organise the survey and subdivision into estates of these islands. The Tobago plan, completed in 1766, included the reservation from clearance and settlement of nearly 2500 ha along the upper flanks of the Main Ridge as "Woods for the Protection of the Rains". In spite of control of Tobago reverting to France between 1783 and 1793, the Main Ridge forest has been officially protected since 1766, although it was not until 1906 that it was extended to almost 4000 ha and given legal status under a Forests Ordinance.

The Main Ridge Reserve is now recognised as providing protection from, rather than of, the rains. The forest stands on a region of steeply-dipping schists, where, with the high rainfall and steep slopes, cleared areas are prone to land-slips. The montane tropical rain forest contains few species of timber value and, apart from occasional cutting of single trees, has been little disturbed by man. But Tobago lies within the Caribbean hurricane belt and has experienced at least half-a-dozen such storms in the last two centuries. After a considerable gap a particularly severe one occurred in 1963, and, as the locals vividly described it, Hurricane Flora "mashed up" the canopy trees and defoliated the understorey. However the lower vegetation recovered quickly, and the protective value of the Reserve was little impaired.

In trying to relocate the Reserve boundaries after the hurricane, I was tempted to suspect that the original surveyors' concern for the "protection of the rains" might have been influenced by concern for their own safety on the slippery slopes leading to the summit! In fact it was often obvious during that work how the Main Ridge induced cloud formation above it while the sky remained clear on either side, and doubtless the 18th century surveyors had also observed that phenomenon.

On none of the other islands for which the Commissioners prepared plans after the Treaty of Paris was any provision made for forest reservation. As a result of the unique feature in the Tobago plan, the Main Ridge Reserve has probably the longest history of forest protection in the Americas.

R.G. Miller

ARTICLES

Measurement of roundwood in New Zealand

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Abstract

Weighscaling is the principal method of measuring forest outturn in New Zealand. The truckload weights are obtained from weighbridges. In the absence of a suitable weighbridge front-end loader based weighing systems are used in the forest. These have replaced most hand scaling operations. Export logs are measured and documented mainly by manual methods. Research is continuing on improving sample methods for weight to volume conversion calculation and automating data collection.

Introduction

This paper describes the present methods of measuring roundwood in New Zealand. Last year New Zealand produced an estimated 14.7 million cubic metres of roundwood.[1] Of this volume 3.8 million cubic metres was exported as logs. Most of these sawlogs are cut from stands of radiata pine. Logs are less than 80 centimetres in small-end diameter and they contain no rot or internal defect.

Roundwood is sold on an underbark volume (cubic metre) basis, although a few sales are based on weight. Log volume is derived from weighscaling throughout New Zealand. Weighscaling is done with weighbridges, but in areas where a centralised weighing site is not practical, front-end loader based weighing is done at the point of loading in the forest. Hand measurement continues to be used in the small operations, sample loads for monitoring weight to volume conversion factors, and the volume of export logs. These are measured by a scale requested by the log buyer.

Up until the late 1960s the saleable volume of roundwood from exotic conifers was scaled using two-dimensional log volume tables applied to individual log measurement of small-end diameter (underbark) and length. By 1968 two million cubic metres (from State plantations) were being scaled annually. In the larger logging operations log volume tables were becoming impractical because they required constant updating to ensure that the outturn estimates were accurate for various populations. Weighscaling was introduced into the large operational areas and gradually replaced hand measurement. However, for the smaller log sales, there were many forests which could not justify the costly installation of a weighbridge.

During the 1970s a single three-dimensional formula was designed to replace an estimated 60 individual two-dimensional log volume tables still in use. The new formula gave log volumes based on small-end diameter (underbark), length, and large-end diameter or average taper. When average taper is substituted for large-end diameter it allows volumes to be based on the two measurements of small-end diameter and length.

Indigenous logs have always been scaled by Hoppus or cylinder formula. Although most of the logging in State owned indigenous forests has ceased, some privately owned estates are producing indigenous softwood and hardwood logs. Overbark mid diameter is measured to the nearest even centimetre class (using girth tape) and length to the nearest tenth metre. Gross volumes are derived from two-way look-up tables after the overbark diameter has been reduced by a fixed bark allowance for that species. The nett volume of the log is obtained after the volume of internal defect is subtracted from the gross volume.

1   *Ministry of Forestry Statistical release, January 22, 1993.*

In 1986, a roundwood manual was issued which documented measurement procedures and recommended techniques for roundwood measurement. Until this time, methods of measuring exotic conifer logs were poorly documented and there was no industry standard which buyers and sellers of logs could refer to. The manual was revised in 1988 (Ellis 1988).

There are no statutory Government standards for measurement or the certification of scalers. The Forest Research Institute has an advisory role in the techniques involved in the scaling of roundwood. Scaling courses are organised and run by the FRI, along with check scaling for quality control or arbitration in dispute. Export log stocks are sampled regularly (for exporting forest companies) to monitor conversion rates between the commonly used scales in the Pacific basin. The FRI continues to develop computer software for handling log scaling data and is involved in the research of new measuring tools and methods.

Weighscaling
Weighbridge
The three types of weighbridge used in New Zealand are load-cell, mechanical, and mechanical with load cell on the lever arm. Where possible the weighing deck is of sufficient size to weigh the whole logging truck at one time. Two weighbridges in the central North Island each weigh about 400 trucks a day but some may operate at less than 30 trucks a day. Some non-forest- owned weighbridges are used and this makes it necessary for truck drivers to weigh their own trucks. A Weights and Measures Act requires that weighbridges are checked and certified annually.

Each truck has an average tare weight which is substracted

A modern loadcell weighbridge.

from the gross weight of each truckload of logs. Tare weights are updated each one or two months. It is not usual for actual tare weights to be applied after unloading each truck unless it is a sample load to be scaled for volume.
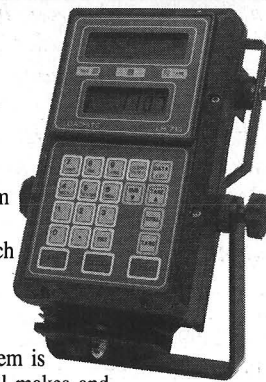
Front-end loader based weighing system
Front-end loader based weighing systems were originally introduced to allow front-end loader operators to accurately load trucks to their legal limit. This was necessary in order to avoid the high cost of fines for overloading on public roads. Roundwood leaving the forest is subject to large differences in green density (Besley 1966), and so the forestry application had certain potential. The new weighing technology allowed the contents of the load contained in the forks to be weighed, and the weights to be accumulated over a series of lifts that comprise a truckload. The weighing system works by measuring the hydraulic pressure required for the main lift rams to raise the load. The pressure is

measured by a pressure transducer, interfaced to a microprocessor, which processes the electrical signal to display and record the actual weight of the load.

One system, developed in New Zealand and marketed under the Loadrite brand, successfully implemented a dynamic weighing technique, which for the first time permitted weighing to be carried out while the loader forks were lifting logs onto a truck. This made the Loadrite system practical for high output operations. In 1983, FRI purchased two Loadrite units and evaluated these for forest use. Later, FRI worked with the manufacturers of Loadrite (Actronic Systems Ltd) in optimising its use as a forest based measurement system and taking part in an ongoing development of the product.

Loadrite weighing system in loader cab

The advantages of the forest weighing system are: low cost, higher accuracy than hand scaling, no truck tares and reduced sample scaling. Acceptance of the system was slow because weighbridges were accepted as the accurate standard. Where the weight from the loader-based system disagreed with an inaccurate weighbridge, the loader-based system was considered to be in error. This is understandable when faults in front-end loader systems and in their operation can result in a weighing error. Truck operators in some areas were accustomed to overloading their trucks. Being loaded to the legal limit caused some resistance because of the apparent reduction in profits (Ellis 1989). Loader operators adapted to the new device quickly where they were cooperative, had the correct training and where the loader was not overworked.

Operated correctly, a typical forkload can be weighed within 2.8% of true weight and a truckload (6 forkloads) within 1.1% (Ellis 1986) at 95% confidence interval. At present there are about 200 Loadrite units working in forestry applications in New Zealand. Of these, 15 units are used for weighscaling for sales purposes or payment of logging contractors.

Weight to volume conversion
Underbark volumes are derived from the weight of logs and bark of each truckload by multiplying the weight by a conversion factor. Sample loads, that are used to derive conversion factors, are usually scaled by the three-dimensional formula or sectionally measured. Conversion factors are stratified for each species, forest and/or customer. There are seasonal changes in conversion factor and in radiata pine the difference between summer and winter factors is about 4% (Ellis 1984). Conversion factors are gradually decreasing through time as the average age of the radiata pine stands being logged reduces from 50 to 30 years.

Sample loads are chosen by simple random sampling, stratified random sampling and cluster random sampling (where loads are randomly selected on a random day). Conversion factors are generally applied in three ways:

> **Interim factor** – at the start of the financial year an interim factor is used to estimate all volumes for that year. During the year sampling takes place and at the end of the year an actual conversion is obtained. The difference in volume estimates between interim and actual factors results in a debit or credit to the customer.

> **Rolling factor** – a factor is used for a defined period but is updated continually by including the latest samples and discarding the oldest (Ellis 1979). The usual application of this method is to update a conversion factor each month based on the most recent three-month period.

> **Latest factor** – a fixed conversion factor is used until it is updated from a new data set.

Where a front-end loader based weighing system is used, conversion factors are generally applied using the rolling factor method. Samples are based on forkloads of logs rather than truckloads of logs.

The number of samples from which a conversion factor is derived is calculated to produce a volume estimate within 2-3% (95% confidence interval). This precision can be achieved by both weighbridge and front-end loader based systems. The front-end loader based system reduces sampling by about 60%.

Handscaling
Volume from log end diameters and length
Most sample volumes for conversion factors and volumes for valuable exotic softwoods are derived from a three-dimensional formula (Ellis 1982). This formula comprises two parts: the cylinder based on small-end diameter (ub) and length and the peripheral part outside that cylinder. The formula is as follows:

$$V = \exp(1.944157 * \ln(L) + 0.029931 * d_0 - 0.038675 + 0.884711 * \ln((d_1-d_0)/L)) + 0.078540 * d_0{}^2 * L$$

where
V = log volume (cubic decimetres)
$\exp$ = antilog of natural logarithm
$\ln$ = natural logarithm
L = log length (m)
d_0 = small-end diameter (cm)
d_1 = large-end diameter (cm)
$(d_1-d_0)/L$ = taper (cm/m)
$=$ to the power of

Diameters are measured to the nearest centimetre and lengths to the nearest decimetre. At each log end the shortest diameter through the centre and the diameter at right angles to this are averaged. Volumes are stated in cubic decimetres.

Volume from small-end diameter and length
In log sales where hand scaling is used, the three-dimensional formula is used by measuring small-end diameter and length. Mean taper is calculated from a sample of 100 logs representa-

tive of the stand(s) or logging area being felled. Logs are then measured at the small-end (ub) to the nearest even two centimetre and length to the nearest decimetre. Volumes may be calculated by programmable calculator or derived from look up two-way tables, printed for a range of mean tapers.

Volume from sectional measurements
Sample volumes for conversion factors in Kaingaroa forest are calculated from sectionally measured logs. Each sample truckload of logs is laid out on an area beside each weighbridge. Each log is measured over-bark with caliper at the butt, 2.0m, 4m, 8m and so on to the small-end. At each point bark thickness is measured with Swedish bark gauge. Volume is derived from Smalian's formula applied to each section.

Volume from counts of number of pieces
Logs of small diameter such as pulp material or posts, poles and stays are generally sold by piece count. The average volume of each piece is derived from a sample of pieces measured accurately for volume. The minimum number of pieces sampled is 30 or an equivalent number to provide a confidence interval within less than 10% of the mean piece volume.

Volume of export logs
All of our export logs are scaled by two methods as directed by the log buyers: Japanese Agricultural Standard (JAS) or Japanese Haakon-Dahl (JHD), which is a local adaptation of the Hoppus formula. The JAS formulae calculate volumes in cubic metres based on the shortest small-end diameter rounded down to the nearest even centimetre class and a nominal length in metres. The JAS formula for logs less than 6.0 metres long is the square of the small-end diameter in centimetres, multiplied by the length in metres and divided by ten thousand. For other logs the JAS formula has a taper term comprised of the nominal length minus four centimetres. There is an addition of two centimetres to the shortest diameter for every six centimetres of difference between the shortest and longest diameters in out of round logs. JAS tends to underestimate the volume of short logs and overestimate the long logs.

The JHD formula calculates the log contents in Hoppus superficial feet. The shortest small-end diameter through the centre and the diameter at right angles to this are averaged. Diameters are rounded down to the nearest half inch class and the nominal length is in feet. Because the Hoppus measure is based on mid-girth the JHD derivative has a built-in taper adjustment so that the Hoppus formula can be based on small-end diameter. The taper adjustment (negotiated in the 1950s) is about half the actual taper in radiata pine. Thus, on average, JHD underestimates the true cubic content of logs by more than 10%.
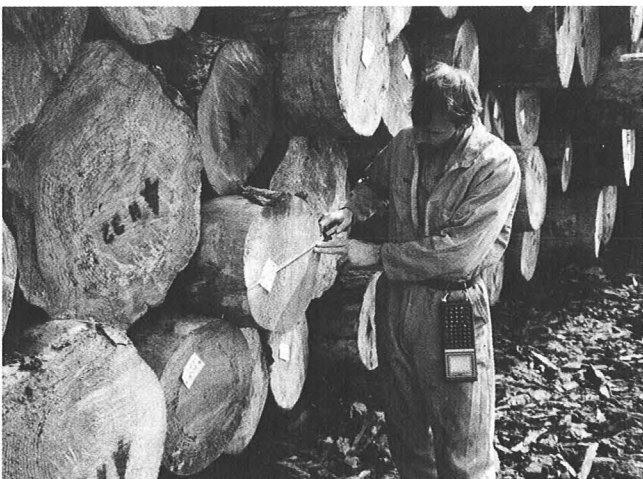

Log scaling with CMT MC-V

Developments
Portable data recorders
Log scaling programs are available for the Husky Hunter computer which is becoming increasingly popular in scaling sample loads for conversion factors. Data entry and checking is performed on the job and a conversion factor (m³/tonne) may be verified in the field. After some initial applications on the Husky using the BASIC interpreter, programs are now compiled using Turbo Pascal. This meant that one language could be used for both CP/M and MSDOS and the Husky operator was sure of rapid response times. Control of the applications is through menus because operators rarely consult user manuals after initial training (Gordon 1993). Husky computer programs for calculating individual log volumes from a variety of methods are also available on IBM compatible personal computers.
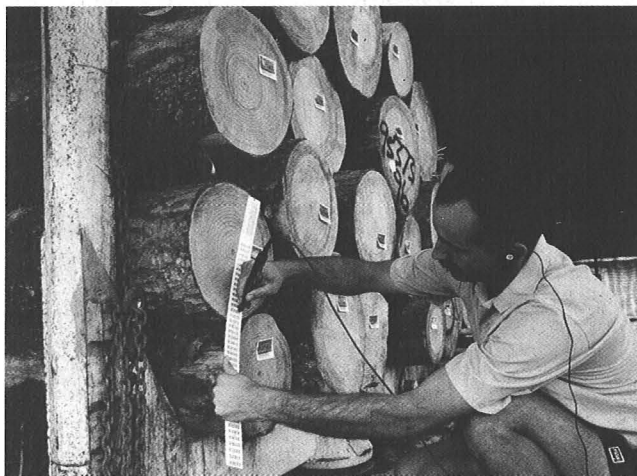
Export scaling with bar-coded ruler and wand

Export scaling operations have been slow in implementing portable data recorders, probably because of the increases in workload at the present time. However, Owen's Services in Mt Maunganui are using a locally designed barcode system for some of their work. The usual Toledo steel rule is replaced by a rule marked in barcode diameter classes which are read directly into an Allan Bradley 2755T3 recorder. Data are then downloaded into an IBM compatible PC.

Grapple-loader based weighing systems
In areas with soft ground conditions, steep topography or limited stockpile space, the rubber-tyred front-end loader is being increasingly replaced by the excavator type knuckleboom loader. Currently there are no suitable weighing devices, for the knuckleboom-type loader with a rotating grapple, available for purchase in this country.

A working group comprising Actronic Systems Ltd and the Forest Research Institute is developing a loadcell for knuckleboom loaders. The loadcell is to be positioned in place of the link between the rotating head of the grapple and the loader boom. The link ensures that the grapple load of logs is held in a verticle plane for most of the time but difficulties arise from the environment, which is harsh enough to damage purpose-made grapple heads and attachments. Accordingly, the loadcell had to be designed to withstand a range of large dynamic and shock loads, while still measuring a relatively small static component which represents the weight of grapple and logs.

In 1989 a prototype cell was tested and at present a pre-production cell (including software) is being finalised. If successful, this new cell should increase the capacity for accurate weighing in the forest and permit the continued improvement in measurement methods.

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 further 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.

Prototype loadcell on knuckleboom loader

References

Besley L. 1966: Importance, variation and measurement of wood density and moisture. Pulp and Paper Res. Inst. Canada. Technical report No. 489.

Ellis J.C., 1979: Weighscaling of radiata pine logs from Riverhead Forest in Auckland Conservancy. FRI Symposium No. 20.

Ellis J.C., 1982: A three-dimensional formula for coniferous log volumes in New Zealand. New Zealand Forest Service, FRI Bulletin No. 20.

Ellis J.C., 1984: Weight/volume conversion factors for logs. Logging Industry Research Association Technical Release 6(3).

Ellis J.C. 1986: The Loadrite – two years on. Forest Industries 17(9):36-38 (Reprint 1943).

Ellis J.C., 1988: Procedures for the measurement of roundwood. Ministry of Forestry, Forest Research Institute, Rotorua, New Zealand.

Ellis J.C., 1989: Loadrite stops overloads. Forest Industries 20(3):22-23 (Reprint 2169).

Gordon A.D., 1993: Use of portable data recorders in New Zealand forest management. Australian Forestry, Vol. 54, No. 4.

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 Viphya 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; Viphya Forest; Malawi; Africa.

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

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