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DESIGN FOR A FOREST SURVEY

By A. P. THOMSON.

1. General.

The National Forest Survey, at present being carried out by the Forest Service, is a comprehensive fact-finding project, designed primarily to find out how much timber is left in the country. In detail, it has these objectives :—

(a) To provide an estimate of the volume of available merchantable timber in the remaining non-protection indigenous forests of New Zealand, the estimate to be by major regions and within each region, by species and diameter classes.

(b) To revise existing National Forest Inventory estimates in order to obtain more acceptable figures for individual forests and minor land subdivisions.

(c) To prepare type maps for all classes of forest land, based on broad vegetation and volume classes.

(d) To survey the extent and degree of natural reproduction occurring on all types of forest land.

(e) To survey the effects of deer and other introduced animals, particularly on protection forests.

(f) To study the gross and net growth rates of potentially manageable indigenous species.

(g) To amass all the ecological data essential for the conservation and wise management of all types of forest land.

The present project differs from most forest inventories carried out in other countries in two respects. Firstly, its major objective has to do primarily with the volume of accessible merchantable forests rather than the total extent of the forest estate. Secondly, an attempt is being made to combine an extensive ecological survey with what is ordinarily a purely volumetric one.

The work is being organised on the basis of "Survey Units," each consisting of a major and more or less distinct natural forest region. For each unit it aims to produce total volume estimates of accepted accuracy (the standard set for merchantable timber is $\pm$ 10%). The design of the work is such that the accuracy is guaranteed for a complete survey unit and not for any constituent portion of it. Nevertheless it will be possible, by continuous local intensification, to use and enlarge upon the original field data so that subsequent estimates for smaller areas will be obtainable with a minimum of extra field work.

The survey units at present demarcated are, for the North Island: Rotorua and Mamaku district, Urewera-East Cape, Central North Island, Kaimanawa-Kaweka, and Taranaki. Already it has been found necessary to split these into sub-units and one such, which received the first attention from Forest Survey staff, is the low-lying Te Whaiti belt on the western slopes of the Ureweras.

2. Theory.

For any total volume estimate it is necessary to get accurate figures for the three factors which go to make up that total. They are: area, average number of trees per acre and average volume per tree. Irrespective of the exact objective, it is always found in Forest Survey work that the factor having most influence on survey design is that of area, whether in aggregate or by types. If published maps exist and these show up-to-date forest boundaries, then an accurate area figure can be obtained by purely planimetric processes. If they do not exist, recourse must be made either to some form of sampling for area or to the modern mapping substitute—the aerial photograph. Overseas experience, particularly American, has clearly demonstrated that sampling for area is by far the largest part of any Forest Survey, and that in comparison sampling for average volume per acre can be done very cheaply and expeditiously. The availability of suitable air photographs is therefore an important means of curtailing field work. In New Zealand the decision was early taken that aerial photographs should form the basis of the National Forest Survey. Reliance will be placed on them for the provision of both total and type area figures.

These underlying principles can be better expressed statistically as follows. The sampling error in the total volume estimate is made up of the individual errors in area estimates and in volume per acre estimates. If by means of maps or aerial photographs it is possible to eliminate the error in area estimate, then the whole allowable error can be thrown into the volume per acre estimate. With a larger sampling error permitted for the latter, it is at once obvious that the intensity of sampling does not need to be as high as it would otherwise have been.

Since estimates are required for different forest types, the method depends upon the ability to recognise and delineate these types on the photographs. Detailed office interpretation of indigenous forest photographs has proved disappointing in its results and it has been found necessary to supplement the interpretation by continuous field comparisons. For this reason the sampling design has been modified to ensure that every photo is taken into the field.

3. The Basis—Aerial Photography.

The photographs used in New Zealand are four inches to one mile vertical, overlapping single prints. Mosaics are unsuitable since on them it is not possible to get the steroscopic vision so essential to interpretation. For ease of marking the photos are matte instead of glossy prints.

Before going into the field the photos are examined stereoscopically and such type boundaries as can be recognised are marked on. The types may refer to different plant associations, to differences in volume per acre in the same association, or to differences in ease of working, i.e. in "availability." The typing is done in the first place on the basis of individual prints and the various types recognised on each print are given domestic code numbers. The location of the ground sample plots is also marked on the photographs. Apart from the actual sample plot measurement, the field party has two tasks to perform, both of which must be done faithfully if the method is to be successful. Firstly, each type with its domestic code number must be described by recording what actually exists on the ground. Secondly, the plot location must be such that the plot falls without any shadow of doubt in the same type as it is shown to do on the photograph. This latter point is of extreme importance, for as long as the plot is definitely within the boundaries of any given type and no bias is exercised in selecting its location, then it does not really matter where it is placed. For this reason accurate plot-location is quite inessential in Forest Survey work, and lengthy and time-consuming line cutting can be done away with.

4. Sampling for Volume.

The ground phase of the Forest Survey consists of the measurement of sufficient sample plots in each type to get a reliable estimate of the average volume per acre within the type. The plot size decided upon is one acre (there is a valid statistical reason for this but the details need not be entered into here). Plot shape was the subject of much deliberation and field trials were made to determine the most suitable shape. Circular plots, which have the advantage of having the shortest perimeter for a given area and hence the smallest number of marginal trees, were found to be quite impracticable. Eventually a 5 by 2 chain rectangular plot was chosen. It was found with such a plot that a five chain centre line could be cut and the one chain distance on either side could be estimated with considerable accuracy. In practice the procedure for doubtful marginal trees is that, in the case of podocarps and larger hardwoods, their distance from the centre line is measured, and in the case of dense small hardwoods, alternate trees are included and excluded. This method works with little chance of error, and does away with the more lengthy task of cutting and chaining plot boundaries.

Theoretically, the sample plots should be located absolutely at random but in practice this is not possible. Instead, they are placed according to a regular pattern so that the plots fall equidistant along parallel regularly-spaced lines. This pattern is known as "systematic sampling" and though it has the disadvantage that exact sampling errors cannot be computed, it is generally conceded to give as accurate results as those obtained by purely random sampling. The plots, of course, are still random in the sense that the field party exercises no judgment whatsoever in selecting their location.

The number of plots necessary in any unit or any type within a unit depends upon the extent of variation in volume per acre. A further statistical consideration must be introduced here. Volume per acre itself is made up of average number of trees per acre and average volume per tree. These factors vary to different degrees, and in order to reduce the field work to its essential minimum, it is desirable that the bulk of the sampling should be done for that factor which shows the greater variation. A considerable body of evidence has already been assembled in New Zealand, to show that tree count has a much greater variance than tree volume. The sampling pattern, therefore, should give more attention to measuring average densities of stands than to measuring average volumes of trees. There are two ways of doing this. One is to measure only a certain proportion of the trees on each plot; the other is to measure all trees on only a certain proportion of the plots. Without doubt the former method would result in the theoretical minimum amount of field work for any one survey unit. (Irrespective of the size of the area, it is never necessary in New Zealand to measure more than 150 trees of one species in order to get probable accuracy in volume estimate of $\pm$ 10%). The adoption of the method, however, would lead to subsequent complications when local intensification becomes necessary. In other words, it is suited to the original job, which aims at providing overall figures for large areas, but it would not produce data which could conveniently be used as a basis for more intensive work over smaller areas. For this reason the second method is being used.

There is the further complication that the intensity of sampling must be dependent also on the value of the type. With so much of its emphasis on the larger remaining areas of good merchantable timber, the Forest Survey must of necessity concentrate its work on these types which represent valuable stands of timber. A higher accuracy is needed and, therefore, more plots per unit of area must be measured. In brief, the manner by which the Forest Survey translates these various considerations into one simple sampling design is by running intermediate lines through the more valuable forest types and restricting the data collected on such lines to tree counts only.

The basic sampling pattern for a survey unit consisted in the first place of lines four miles apart and plots at half mile intervals along the lines. Without doubt this design would have given a sufficient number of plots to guarantee the accuracy of the total figures for the original survey units. As mentioned already, however, the need for more detailed information over smaller areas has led to the formation of sub-units, and to these the original sampling intensity does not apply. Furthermore, it has been found that type delineation in the office cannot always be done without the possibility of errors being introduced. In order to supplement the office typing by field examination it is therefore necessary, in these early stages of the work, to have at least one line going through each photo. This means that the line interval must be reduced from four to two miles. A typical sampling pattern for a sub-unit,* therefore, consists of parallel lines two miles apart with one-acre plots at 20 chain intervals. Intermediate lines one mile apart are run through those portions of the forest which have a volume per acre of more than 10,000 ft. B.M. Plots are placed at similar intervals, but no volume measurements are made and the number of trees per acre, in broad diameter classes, is all that is recorded.

The lines always run due east-west. This not only bring them at right angles to the major axis of the topography but, by a fortuitous chance, it coincides with the direction of the aerial photography flight-lines. The lines are not cut or chained but are merely followed by taking compass bearings. Location of each plot is decided by reference to the aerial photographs and the ground identification of visible topographic features. As stressed before, accuracy in plot location is not important provided that the plot falls within the correct type. When the commencement of a line can be identified from the photographs, no base line is cut. In some cases however a north-south line is cut and chained, and from this the correct one mile intervals are established.

The timber measurement on each plot embraces all trees 12 in. D.B.H. and over. Trees of unmerchantable species and dead and reject trees of merchantable species are classified as culls. They are tallied and booked by species in broad ocularly estimated diameter

* The pattern here described refers to the Rotorua sub-unit. Others will have slightly different patterns.

classes. Merchantable trees are carefully measured for net D.B.H. and net merchantable height, according to usual timber cruising practice. As the field staff do not have the same opportunity as district cruising rangers to become fully conversant with local defect occurrences, any tendency to underestimate defect is countered by an instruction to be severe in making deductions. Trees which would yield peeler logs are indicated on the field tally sheet by an appropriate convention.

5. **Recording Ecological Data.**

As the nature of the objectives quoted above would suggest, there is no limit to the amount of ecological data which could be recorded. In general, adherence is given to the principle that if time and money is being spent in having field parties systematically traversing the forests, then all possible information which may be of value should be recorded. The work on any one plot, therefore, consists of a systematic record of all the ecological facts which are pertinent to the composition, past history and likely future development of the forest on that plot. The only limitation recognised in this rather ambitious programme is that imposed on the staff by lack of previous training in the basic biological sciences.

Obviously one acre is too large an area for which to make a complete and detailed botanical description. Accordingly, two smaller plots are laid off. The "intermediate" plot is a rectangle one chain long by half a chain wide. On it all plant growth between 4 in. and 12 in. D.B.H. is recorded. Poles of merchantable species are tallied by 2 in. diameter classes, and everything else is tallied, by species, in the one broad class of 4 to 12 in. D.B.H. The purpose of this plot is to provide information on the diameter distribution of young forests; as can be imagined, it has more applicability to beech forests than to podocarps.

The second plot or "quadrat" is smaller still, being only half a chain long by a quarter chain wide. This is the unit for regeneration counts and floristic lists. Saplings of merchantable species between 1 and 4 in. D.B.H. are tallied and the occurrence of regeneration is indicated by a conventional frequency code. Regeneration refers to seedlings of merchantable species which are over 6 in. in height. The floristic list consists of a record of all plant species on the quadrat (except mosses, liverworts, lichens and fungi), and their frequency of occurrence is indicated by the following simplified code:—

Main part (of a tier)	M
Widely represented	W
Single specimens	S

Parties are instructed not to give a name to any plant whose identification is in any doubt but to collect and forward specimens for office identification. Collecting for herbrium purposes is also undertaken but this is general during the course of the work and is not confined to the plot boundaries.

The intermediate plot and quadrat data are quantitative in nature. Qualitatively the complete acre plot is further described under a heading "Association and Remarks." The description does not include details of species but is couched more in terms of growth forms. It aims to describe the constituent tiers of the association and the extent of development and floristic dominant of each. The tiers recognised are :—

1. Dominant canopy trees.
2. Sub-dominant canopy trees.
3. Tall shrubs and small trees.
4. Shrubs.
5. Herbaceous plants and ground ferns.

Other points of interest not recorded elsewhere on the field tally sheet are included in the "Association and Remarks" column. Quality of timber, wind damage, prevalence of native birds, and evidence of insect or fungal attack, are typical subjects dealt with if there is anything significant to be noted.

Animal damage is recorded separately in a formalised manner. Two major forms of damage are recognised, browsing of leaves and chewing of bark. The extent of either form of damage is indicated by the following coded classification :—

0. No evidence of damage.
1. Damage noted on single specimens.
2. Damage considerable but not sufficient to induce a down-grading of the association.
3. Damage so considerable that it will result in the association being unable to reproduce itself (assuming that the intensity of infestation remains the same).
4. Complete destruction of all seedlings and undergrowth.

In every case the animal responsible is indicated and the species damaged are noted.

A soil pit is dug at a suitable site near the plot centre. Using the broad texture classes of sand, sandy-loam, silt-loam, clay-loam and clay, a brief description is given of the soil profile. Particular attention is paid to the litter, and sufficient information is recorded to classify the soils into mull or mor types. The canopy tree over the soil pit is noted. Drainage is simply classified as "good" or "bad," and topography as "flat," "rolling," "moderately steep" or "steep."

Finally, the average density of the canopy over the quadrat is given a quantitative value, using 25% denisty classes.

6. Other Information.

To complete the record, various other types of information must be noted for each plot. Altitude is given to the nearest 100 feet. Aspect is shown to the nearest 45 degrees and the average slope of the plot is estimated in degrees. Notes are taken on the effects of fire, if tbis has occurred, and on the occurrence and results of any form of past exploitation. Lastly, the plot is assigned to a "protection" or "non-protection" category and both the plot and the surrounding forest to their correct "availability" categories.

It will be seen that there is some duplication of information. This has been arranged deliberately and in several respects the plot data are self-checking.

The recording of all this information obviously takes up a considerable portion of the field parties time. To hasten the progress of the work, particularly in the case of sub-units for which volume estimates are urgently needed, a compromise has been reached by recording the ecological data on every second plot only. The alternate "timber plot" work consists of tree measurements with the addition of a very brief description of the association. Similarly, the "tree count" plots on intermediate lines do not include the detailed ecological data.

7. Mapping and Computations.

The mapping and computation work is as yet in its early stages. The computations, though laborious, are simple. They will provide average volumes per acre by species and by diameter classes for all the plots in one unit and in one type. They will also include the statistical work of computing the standard deviations in volume per acre, and from these the approximate standard errors. The statistical results will show whether or not the intensity of sampling has been adequate and will provide the information necessary to determine sampling intensity for other units.

The mapping or rather photogrammetric task to be undertaken consists in the first place of correlating the various types marked on each photograph and amalgamating them into a single series throughout the unit. Constant checks on the typing will be made by reference to the sample plot data. The final type boundaries will then be transferred to a base map by use of a stereoscopic plotter and type areas obtained from the maps so prepared. The last computational step will then consist of multiplying type areas by average volume per acre within the type. This will be done for each species and for each 2 in. diameter class within a species. The final end product of the project will consist of a series of vegetation maps showing the present distribution of all classes of forest.

8. Summary.

(a) Vertical air photographs at a scale of 4 in. to 1 mile are the basis for a National Forest Survey at present being undertaken by the Forest Service.

(b) Type boundaries are marked on the photos. The types may have reference either to differences in plant association or in volume per acre within the same association.

(c) Sampling for volume per acre is done by a systematic line plot survey using rectangular one-acre plots.

(d) Detailed botanical and ecological data are recorded for a certain proportion of each plot.
(e) Final results will give total volume estimates by species and by diameter classes for major forest regions. Figures will be obtainable for that proportion of the total volume which is considered merchantable by present-day standards.

FOREST ASSOCIATIONS OF THE LONGWOOD RANGE, SOUTHLAND.

By J. T. HOLLOWAY.

This preliminary note is intended mainly to outline the complex nature of the ecological problem presented by the forest within this area. It is hoped that a fuller account may be given at a later date.

The Longwood Range has its main axis from north-west to south-east, but has extensive outlying spurs radiating from the main portion of the range. In effect it is a highland area of approximately circular outline and with a diameter of approximately 17 miles, the maximum elevation being 2,500 feet. It is almost entirely forested, from sea level behind Colac Bay on Foveaux Strait to small open tops above 2,300 feet. Marginally the forest has been cleared for agriculture but such clearings are in the main confined to the easier lower slopes below 400 feet elevation. The present forest area is approximately 77,000 acres which includes extensive remaining low altitude areas mainly within the basins of the Waimeamea and Pourakino Rivers.

Geologically the range is most complex. It is built up of rocks varying from granites, norites and basalts to metamorphic rocks and to late tertiary sandstones and mudstones with extensive recent alluviums within the stream basins. Topographically the land forms are mature with rounded slopes and spurs but toward the west steep gullies and sharp ridges are characteristic of the areas of younger sedimentary rocks. These marked stratigraphical and topographical complexities have resulted in the development of a very considerable range of soil types.

Prevailing winds are from the south-west and north-west. Winds from the former direction may be experienced for weeks on end at any season of the year. They are very cold, frequently reach gale force at higher levels and bring heavy rain with snow, sleet or hail at any season. Snow lies periodically on the open tops throughout the winter but only very occasionally at sea level for one or two days at a time. The north-west winds may also bring heavy rain which may be cold after passage over the mountainous country to the west in winter or spring, or warm in summer or autumn. In the latter