

Discussion

New Zealand's annual cut and roundwood measurement is due to rapidly increase. The understanding of roundwood measurement and standard of scaling has improved to the point where procedures are documented and reasonably uniform over the whole country. However, there are sawmillers who dispute measurements and procedures in an attempt to negotiate a price reduction on log purchases. New Zealand could benefit from fur-



Prototype loadcell on knuckleboom loader

ther development of standard procedures into a national set of standards, which some countries have already implemented. In this country, full-time scalers can still earn little above the minimum adult wage. Although management generally recognises the importance of scaling, a scaler's certification would help to maintain high scaling standards and give the task of scaling more esteem.

Research into forest-based weighing systems will continue, as this provides an inexpensive way of scaling roundwood, and improves the precision of the volume estimate. Changes in volume formulae, recording of information and presentation of results have become much simpler with the use of computers. Research and development of computer software, which incorporates research results, has been and will continue to be the easiest and most effective way to implement change.

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THE STRUCTURED WALK

A practical inventory system

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Abstract

A simple and practical methodology for forest inventory is described. The software and some of the field techniques were developed for New Zealand conditions but have now been tested and modified as a result of an inventory of a 54,000 ha plantation pine forest in Malawi, Central Africa. Each of the 3500 stands in Vipha Forest was sampled in 1990/1991, under the auspices of the United Nations' Food and Agriculture Organisation and the direction of the New Zealand Forest Research Institute. This report details the procedures that were used there, in the belief that they could have wider application elsewhere.

Keywords

Inventory; forest inventory; forest management; Vipha Forest; Malawi; Africa.

Introduction

Forest management is confronted with the problem of defining inventory methods and sampling schemes that are cost-effective. Data requirements are changing, in line with the trends both towards more intensive silvicultural practices, and towards more intensive forest planning. Increasingly, data must be precise, detailed, and at the stand level.

"Management inventories" are those which provide information used in growth prediction, silvicultural scheduling and post-operational assessments. For these, information is required on height (usually predominant mean height or mean crop height), on basal area per hectare, on pruning status (pruned height and D.O.S.¹), and on the stocking of trees in total and for each class of pruned height.

This information is required for each stand, often small in area. Inventories of populations which comprise several stands are usually inappropriate for scheduling silviculture, and are of lower value to management.

For management inventories, we recommend that each parameter be estimated by the method that is considered to be most appropriate from both statistical and cost standpoints. Thus heights should be derived from individual tree samples, basal

¹ Diameter Over pruned Stubs. This is the largest diameter in the zone of pruning, as measured immediately after the operation.

areas should be estimated from point (angle) plots, and stocking by small circular plots where only a count is made. The number of samples can then be adjusted to correspond to the variability of each parameter and the precision that is required. When the area of each stand is small and many inventories have to be conducted, rather than locating the plots randomly or in a grid pattern, a "structured walk" may be taken through the stand to minimise non-productive time.

The Forest Research Institute (FRI) has undertaken a number of forest inventories within New Zealand which have tested the effectiveness of FRI techniques and software on an operational basis. Such field-testing should be considered an intrinsic part of any technology development.

A further test of the robustness of the FRI inventory systems came with an invitation from the United Nations' Food and Agriculture Organisation to provide a resource monitoring system and examine management options for Viphya Forest, Malawi, Central Africa. This 54,000 hectare forest was planted on rolling high-altitude grassland between 1950 and 1982. It comprises mainly *Pinus patula*, but also has a substantial component of *P. elliottii* and *P. kesiya*, grown for pulpwood. Most of the stands were unthinned, and many were 100% pruned to 1.8 m for access. A significant proportion, however, had been managed on a thinning and pruning regime traditionally used by the Malawi Department of Forestry.

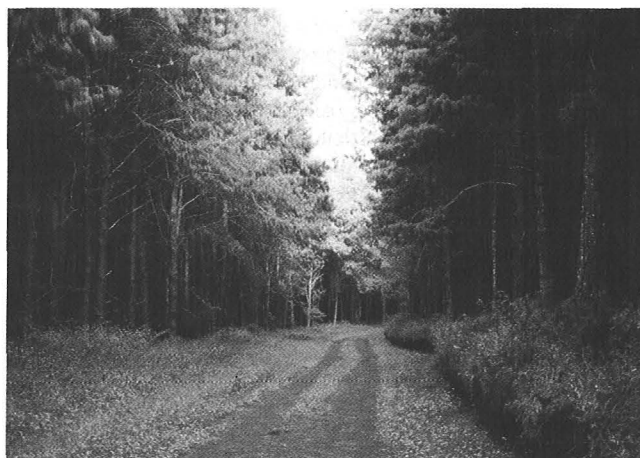


Untended *Pinus patula* stand, Viphya Forest Plantations, Malawi.

The forest is divided into 3500 even-aged stands (or 'sub-compartments') varying in area from between <1 ha and >100 ha, but averaging 22 ha. There is a good roading network, and reasonable, if old, compartment maps. The level of hindrance from understorey vegetation covered the full range from very light to very heavy.

At the commencement of the inventory, stand records varied in detail and reliability and were located on paper (without duplication). Each stand record was situated in an appropriate forest 'station' (or sub-headquarters), and there were many of these. In other words, it was very difficult to search, aggregate, and sort the existing database as a whole. It was practically impossible to answer a question such as: "what is the area of medium-pruned *patula* pine in the age classes 15 and older, and, for this component, what is the average and distribution of the stockings, heights and basal areas?"

A major objective of the contract was therefore to computerise all existing forestry records. A forest database system, the FRI proprietary software STANDMASTER, was used for this purpose, with the program STANDIN processing inventory field data to obtain estimates of stand parameters in a form suitable for inclusion in STANDMASTER. [Note: STANDMASTER has



High-pruned *Pinus patula* stand, Viphya FP, Malawi.

since been superseded by FORESTMASTER].

Each stand was visited, to verify the species and silvicultural treatment records. In many cases, there were major discrepancies.

All larger stands (>4 ha) were sampled for basal area, stocking and height, and a subjective assessment of pruned height and stand health was made. In smaller stands, height only was measured.

What constituted a sample plot?

We required a knowledge of three parameters: basal area, stocking and height. In Malawi, it would have been wasteful of resources to measure all three in every plot, because height did not vary greatly within a stand, and stocking tended to be less variable than basal area. (The stands were largely unthinned and whilst mortality was relatively uniform within a stand, basal area growth potential was quite variable.) Moreover, if all three parameters were measured simultaneously, it would have been necessary to use the same type of plot. The most cost-efficient type of plot for basal area is an unbounded or angle gauge plot, measured using a prism or relascope, whereas for stocking it is a bounded plot. For the latter, circular plots are best, as they are very quick to establish, and have the minimum edge effect for a given area.

The height measure required was top height, defined in Malawi as the average height of 100 largest DBH trees per hectare. This is best approximated by finding the largest DBH tree in a circular plot of one-hundredth of a hectare.

If each parameter were to be independently estimated, then separate plots and locations should be used. To minimise time and cost when more than one parameter was required at a given location, the plot centre was shared. A plot location could be the centre of a basal area plot, the centre of both a basal area and a stocking plot, or the centre of three plots (basal area, stocking and height).

How many plots per stand?

In any stand inventory, the optimum number of plots depends on four things:

- the cost of collecting data;
- the degree of precision that is required;
- the inherent variability of the parameter to be sampled;
- the plot size.

In this case, the budget was the primary constraint. We strove to obtain the greatest precision possible within the time-frame permitted by the finance available for labour.

Ideally, sufficient plots in each stand should be sampled for the confidence interval for each parameter (basal area, stocking, height) when expressed as a percentage of the mean to be within acceptable limits. This is called the Probable Limit of Error or PLE.² This would mean that a pilot sample should be measured in all stands to assess within-stand variability. In view of the time taken to reach and enter each stand, pilot sampling of each stand was impracticable.

A sample size was determined by trial and error at the start of the inventory, that *on average* gave an acceptable level of precision (15%), and would enable the inventory to be completed on time. This left open the possibility of returning to stands with a high variability and adding new plots.

Larger stands required more plots, because of greater variability, due to such factors as changes in topography, and because of their higher value.

It was considered too difficult to have a 'sliding scale' of sampling intensity per stand depending on area. Up to ten teams were operating simultaneously, with only three vehicles, and it was important to share the work equally.

Working within these constraints, a medium-sized stand (4-40 ha) was sampled at a total of only eight locations, but two of these were only "basal area sweeps", i.e. the basal area was directly assessed with a prism. At the remaining six locations basal area, stocking and height were measured.

In small stands (<4 ha) height only was recorded from four plots. Height measurement was vital for determining site index, but other parameters could be extrapolated from larger stands of the same crop type and age-class.

In large stands (>40 ha), 15 locations were sampled, comprising 15 basal area sweeps, ten stocking plots and six height plots.

How many trees per plot?

The most efficient average number of trees per plot for a basal area sweep was deemed to be eight trees, or five trees if visibility was poor. Poor visibility could be due to either undergrowth or lack of thinning and pruning. To compensate for the smaller sample when visibility was poor, an extra four basal area sweeps were required in a medium-sized stand.

If fewer trees are used, each assessment is less precise. The small plot size enabled time saved to be spent in establishing more plots. If more trees are used, there is a likelihood of measurement error, as well as inefficient use of time. From existing stand records, a guess could be made as to the stand's probable basal area, and a prism selected (in advance) that would, on average, give the right number of trees per plot.

Similarly, 15 trees per plot was thought to be the most appropriate number for estimation of stocking. With more trees the plot becomes laborious to lay out and the possibility of a false count increases. Plot area was determined in advance from stand records. Height measurement of one tree per plot was adequate. If the pre-planned plot size was found to be inappropriate, an

² The Probable Limits of Error or PLE, a term peculiar to New Zealand forestry, refers to the confidence limits expressed as a percentage of the estimated mean. For example a PLE of 10% at the 95% probability level implies that the true mean was likely to lie within 10% of the estimated mean 95 times out of 100 (Goulding & Lawrence, 1992).

Given the resources available, it was possible to obtain, for most stand parameters, a PLE of 15% or less. Under the Malawian conditions, this was an acceptable compromise between cost and precision at the stand level. The first use of the results was to "crop-type" the forest, and amalgamating the estimates of the stand parameters for stands within the same age-class of a crop-type would result in lower PLEs. At 15% PLE the estimates would still be precise enough to be used at the stand level for operational scheduling.



Piers Maclaren, Vipha resource planning foresters and the field crew leaders at the end of the supervising inventory training course, 1991.



Malawian landscape.

adjustment was made at the commencement of the stand inventory, but never part-way through. Only gross errors in stand records justified a change. Plot size was kept constant within any single stand.

How were the plots located?

The orthodox statistical technique allocates plots randomly on a map of the stand. Map positions are then located on the ground. In practice, this method is inefficient with respect to walk-time. More importantly, it is often difficult for the field-crew to establish plots in their correct location, and even harder for quality-control crews to find them again. Random allocation involves a mixture of distances and bearings, and requires good maps and drawing skills, and a good proficiency with geometry. There is also a risk that important areas of a stand will be inadequately sampled.

As a compromise, it is common practice in New Zealand and elsewhere for plots to be allocated in a systematic way on a grid. Although the calculation of confidence limits for such a sample is not statistically possible, the values are still routinely calculated and do give some indication of the precision of the estimates. For larger areas, this method is still recommended, although for reasons mentioned above it was not used in Malawi.

In order to meet productivity targets on stands of less than 40 ha (the vast majority), plots were located at regular intervals along "structured walks", established in such a way that the stand

was evenly covered. The field crew entered the stand along a pre-planned course, usually changed direction once or twice, then returned to a point close to where they started, measuring plots en route. In this way the amount of time spent walking was minimised. Distances between plots depended on the size of the stand, but were standardised at 50, 100 or 150 m. Care was taken to minimise the risk that the sampling pattern did not coincide with natural or man-made patterns of tree growth or form.

Figure 1 is an example of a completed map, showing a typical "structured walk" with directions, distances and types of plots indicated. Maps were drawn up the evening prior to measurement.

In order to assist location of the walks on the ground as well as on the map, the field crew commenced at a place identifiable by proximity to a conspicuous feature (e.g. "50 m due west from the bridge, along the road"). Lines, distances, and compass bearings were marked in advance on a compartment map, and checked by a supervisor.

Each field crew learned to mark its own maps, to compute its own basal area factors and stocking plot areas and to calculate the necessary compass bearings and distances. Plot types were identified by different codes on the maps.

What field techniques were used?

Each team of two people would guide its driver to the drop-off point, and make arrangements for pick-up at a specified time. The starting point on the road would be marked, and the team would set off into the undergrowth along the pre-defined compass bearing.

Hip-chains were used for distance measurement, as this is the easiest and most accurate method, allowing subsequent checking (the cotton can easily be followed a few days later). Programmable calculators were used to adjust the horizontal distance for the effect of slope.

At the predetermined distances, plot centres and individual trees were numbered clearly (with a vertical stick and chalk respectively) to assist quality control. In a basal area sweep plot, one member would assess basal area while the other continued the walk with the compass and hip chain. If stocking or height were required, one person would take the basal area sweep, while the other calculated the required radius from the prescribed area and measured slope. The circumference of bounded plots would be delineated by marking all perimeter trees. With experience, field crews could judge which trees fell within a stocking plot, and only a few marginal trees would be checked with a tape measure. The calculators were programmed with formulae for plot

radii, together with the marginal distance for basal area sweeps, and tree height formulae.

Data were entered on two standard forms. One form contained all the information from previous records pertaining to the stand, and this would be checked for accuracy. Corrections could be inserted directly into STANDMASTER. The other form was for new measurements and was designed to simplify computer punching for the program STANDIN.

Experienced teams could each average four medium-sized stands a day.

Quality control

Most workers were keen to do their best, and quality control was usually just a way of discovering whether anyone had failed to understand a technical point or to master an instrument. None of the field crew had ever used a calculator, compass, hip-chain or prism and it took time to teach them. It was important, even for well-motivated staff, to know that someone was taking an interest in their performance.

Sadly but predictably, there was the odd instance of a team taking short-cuts to save effort. Quality control ensured that such behaviour was identified before it became widespread. Rumours of slack behaviour had the potential to wreck the morale as well as the credibility of the entire inventory. Well-documented quality control had the opposite effect.

All teams were examined periodically by testing results against standard plots with known measurements. Weaker teams were identified and kept under close supervision. The most highly motivated and most accurate team was appointed as the "quality control team". They would choose stands at random from the previous day's measurements, and obtain their own results for comparison.

The quality control team relocated plot centres by following the hip-chain cotton, and by using the map marked by the original crew. A formula was devised whereby the quality control crew scored the accuracy of previous measurements. Teams seemed to take pleasure in improving their performance with increasing experience.

One unanticipated problem was sometimes encountered. The cotton used in hip-chains was greatly admired by the village women, who would sometimes follow behind a team winding it back up!

Conclusions

Because of the logistic difficulties of executing a major forest inventory in one of the world's poorest nations, the methods used in the 1990/91 inventory of Viphya Forest were unorthodox. But these methods **worked**, to the extent that the average Probable Limit of Error for basal area and stocking estimates was $\pm 15\%$, with $\pm 10\%$ for height, and the inventory was completed on schedule. More sophisticated sampling procedures might have been impossible to teach or to implement in the field, and in any case would not have resulted in cost savings.

The "structured walk" with different plot types matched to the parameter of interest enabled the inventory to be carried out at stand level for a forest with 3500 stands. The program STANDIN proved ideal for processing this data (MicroMARVL is recommended whenever merchantable volumes are required). This methodology, or variants of it, is quite suitable for radiata pine plantations, and should provide accurate information on the basic parameters of a stand at a reasonable cost.

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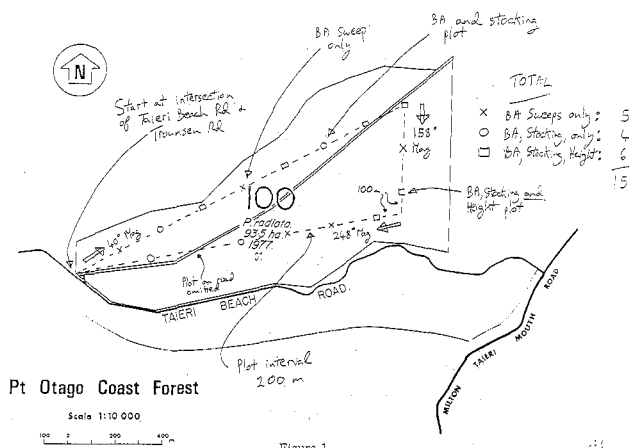


Figure 1
EXAMPLE OF A COMPLETED MAP