interval (n th). The greatest care would have to be taken to guard against any bias in selecting the samples. It is most important that every n th merchantable tree should be measured, irrespective of whether that tree was large or small, sound or defective. The only occasions when the exact n th tree would not be measured would be when it was unmeasurable. In such a case the following tree would be taken and the interval resumed at n-1. Thus if n was 4, the trees to be measured were numbers 1, 5, 9, 13 etc., and if No. 9 was unmeasurable, then No. 10 would be measured, followed by Nos. 13, 17, 21, and not by 14, 18, 22.

(e) The volume would be worked up *pro rata*, in the conversion factor groups, as represented by the sample.

(f) (Correctly). The Coefficient of Variation would be worked out for the sample and from it the exact number of sample trees would be computed. If the number was lower than that already measured, no further field work would be needed. If, however, it was higher, a further sample would be taken, and this would be done by any convenient method which was not inconsistent with the principle of randomicity.

8. Conclusions.

(a) Table II shows that the Coefficients of Variation for N.Z. species are such that all but the smallest cruises could be done sufficiently accurately by using a sampling method. The saving in both office and field work would be very considerable.

(b) Table IV shows that if such a system were introduced, the results would be consistently accurate to within the specified limit of error $\pm$ 5%. It also shows that the sampling errors entailed would be compensating.

9. Summary.

(a) Past difficulties of strip-cruising in New Zealand have been caused by abnormal variation in both density and type-distribution.

(b) These difficulties can be overcome by making 100% tree tallies and sampling for volume only.

(c) In order to discover what intensity of sampling would be needed, the figures for past cruises were analysed and the Coefficients of Variation assessed.

(d) The results show that a sampling method would be perfectly applicable to medium or large size cruises. A series of tests demonstrated that the errors entailed would be well within the prescribed margin.

(e) The major practical difficulty would be to assess Coefficients of Variation in advance. Various means of doing this are discussed.

(f) The adoption of such a sampling system would result in very great savings in both field and office work.

SOME NOTES ON UTILISATION OF TIMBERS IN THE SOUTH-WEST PACIFIC.

By STEWART CAMERON.

Prior to the Japanese advance South into the Pacific in early 1942 the exploitation of the milling timbers in the islands of the South-west Pacific area had been limited either to operations which, established in the more densely populated areas, cut to satisfy local demand, or to the extraction of commercially valuable woods like Laup or New Guinea walnut (*Dracontomelum mangiferum*) for which an overseas demand had arisen. In New Caledonia and in New Guinea there were several small mills of relatively modern design, whilst at Vanikoro in the Santa Cruz group, milling of *Agathis spp.* was carried on by an Australian syndicate. In many other islands, in New Britain, for example, mission stations ran small sawmills as an integral part of their organized activities to fill their housing requirements. According to the Annual Report to the League of Nations by the New Guinea Mandate Administration for the year 1st July, 1939, to 30th June, 1940, the total production in the New Guinea Territory was 3,961,884 board feet. Of this the log export in Hoppus measure amounted to 3,167,386 board feet and the export of sawn flitches to 90,990 board feet. The greater part of the sawn flitches exported and 1,911, 214 board feet of the log export consisted of *Dracontomelum mangiferum.*

As the American Forces landed in the recapture of Japanese held islands they brought with them Navy Construction Battalions and Army Engineers Units who set up portable mills, confining their cutting to accessible coastal stands, in order to produce construction and bridge timbers. In New Guinea the Australian Army started mills manned mainly by their Forestry Companies who had earlier in the war seen service in the United Kingdom and the Middle East.