Forest Estate Modelling (Part 2) *

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The Problem

Given adequate models of growth and yield, and data on costs and prices, it is not too difficult to find "optimal" silvicultural regimes and rotation ages on an individual stand basis. A rigid application of these prescriptions to a forest, however, may produce unacceptable results. The annual production would vary, following a curve resembling the age distribution for the stands in the forest. Similar fluctuations would appear in the revenues, and in the labour, equipment, and finance requirements for harvesting and slivicultural operations.

Except possibly for a small producer contracting-out all forest work and operating in a near perfect market, the strict application of regimes derived on an individual stand basis will generally be far from optimal. A major reason is that the costs and revenues, assumed to be constant in the single stand analysis, are actually affected by the scale of production. There are costs associated with the expansion of production/processing capacity, and with the maintenance of unused capacity. In addition, there may be constraints arising from contractual commitments, etc.

There is a need then, for tools that can assist in planning the management of aggregates of forest stands. These aggregates, or "forest estates", can be individual forests, groups of forests, regions, or whole countries. We consider here only even-aged forests, and focus on general-purpose modelling tools used in New Zealand.

The Classical Approach

It we had a homogeneous forest with equal areas in each age class up to the optimal rotation age, the optimal management derived from a stand-level analysis would also be optimal at the forest level. In addition, there would be an even annual flow of production, costs, and revenues.

Traditionally it was considered the job of the forester to aim for this simple and satisfying state of affairs, the achievement of a "normal forest". The steady-state characteristics of the normal forest were intensively studied, including ways of handling the complications associated with the presence of various crop types with differing growth rates. Knowledge about how to transform an arbitrary non-normal forest to the target normal forest is less satisfactory, however. A number of more or less *ad-hoc* forest regulation formulae and procedures, often having little or no economic justification, have been developed for this purpose.

Some remarkable examples of near-normal forests, attained after centuries of continued forest management, exist in Europe. Some countries still base their forest management on the concepts of the normal forest and on traditional forest regulation

*In: Levak, H. (Ed.) *1986 Forestry Handbook*, pp. 97–99. New Zealand Institute of Foresters (Inc.), Wellington. 1986.

formulae. Under New Zealand conditions, however, these methods are inadequate. Apart from the questionable desirability and/or feasibility of a steady-state situation, most forest estates will be far from normality at least for many decades. Planning for the efficient management of forests with the kinds of age and crop type distributions that now exist is essential.

1 Simulation Models

Simulation has long been used by foresters to answer "what if" questions about the effects of forest management. Essentially it consists of building a simplified abstract representation of the forest (a model), e.g., by a set of tables and rules, and using this to predict the consequences of different management alternatives. The ready availability of computers has reduced the work involved in carrying out these simulations, and so made it possible to analyse many more alternatives at a much higher level of detail.

There are 2 simulation systems in general use in New Zealand for long-term forest management planning: RMS80/RMS85 (Allison *et al.* 1979, Allison 1980, 1985), and IFS (Garcia 1981). Both simulators, in common with older non-computerised procedures, use a similar conceptual model of a forest estate. This model can be understood, in general terms, by reference to Figure 1.

The forest is described by a classification of areas into "crop types" and age classes. Stands are grouped into crop types according to growth, silvicultural regimes, harvesting methods, location, ownership, or other characteristics, as appropriate to the planning exercise. Events are recorded for time intervals ("periods") of length equal to the number of years in an age class.

Figure 1 illustrates the model for 1 crop type with 5-year age classes. The state of the forest at the beginning of a 5-year period is described by the area in each crop type and age class. During the period some of the area in each class may be cut, and the remaining area moves into the next age class at the beginning of the next period. The harvested areas may be replanted immediately into the same or different crop types, or left unplanted.

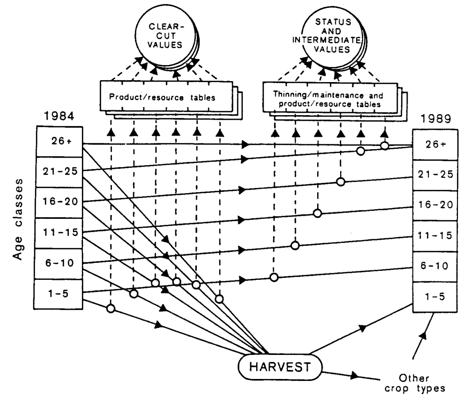

Figure 1: Conceptual model of forest estates

The areas cut from each class are multiplied by the appropriate entries in harvest product/resource tables, to compute volumes produced, or resources required or generated in the period. The residual areas may be multiplied by entries in the same produc/resource tables to asses the growing stock, and by entries in another set of tables to account for intermediate products/resources such as thinning yields and silvicultural costs. It is also possible to transfer areas between crop types; this is useful for modelling alternative silvicultural regimes or changes of ownership.

In using these simulators, the user specifies (or accepts defaults for) the actions to be taken in each period. Decisions include the areas to be harvested from each crop type and age class, areas which will be replanted, and areas to be transferred across crop types. There are various alternative ways of specifying these actions. For example, the user may just give the total volume to be produced in the period, and the program automatically distributes the necessary cut among crop types and age classes according to predetermined rules. A number of different reports can be produced to describe the results of applying a particular management strategy.

RMSBO was developed by NZ Forest Products Limited, and has been used mainly by the largest private companies (NZ Forest Products and Tasman Forestry), and by the School of Forestry of the University of Canterbury. It operates in batch mode and is written in Fortran. A distinctive feature is the computation of a number of "forest mass" measures developed by Allison (1978). These measures indicate similarity of the current state of the forest to a normal forest; they have been found useful in communicating with top management, and for some valuation and yield control and analysis purposes.

IFS, developed at the Forest Research Institute, has been largely used by the New Zealand Forest Service and by some smaller forestry organisations and forestry consultants. It is primarily an interactive system, although it can also be used in a batch mode. Versions in several Basic dialects are available for ICL and VAX mainframes and for a number of microcomputers.

Optimisation Models

Simulation uses trial-and-error to search for an acceptable management strategy. Only a limited number of possible altenatives can be tried, and in many instances much superior solutions may be overlooked. Given a clear statement of objectives and constraints, optimisation techniques can be used to find a "best" solution. It must be recognised, however, that the objectives and constraints used in optimisation models are often gross oversimplifications, and many relevant factors that are difficult to quantity are ignored. Also, currently available optimisation methods are not suitable for handling as high a level of detail as the simulators.

By far the most commonly used optimisation technique for long-term forestry planning is linear programming (LP). Several applications of LP have been carried out in New Zealand. Some of them were developed by operational research experts in collaboration with management for modelling a specific situation (e.g., White and Baird 1983). Two general-purpose LP-based systems for use by forest managers are CPLAN (Shirley 1979) and FOLPI (Garcia 1984).

CPLAN, like most LP forest management systems, follows the so-called Model I formulation (see, for example, Clutter *et al.* 1983). Individual stands are grouped into "cutting units", which correspond approximately to age classes within crop types. For each cutting unit. a number of management alternatives are nominated. These alternatives specify the management of stands over the whole planning period, and should cover all the reasonable combinations of silvicultural treatments and successive harvesting ages. The flows of the relevant products, resources, costs, and revenues for each management alternative must be provided. The manager specifies an "objective function" or end result to be maximised or minimised, for example, present net value, and a series of constraints on the flow of products and/or resources. CPLAN then generates the best over-all management strategy by determining how much of each cutting unit should be treated according to each management alternative. Solution of the model may be followed by post-optimal analysis, where the effects of changes in constraints, alternatives, and resource flows are investigated.

FOLPI does not use the Model I formulation. Instead, it is based on a model of the forest identical to that used by the simulators described above.

Given an objective function and a set of constraints, LP is used to calculate for each period the areas to be cut from each crop type and age class, the areas and destination crops for replanting, and any transfers of area across crop types. The same input data files are used by IFS and FOLPI, and reports identical to those produced by IFS can be generated interactively. Objectives and constraints are specified in a form that does not require any detailed knowledge of LP.

Conclusions

In forest management it is usually not sufficient to analyse silvicultural alternatives for individual stands. In most instances, the interactions over time between stands within forests, regions, and countries are paramount.

Several simulation and optimisation forest estate models are available in New Zealand. Often the use of a simulation model by itself will give satisfactory results. In other situations best results would be obtained by applying first an LP-based system, and then using a simulator to explore the effect of deviations from the "optimal" solution.

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