# THE USE OF ELECTRONIC COMPUTERS AS A TOOL OF FOREST MANAGEMENT

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## *SYNOPSIS*

*Processing of forest inventory data by electronic digital computer is essential if foresters want to use inventory data as a sound basis for the development, management and most profitable utilization of their forests. It is shown that, in order to realize the full potential of ED computers, some field practices should be modified in addition to a simple transfer of computational load. Only when many forest variables are examined simultaneously on computer can advances be made in rationalizing forest management.*

This paper aims at providing field foresters with some background of the utility of electronic digital computers in processing exotic forest inventory data and in assisting with decision-making for forest management. The content is as non-technical as possible and is orientated towards an understanding of the benefits to be gained by and the reasons for modifying present field practices to make optimum use of a computer facility. Examples of the utility and versatility of computers are given, and suggestions are made as to how they may be used with greater profit to the industry.

Many foresters remain unconvinced of the assistance computers can give in analysing tedious routine calculations, ostensibly because of their past unhappy associations with the frustrating delays that often accompany the processing of large amounts of data. Such unfortunate experience, however, should not be used to minimize the reasonableness of exploiting the opportunities which computers offer in this field, but to emphasize that a thoroughly well-founded system is needed to ensure speedy processing of inventory data. It is very true that the value of an inventory declines sharply the longer the data remain unprocessed, but when an EDC system is properly organized, computers do achieve very fast turn-rounds.

Plantation forestry is a business; it is a means of either earning money or saving imports by capital investments in growing tree crops. Nowadays, more than ever before, there is an onus upon forest managers to operate their business efficiently. To do so, they must have, among other things, more reliable, more detailed and more realistic information about their tree crops than they had in the past. It is now insufficient to have approximations of present and future total stem volume in the forest; it is imperative that foresters quantify particular aspects of their resource in order to rationalize the utilization of their produce in existing and in potential industries. For example, it may be necessary

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to estimate the number of available clear boards of various lengths, breadths and thicknesses, or the amount of suitable peeler logs, or the frequency and size of knots over the range of saw log material, or the quantity of posts of different sizes that could come out in an early thinning, and so on.

Two considerations clearly emerge: firstly, foresters cannot rely upon national or regional tables to provide this type of information; and, secondly, they are faced with an ever-increasing burden of more and more detailed inventories. Oconsequently, the prospect of many more hours working on desk calculators should encourage foresters to welcome a suitable alternative to escape what is to them unprofitable drudgery.

Processing of inventory data by computer allows foresters and their assistants to allocate more time for data collection in the field and frees them from the desk calculator. There is, however, much more to this transfer than is commonly believed. It is proposed to discuss this in general terms at first and then to consider specific examples in a little more detail.

*The General Situation*

It is possible to cite many examples of forest inventory in New Zealand where some of the information collected, because of limitations in the available means of calculating results, may not have been used to best advantage; some more, because of the further deficiency in human capabilities, may have been used improperly and much, because of lack of forethought, may not have been used at all. Processing by computer can, if so designed, overcome all these inefficiencies. Firstly, data can be manipulated by computer without the forester having to worry about the complexity or tedium of calculation; secondly, once the coded instructions on how to manipulate the data (called a computer program) have been written and tested, the results derived from any given input are always free of errors; and thirdly, there is no point in (and possibly no means of) recording data that cannot be utilized in the program.

For foresters contemplating processing by computer, there are, of course, prerequisites other than conforming within the general framework of the method of inventory, prerequisites which should be considered essential even when contemplating manual computing, but the formulation of which is often delayed unduly. They are:

(1) Exact knowledge of what information is required and how to assess it;

(2) Rigorous consistency in recording data in the field;

(3) Exact specification of the results needed and the means for deriving them.

If computer processing does nothing else than enforce these three prerequisites and release foresters from desk calculating, it will have made a valuable contribution to raising the standard of forest inventory. But it can make more, equally important improvements if some established field procedures are discarded and others are modified. Present inventory practices are often geared to economy of effort in subsequent handling of data on desk calculators. By retaining them, the most appropriate form of inventory may not be used and the full benefits of electronic data processing not realized.

*Measurement of Tree Volume*

No matter how elaborate manipulation of data becomes, the utility of estimates of volume per acre depends ultimately on the representativeness of tree volume functions. Nobody has yet derived a way of directly measuring volumes of standing trees. Thus, for a given population, volumes are usually obtained from known relationships between more easily defined characters such as diameter at breast height and volumes of a sample of trees calculated from diameter measurements along the stem. The conventional method of sectional measurement aims at simplifying subsequent manual calculation rather than adequately assessing tree volume. Thus, diameter measurements are usually made at fixed or percentage distances along the stem so that much of the computation is facilitated by having only one length of section. It is, however, much more important to regulate the drop in diameter, so that errors in the basic assumptions regarding stem shape are minimized and interpolation of taper is given more meaning. This theme has been very fully developed by Grosenbaugh (1954, 1966). It is immaterial to the computer, of course, that the steps in both diameter and length are irregular, but this does have a considerable impact on the adequacy of volume calculation. Obviously, if a sudden reduction in diameter occurs in the middle of a fixed sectional length, neither the volume of the frustrum nor its mean taper is well described without additional measurements. Suppose, for example, that a ten-foot length of section has diameters of 20, 19.5, 17.5 and 17 in. at 0, 2.5, 3.5 and 10 ft along its length. By using Smalian's formula on the two end diameters, the volume is made to be $\dfrac{2.182 + 1.576}{2} \times 10 =$ 18.79 cu. ft; but by using (for simplicity only) Smalian's formula again, but on three subcomponents of the frustrum, the volume is made to be

$$\frac{2.182 + 2.074}{2} \times 2.5 + \frac{2.074 + 1.670}{2} \times 1.0 + \frac{1.670 + 1.576}{2} \times 6.5$$

or 17.74 cu. ft. The difference of 1.05 cu. ft is 5.9% of the latter estimate, and will be consistently positive in these circumstances, which are not at all uncommon. Grosenbaugh has shown, furthermore, that not only is the estimate of volume improved by stepping the diameters regularly and using formulae more elaborate than Smalian's, but also taper can be easily and more informatively derived. This further important consideration will be discussed later.

The derivation of a representative estimate of tree volume is the first ingredient of a good tree volume function; the second is the development of an appropriate prediction model for all trees in the population being sampled. As this is more the concern of the research than of the field forester, it is perhaps sufficient to say here that the use of computers in developing prediction models has enormously improved precision in estimating volume.

*Inventories of a Special Nature*

Foresters are becoming increasingly aware that their calculations of tree volume, both individual and aggregate, must derive from accurate data and be reliable within economically acceptable limits. This good intention, however, may be easily mishandled or sources of error overlooked. For example, Beekhuis (1966) has demonstrated the excellent potential of the relationship between volume per square foot of basal area and mean stand height. His results were based on many data and applied eventually to national averages. The misapplication of this technique in a particular situation can be dangerous and errors of estimate can be misleading, because:

(1) No account is taken of the instrument and operator bias and the errors of volume calculation built into the tree volume functions used.

(2) No account is taken of the representativeness of the sample in defining the population to which the tree volume function pertains.

(3) No account is taken of the precision of the model on which the tree volume function is based.

(4) No consideration is taken of the adequacy of the tree volume function used for the population now under review.

These are examples of hidden errors, and there are more. They could all be included, if definable, in a computer solution. It is better, however, to contemplate an entirely new concept, when very refined estimates are needed.

Foresters in New Zealand have largely ignored the tremendous potential of multi-stage sampling in assisting with mensurational problems. One of the simplest and perhaps most potent examples of such a technique is the volume-basal area line; by relating the volumes of a few sample trees to their basal areas derived from sectional measurements like those just described, by an equation of certain statistical properties (called a regression), the volumes of any tree and its precision may be estimated merely from a measure of its diameter at breast height. If all diameters in a certain number of plots of known size are measured, mean volume per acre (and its error) is easily derived. This is called "double sampling with regression" and can yield excellent results with relatively little effort. If the same procedure be repeated over and over again in different situations, however, the availability of a computer and standard computer program to handle the hard calculation would effect a great saving of effort.

Consider a slightly more complicated extension of this same technique. In order to assess the current growth rate of a stand, some of which is substantially infected with *Dothistroma pini*, three stampling stages could be profitably used: firstly, a broad delineation of areas of different average disease rating is made subjectively; secondly, objective measures of mean size, mean disease rating and their variability are made within each stratum; and thirdly, measures of actual increment are related by regression to size and disease rating of individual trees. Then volume increment per acre can be built up from information in the third stage, up through the second to the first and final stage. This system is probably too complex for field foresters to tackle by manual calculation, but its solution is relatively simple by computer and very well worth while obtaining for management information.

The derivation of merchantable volume of a stand is another problem which would benefit from multi-stage sampling. Firstly, frequency distribution per acre of stems of different sizes and broad categories of defect are determined; secondly, a total stem volume is allocated to all trees; and thirdly, deductions for all classes of trees are made on the basis of realistic taper studies, like those indicated in the section "Measurement of Tree Volume". The solution of this problem, where the characteristics vary in many dimensions simultaneously, is practicable only on computers, because it is necessary to compute the analysis not on the outmoded concept of the mean tree, but on the aggregate of stem frequency of various classes per acre.

### *Development of Increment Functions*

A knowledge of growth of the forest is very valuable to the forester. Many workers have developed growth functions without computers, but, with such facilities, a considerable enrichment of feasible solutions becomes available. Traditionally, growth has been measured in plots of known area, trends of total or net production on age constructed (usually graphically) and estimates for a specific crop derived from the most appropriate trend. This method is insufficiently accurate for present day needs. For example, consider a 17-year-old crop of *Pinus radiata* of which the standing volume per acre is 5,000 cu. ft per acre and the CAI is very well described on an individual tree basis by the equation

$$Y = -0.69211731 + 0.06705179X_1 + 0.04715750X_2$$

where $Y$ = current annual increment of volume

$X_1$ = present volume

$X_2$ = present length of green crown

If the stand were composed of 250 trees each of 20 cu. ft and with a green crown length of 30 ft, the CAI would be estimated to be 515 cu. ft per acre. If, on the other hand, the stand were composed of 200 trees each of 25 cu. ft and with a green crown length of 40 ft, the CAI would be estimated to be 574 cu. ft. The difference amounts to 59 cu.ft, which is 11.5% of the figure for the first stand distribution. The difference would be successively compounded in each single year of the period under review. Only by using increment functions more complex than the conventional ones and those not based on stand averages can projection be improved. This of course demands use of a computer.

*Permutation of Data*

One of the most powerful attributes of an electronic computer is its ability to rearrange data of many dimensions with great speed. Whereas the process of manually calculating volume per acre and its precision for all crops aged 30, 31 and 32 in cutting sections 1 and 2 and then recalculating the same for each age and cutting section separately is tedious, the answers can be very quickly effected by computer, once the basic data have been assimilated. In the recently published manual of exotic forest inventory (Lees, 1967) permutations for a range in each of seven categories, species, age, compartment, management unit, site, thinned or unthinned and pruned or unpruned, can be accumulated. This provides forest managers with a very useful means of improving their knowledge of the capacity of the forest.

Data permutation can also be used effectively to stratify raw inventory information in the computer. Well-designed stratification of a variable population economizes the effort needed and enhances its results in deriving a mean value for a given level of precision by subdividing the whole unit into easily recognized parts of less variability — without necessarily having a high degree of correlation between site and growth. Where the best means of stratification is not evident before making the inventory, it may be an advantage to cater for several possible objective criteria, stratify with all combinations of the criteria, and then select the best result.

*Decision-making in Forest Management*

Decision-making in forest management without access to computers is mostly an art; with computers it becomes more of a science. Foresters must often make a choice of management practice from very many possibilities without really knowing beforehand, or afterwards, which would have been best. With computers, it is feasible to simulate the effects of various decisions by trial and error with mathematical models and then weigh up the consequential advantages and disadvantages of each solution on paper. The most profitable one can then be selected.

In forest management there are so many variables acting simultaneously that it is preferable to work with realistic data rather than a range of artificial values if much unnecessary work is to be avoided. Thus, the simulation process should be generated from actual inventory data which must be readily on hand. Computers with certain facilities are able to store many programs and large amounts of data, any section of which can be implemented within a very short time. If programmes for the inventory procedures examined briefly here, for inventories of more general content and information such as the effects of silviculture on outturn of produce, work studies, costing studies, mill conversion factors, marketing trends and many more topics were all stored and made readily accessible, rationalized forest management could become a viable and attractive reality.

## CONCLUSIONS

These examples are but a few of the many benefits computer processing offers. Because New Zealand foresters are only now beginning to make use of computers and indeed of methods of inventory suited to computer processing, it is only reasonable to expect that many field foresters are suspicious of and actually resist change, particularly when initial efforts are subject to lengthy delays. These delays do occur during the transition stage, but foresters will help to shorten it if they adopt willingly new techniques such as have been discussed here. This paper shows that the use of computers will improve both the quantity and quality of information which may become available and thus achieve that better knowledge of forest capacity which is essential to economic management.


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