# *PART 4*

# *RESOURCE AND MARKET CONSTRAINTS*

# EVALUATING THE ROLE OF THINNING IN DEVELOPMENT FORESTRY

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ABSTRACT

The problems encountered in evaluating the role of thinning are displayed by considering a simple General Development Model for the creation of new forest industries and their associated plantations. Thinning is seen as having important effects on meeting objectives. The current position in developing models to aid decisions is explored by reviewing models used at the stand, plantation and national levels in Australia and New Zealand.

## INTRODUCTION

This paper is set in the context of the extensive plantation schemes based on fast-growing species that are being undertaken in regions throughout the world to start new industries. These plantation-industrial projects make important contributions to such national objectives as increasing economic growth rate, stimulating other sectors, replacing imports or providing employment. Such issues are commonly studied under the mantle of development economics. The creation and management of these new plantation projects causes new problems to be posed in silviculture, harvesting, management and economics and warrants their designation as a new branch of forestry "development forestry". Development forestry can be regarded as the application of the themes of development economics.

In development forestry we are primarily concerned with the dynamics of economic growth, with the *rate* of expansion of the overall enterprise. This is in marked contrast to the traditional concept of "sustention forestry" which is concerned with achieving and continuing the conservation ideal of a steady balance between man and nature. In development forestry we are concerned with supplying the increasing demands of increasing populations using the powerful opportunities offered by intensive management, by fertilisation, by tree breeding and by better utilisation. We are concerned with achieving the maximum rate of economic growth possible from the resources at our disposal.

To see the role of thinnings in development forestry a general development model of the expansion of a plantation-industrial project is needed and this paper describes

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a simple example. Complex interactions exist between market growth, industrial expansion, plantation expansion and the policies for clearfelling and thinning. The problem of finding the best thinning policy for industrial plantations is therefore both difficult and important. It has received intense study particularly in Australia and New Zealand which contain some of the older plantation schemes. This paper reviews many of the computer models that have been developed to help solve the problem. Because of the size of the total problem, present work has generally modelled only components of the overall system. Many of these have been studied with great sophistication and a substantial body of methods developed. Less attention has been paid to methods by which the components can be linked into overall plantation planning. There has been virtually no development of methods or systems for the integration of plantation and industrial planning. The challenge for the future is to develop structures that would enable the component models to be brought together in a way that would assist a rational approach to developing the total plantation-industrial system.

### *General Development Model*

In the simplest form, we can consider the creation of a plantation-industrial enterprise in a new region. A demand is forecast, plans are made, land is acquired, planting commences and after an appreciable "lead" time a new mill is built to sell particleboard, sawn timber, pulp, paper or whatever on the market. Planting continues and the industry expands and diversifies.

Forecasts of future consumption typically show a gradual increase due to increasing population and *per capita* consumption. Planting is often started at a modest annual rate and expanded as techniques, organisation and market forecasts improve. The yield arising from conventional thinning and felling regimes consequently shows a gradual increase. Modern industrial plants come in large expensive units which need to be used near to capacity from the start and whereas demand and resources increase gradually, manufacturing capacity must be increased stepwise. Thus demands, resources and capacity rarely match each other as can be seen in Fig. 1. The market-industry-plantation system can have three possible states depending on whether the dominant constraint on further expansion is the market, the wood resource or industrial capacity.

Each of the three constraints can be manipulated by management. The plantation manager can vary either thinning practice or clearfelling age and usually both to alter his production schedule. The industrial developer can choose the size and timing of expansion steps and the market can be manipulated through price and quality. Determining each of these manipulations is difficult but the task of determining the combination of manipulations that will produce the best contribution to national goals is daunting. The problems are further complicated as the system operates with considerable uncertainty and can never be exactly tailored. Many things can vary such as markets, market forecasts, the availability of enterprise and capital for construction, as well as yield forecasts and the actual success in establishing and preserving the plantations.

### *The Role of Thinning*

The general development model can now be used to demonstrate the varying roles of thinning by considering the different states of the plantation-industrial system:

| State of System Constraints | | | Effects on Role of Thinning |
|---|---|---|---|
| **Markets** | **Capacity** | **Resources** | |
| **LIMITING** | Adequate | Adequate | Wood prices low. Difficult to sell higher cost thinnings. |
| Adequate | **LIMITING** | Adequate | Substantial premiums for good quality and sizes. Difficult to sell small material which may be thinned to waste. Thinning from above considered. |
| Limiting or Adequate | Limiting or Adequate | **SURPLUS** | Wood prices low. Difficult to sell thinnings at all. |
| Adequate | Adequate | **LIMITING** | Wood prices high. Thinning essential to expansion. |

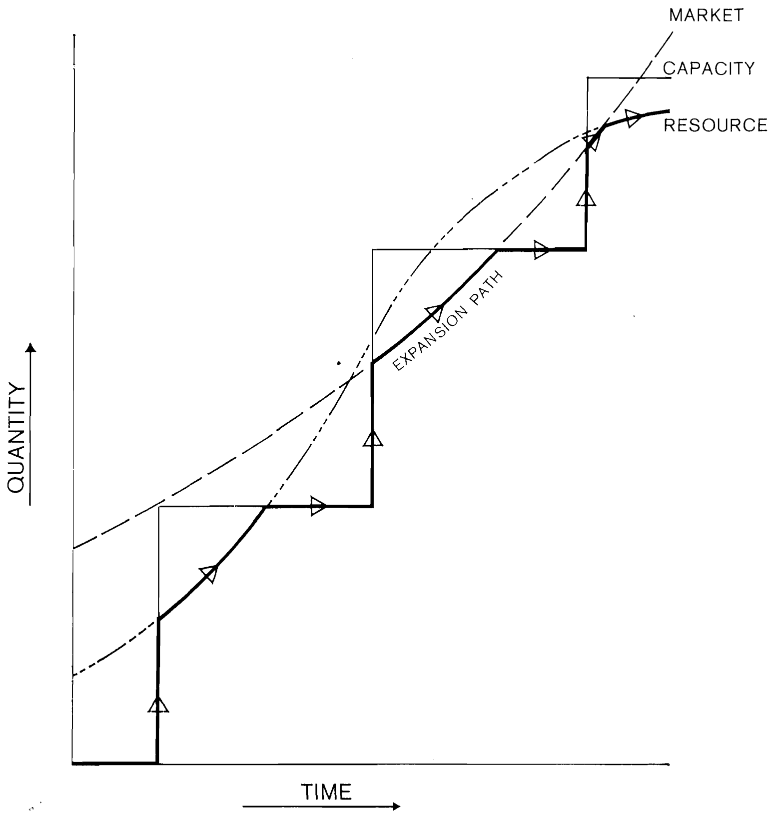


FIG. 1—Expansion of the Plantation-Industrial system.

*Market Constrained State*

When the expansion of the system is constrained by the limited markets available then one expects that prices will be depressed. Industry will consequently be less able and willing to pay the additional cost for wood produced from thinning operations and will press for cheaper wood from clear felling.

The problem of managing industrial plantations with limited markets was severe in regions which used the planting of great areas of *Pinus radiata* as relief work for the unemployed during the depression of the 1930s.

The extensive areas in South Australia and other Australian states and the quite enormous plantations in New Zealand became available as a wood resource long before there were either markets or industrial capacity to absorb their potential production. Thinning was either not possible or was badly delayed and great volumes died by suppression and insect attack. Log quality was often poor as dry knots were prevalent in the timber.

Industrial and market capacities eventually increased and substantial logging commenced. However, it is difficult to commence thinning in *Pinus radiata* stands at an advanced age as the stands become unstable. Clearfelling was needed to create a more balanced distribution of age classes. With a surplus of large old wood from clearfellings, thinnings from the young plantations were particularly unattractive to industry. The New Zealand solution has been to go to regimes with early unmerchantable thinnings and pruning. In South Australia industry's capacity to absorb thinnings was directed to ensuring that the younger stands were brought up closely to schedule at the expense of trying to rehabilitate older stands with delayed thinning operations.

*Capacity Constrained State*

When the expansion of the system is constrained by limited capacity, management must seek to alter the wood input to increase the mill throughput. Typical requirements on the forest are:

- Sawmills — increase average log diameter, increase recovery,
- Chippers — log size very markedly affects productivity of some chippers and for these a controlled range is necessary,
- Pulpmills — increase proportion of wood with high pulp yields per volume of wood, low cooking liquor requirement or longer fibre length.

In a capacity dominated state, there are substantial economic benefits for marginal changes of this nature.

Thinning policy can substantially affect mill input and has very significant effects in the capacity dominated state.

Thinning from above will produce large logs in the present at the expense of the future. A common management dilemma is that whereas in the short term it is usually undesirable to manufacture from large quantities of small young wood, it is these very early thinnings that enable the desirable large sizes to be produced as early as possible in the development of the project. An alternative is to thin to waste as in some New Zealand regimes.

*Resource Constrained State*

Management has several opportunities for increasing the expansion of the system when it appears to be constrained by wood resources and substantial economic benefits are available to make adjustments.

The obvious action of increasing the planting rate only has an effect when the additional areas come into production in 5, 10, 15 years. In development forestry we are very concerned with what can be done to shorten the "lead" time between perceiving the need and achieving an expansion.

Increasing the proportion of the existing trees that is utilised has immediate effects while fertilisation of older stands may enable yield to be increased fairly quickly. However, if these are insufficient, the only way of expanding is to cut more trees down.

The newly developing project has plantations which are almost certainly below the age of maximum M.A.I. Thus clearfelling the oldest stands reduces the productivity of the enterprise. Thinning however enables immediate yields to be obtained while retaining existing stands in production.

The intensity of thinning controls the time and quantity of yields available; light thinning giving early yields with little loss of subsequent increment, heavy thinning giving greater early yields at the expense of some subsequent increment.

An intensive thinning programme early in the life of the project has some important effects:

1. By being thinned early, the stand produces large size trees very quickly and this enables diversification into plywood or sawing to be considered earlier than would otherwise be the case. The whole process of development is hastened.
2. The form and quality of the remaining trees is affected; green level of crowns is kept low and branches are alive. This results in green knots as opposed to dry but also in larger knots and poorer tree form. Pruning may be needed to correct this.
3. The absolute increment of the stand is slightly depressed but the standing volume is substantially reduced. The increment when expressed as a percentage of the standing volume is greatly increased. In development forestry, the physical objectives may be expressed as to maximise increment percent as opposed to maximising increment or total volume production itself. This has a close parallel in micro-economics where one would select the maximisation of the Rate of Return on investments as the correct criterion for the evaluation of capital investment opportunities for a newly developing enterprise whereas the maximisation of Net Present Value would be preferred for older established industries.
4. Several risks to the plantation may be lowered. The stands are more windfirm and general hygiene is improved. In the event of loss of an area the salvage of a well thinned stand is more easily arranged and for a given area the volume to be salvaged is less.

### *Decision Models*

Having demonstrated the nature of the problems facing the development of the plantation-industrial system, this paper reviews some of the salient models that are being used to aid their resolution. Emphasis is given to Australasian models with which the author is familiar. This is not to ignore the wealth of experience and literature about models used in Europe and Northern America but is designed to show the extent to which modern methods can be harnessed to development forestry problems.

The decision process exists at national, project, plantation and stand levels. The overall problem is so large that it must be broken down and this is reflected in economic and political organisation. These divisions which permit solution can become formalised as institutional barriers preventing optimisation. In Australia, for example, overall planning is very difficult in the face of the divisions between Commonwealth and State Governments and between the State Governments which mostly control the plantations and industry which is almost exclusively private.

In Australasia it has been found that considerable effort over a long period is required for the preparation of sound data to use for forest planning. The development of systematic approaches to this task has been described in both Australia and New Zealand (Dargavel, 1975; Allison and Barnes, 1964; Twitchin, 1970).

### *Stand Models*

Models to simulate the growth of the stand and effects of alternative thinning treatments are basic to any real consideration of the thinning problems. They are difficult to construct because the growth and response functions require data from long-term thinning experiments which are expensive to collect and difficult to analyse.

Most of the models mentioned enable stand economics to be evaluated and log assortments predicted.

Beekhuis (1966) working with *Pinus radiata* in New Zealand and Crowe (1967) working with *Pinus patula* in South Africa, have developed models which estimate stand characteristics for various thinning regimes. Both models bring together fairly simple biometric functions, some prepared by graphical analysis. A stand simulation is made by following through a nominated calculation procedure by hand.

In Australia, stand models programmed for computer execution have been made in most States. The models consist of growth and response functions assembled together. The functions are generally fairly simple and have mostly been developed by linear regression analysis of experimental data. The models contain some functions or elements estimated by quite ad hoc approaches. For *Pinus radiata,* Hall (1974) developed a model which enabled the effects of alternative prescriptions "from above", "from below", etc. to be evaluated in addition to frequency × intensity interactions. Stark (1974) working mainly with *Pinus elliottii* and *Auracaria cunninghamii* in Queensland developed an elaborate model which gave special consideration to thinning prescriptions designed to favour the production of veneer logs. In Victoria the growth of even-aged stands of natural regrowth of *Eucalyptus regnans* has been analysed intensively using data from long-term growth and thinning experiments (Opie, 1972). The estimation of natural mortality was an important component. The resultant functions were assembled into a model to simulate the growth of this species under various spacing and thinning regimes.

Clutter (1963) has for many years emphasised the need for stand models to be constructed from sets of functions which are mutually compatible. These requirements and very advanced biometric analyses involving non-linear estimation have been used in a model constructed recently for *Pinus radiata* in the plantations of N.Z. Forest Products Ltd (Clutter and Allison, 1974).

Generally stand models are available for the major plantations in Australasia although considerable work is in progress to refine and improve them.

*Plantation Models*

The central plantation management decisions are the determination of the schedules for planting, thinning and clearfelling. Modelling these decisions requires:

| | |
|---|---|
| — Stand data | the assembly of data about the area and condition of the various present and future stands |
| — Stand models | forecasts of the future yields from each stand according to one or more alternative thinning and felling regimes |
| — Decision process | A process for combining the alternative yields forecast from the various stands into a set feasible for the plantation as a whole. |

The development of models has followed a path of increasing the realism and hence complexity with which each of these phases is considered.

*Yield Table Extension*

Early practice was limited to extending the area of each age class by yields from a standard yield table representing the average site quality for the region. The term "allowable cut" borrowed from sustention forestry was applied to the resultant projection and industry encouraged to develop up to this limit. Refinements for differences in site quality and other matters were introduced (Keeves, 1970). The implied decision process is to induce the resource constrained state and manage the forests on a set schedule.

*Yield Table Extension — Computerised*

The effort required for the calculations by purely clerical extension can be formidable for a big plantation and restricts the number of stands and alternative regimes and decisions that can be considered. Computer processing has enabled the yield table extension method to be more realistic and much more flexible.

Dargavel (1969) for Victorian industrial plantations and Leech (1974) in South Australia have developed models which enable the stands to be considered in detailed classifications by site, stocking, and topography, etc. Sets of variable-density yield tables are supplied covering a limited number of variations in thinning regime and felling policy. Several alternative long-term yield projections are thus produced for comparison with desired industrial expansion plans. Although simple, both these models proved very useful and enabled substantial increases in the cut to be commenced. Because of their simplicity it has proved relatively easy to add refinements covering such things as discounted cash flow analysis, anlysis of fire and storm risk and display of possible effects of rotational decline of productivity.

*Industrial Supply Projections*

A development of the yield table extension method was provided by a model constructed for the State's plantations of *Pinus radiata* in Victoria (Gibson, Orr and Paine, 1969 *et seq.*). This model incorporates a fairly simple stand growth model which enables yields to be calculated for each separate stand by the application of set thinning regimes. The model can be operated in two distinct modes clearly recognising the possible separate states of the General Development System:

- To represent the system in the resource constrained state the forest stands are scheduled for clearfelling according to a nominated rotation. This is the normal yield table extension procedure.

— To represent the system in the market or capacity constrained states the available thinnings are scheduled and then sufficient stands are scheduled for clearfelling to meet the industrial demands.

The result of this latter mode is the direct production of a cutting plan that will satisfy a nominated industrial expansion schedule. If the condition of the forest at the end of the projection is unsatisfactory, alternative expansion plans can be considered and evaluated.

A similar model has been developed to produce very detailed schedules for the short-term management of industrial plantations in Victoria (Dargavel and Marshall, 1974). Scheduling a variety of thinning operations is achieved by a sequence of decision rules concerning priorities for filling sawlog and pulpwood demands and priorities for various thinning operations.

Higgs (1974) developed a model for scheduling thinnings and clearfellings in Tasmanian plantations over a 15-year period using priorities calculated from the stand conditions.

*Plantation Optimisation*

All the models mentioned above use limited pre-defined decision rules for scheduling. Clutter provided a breakthrough in the techniques of yield control with the successful development and implementation of the "MAX-MILLION" planning model (Clutter, 1968; Ware and Clutter, 1971). This enables a number of alternative strategies to be considered independently for each stand and the *optimum* combination found by linear programming. Clutter's approach removes the limitation of having to pre-define the decision rules to be applied to all stands. Although the model was developed to schedule stands for clearfelling its formulation is easily adaptable to the evaluation of a limited number of alternative thinning regimes. The unique feature is that the best treatment for each separate stand is found.

Clutter's formulation was adapted for scheduling cutting in the ash forests of Victoria (Weir, 1972). Thinning regimes were evaluated and generally rejected in preference for clearfelling. The formulation was also adapted for planning the yield from plantations of *Pinus radiata* in N.S.W.

### *Project or Regional Models*

The development of models that incorporate *both* the expansion of the plantations and the expansion of industry is a difficult task as different disciplines, interests and organisations have to be integrated.

Conflicts of short-term interests between the State plantation owners and private industrial companies are inherent for most plantation regions in Australia. Resolution is achieved by negotiation and explicit models to evaluate the effects to *both* parties of alternative plans have not been made. Development often proceeds with a paucity of information. Only where substantial parts of both the plantations and the industry are owned by the same organisation does there appear to be the possibility of using overall project models at present.

New Zealand has been more successful in its approach to regional planning at least in part because it lacks the conflicts between State and Federal Governments. There have been a series of reports by Fenton (1972) on development models and their methodology. The effect on industrial development of alternative silvicultural regimes has been explicitly evaluated and shown to be of significance.

General methods for planning industrial expansion have been outlined in a recent FAO (1973) guide which gives some consideration to forest development. Studies of the economics of various sizes and processes in the pulp and paper industry have shown the substantial economics of scale that exist and the desirability of integrating pulp and paper manufacture. Some of these studies extend to evaluate the effects of additional haulage costs required for larger mills.

From what is available it is apparent that it is not realistic to plan plantations in isolation from planning the industries that will use their products. The thinning regime adopted can be expected to have a significant impact on industrial development. It is thus not possible to see the role of thinning clearly in the absence of some structures for joint plantation and industrial planning.

*National Models*

The problem of achieving joint planning at the national level has been approached in both New Zealand and Australia by holding national conferences at which a concensus is aimed for. These conferences are supported with reports from a specialist working parties and draft plans prepared by a central group (Australian Forestry Council, 1974; Hosking, 1972).

In Australia developing plantations is seen as the only way to meet the difference between forecast demands and expected supplies from natural forests. Selecting among alternative planting rates is seen as the key national forestry decision. For the selected national planting rate, it was found that continuing the plans and silvicultural regimes adopted by the States would result in a national shortage of sawlogs and a surplus of pulpwood. For national planning some method of adjusting this imbalance was required and a yield table extension model was used. In this the whole country was represented with one species, one site quality, one thinning regime and two alternative rotations, 40 and 50 years. A move to the shorter rotation provided the required earlier production of sawlogs. Many other strategies for meeting objectives are available but the roles of fertilisation and of thinning have not yet been evaluated at the national level. Clearly the great differences between species, sites, regions and States need consideration in such evaluations.

New Zealand has been extremely successful in applying their experience gained with project or regional models to the national level. The essential methodology is one of yield table extension with a limited number of site and regional differences being recognised. The national planning model seems to rest soundly on the project and stand models that have been constructed. One is impressed by the ability to evaluate the effects of alternative silvicultural and thinning regimes at the national level. The studies however appear to be plans by the forest authority for industrial development and do not reveal consideration or modification for the views of industry.

## CONCLUSION

By using a simple general development model this paper has shown that the role of thinning in development forestry will vary according to the domination of the plantation-industrial system by market, capacity or resource constraints. It is clear that alternative thinning regimes can have important effects on even national objectives and that the selection of the correct role of thinnings is an important and complex task.

There has been intensive activity in developing models which will evaluate the effect of alternative thinning regimes on stand development and working models now exist for most major plantation areas in Australasia. The construction of plantation or regional models is more difficult but many examples exist to illustrate available methods.

The development of methods that would consider the joint development of plantations and industries appear to require that some of the present political, social and organisation barriers be reduced.

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