The Reservation Price of Forest Stands

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Abstract When timber prices are high, small forest owners face the decision whether to sell a stand of forest before the accepted 'maturity' period. Whether or not the decision to sell is made, it must reflect the optimal value of the stand of trees after accounting for between year variability in prices. The aim of this project was to develop a prototype decision model for forest owners/ farm foresters to determine a reservation price for forest stands. It indicates to the forest owner the price above which the stand should be sold to maximise net returns. The reservation price is affected by the probability distribution of log price, the annual yield increment of logs, interest rate and the value of bare land. A dynamic programming technique written in Microsoft Excel and Visual Basic was used to develop the model. The model was used to estimate the reservation price for a stand of *Pinus radiata* from ages 12 to 40 years. The change in wood yield with age was modelled using the Forest Research Institute's STANDPAK package for two regimes: framing (with no pruning) and clear wood (with pruning). In addition to determining the reservation price of a forest stand, the value of an 'immature' forest under fluctuating log prices can be calculated. The model can therefore be used to design an optimal silvicultural programme for a stand of forest.

1. INTRODUCTION

Domestic log prices in New Zealand have fluctuated over the past four years in response to overseas demand for wood. In 1993 log prices were particularly volatile reaching a high of about $370/m^3 for pruned *Pinus radiata* logs [Massey University, 1997]. Prices have since fallen and pruned logs currently sell for about $150 m^3 [Edmond, 1996]. A grower may choose to sell a stand of trees at the current market price or wait for a higher price in the future. If the value of the forest crop at the offered price is higher that the expected future value then the grower should sell. For a distribution of log prices and rate of wood volume increase, an optimal reservation price for a forest stand can be calculated [Brazee and Mendelsohn, 1988; Lohmander, 1988]. This paper presents a model for calculating the reservation price of a *Pinus radiata* forest stand and indicates how the value of a young forest stand can be derived when log price is stochastic.

2. METHODS

2.1 Optimal Pricing of Stands

The forest manager's objective is to maximize the value of a forest stand. This value can be affected by silvicultural treatments and the expected price of grades of logs recoverable from the forest stand. Following Lohmander [1988], the problem can be stated as:

$$\text{Max } W(t) = (Wt)^* = \int_0^{p^*(t)} W^*(t+1)F'(P)dP + \int_{P*}^{\infty} e^{-rt}[PV(t)+L]F'(P)dP \qquad (1)$$

where

- P price of standing volume of wood;
- W(t) expected present value at time t just before P_t has been observed and the forest has not yet been harvested;
- P^* the optimal reservation price;
- L expected present value of land after the forest has been harvested;
- F'(P) the probability density function of P;
- r the discount rate;
- V(t) the volume of the stand as a function of time.

The first term of (1) is the expected value of the forest stand if the offered price is below the optimal reservation price. In this case the forest is not harvested in the current year. The second term is the expected present value if the offered price is equal to or exceeds the reservation price at a given discount rate. (The opportunity cost of land is included in the calculation).

Assuming F'(P) is strictly positive, the optimal reservation price can be calculated from (1) as shown by Lohmander [1988]

$$P^{*} = (e^{-r}W^{*}(t+1) - L)/V(t)) \qquad (2)$$

If $W^{*}(t+1)$, the value of the standing forest, is known then the reservation price at time t can be determined. The value of the standing forest also depends on what happens to the forest in the future. The forest may be harvested if the offered future price exceeds the reservation price, or left unsold. The problem can be solved by working backwards from an age which exceeds the accepted rotation age of the stand of forest. At this age a minimal value can be assigned to the forest.

2.2 Forecasting Stand Volume and Stumpage

A suite of computer programs, called STANDPAK [Whiteside, 1989], have been developed in New Zealand to model the growth and log grades of *Pinus radiata*. STANDPAK comprises a number of interrelated modules [West, 1993] which perform specific tasks and produce reports which may serve as input to other modules. STANDPAK was used in this study to model the volume and stumpage of a forest stand. The modules and linkages are shown in Figure 1.

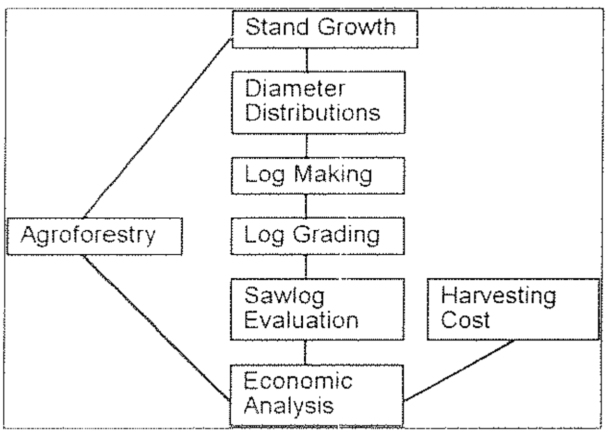

Figure 1: STANDPAK modules and linkages [West, 1993].

The Stand Growth module predicts the effect of site and silvicultural treatments, such as thinning and pruning on stand growth, stocking and yield from age three to maturity. Diameter over stubs, a variable that is influenced by the frequency of pruning, and determines the size of the defective core of a tree, is also predicted.

The Diameter Distribution module uses information on height, age and diameter at breast height and basal area from the Stand Growth module to predict the distribution of stand diameter and yield of wood in each diameter class. Using a specified cutting strategy, the trees in a diameter class are cut into logs by the Log Making module. This module also assigns to each log cut quality parameters (defective core, branch size, and distance between branch whorls, wood density and sweep).

The Log Grading module uses the quality parameters assigned to each log from the previous module, and the user-specified grading system to grade logs. Considerable flexible is provided in the way a log might be graded. Grading specifications can use parameters such as the small end diameter of the log, length, sweep, branch size, internode length, and whether the log is pruned or unpruned.

For each grade of log, the Sawlog Evaluation module uses saw patterns and mill type to predict physical yields and residual log values. The monetary value of the saw log can be estimated using log prices less the sawing cost.

The profitability of understorey grazing can be assessed in the Agroforestry module. The reduction in pasture production and quality due to thinning and pruning, and the subsequent reduction in livestock carrying capacity can be estimated at any stage of the development of the forest stand.

The Harvesting Cost module estimates the cost of harvesting and transportation for a clear felling operation. This information is used in the Economic Analysis module which uses the annual cash flow generated by the stand to calculate the internal rate of return, net present value and break-even price for a range of discount rates.

Most of the models used in STANDPAK have been developed from data collected from permanent sample plots established in a number of forests (including stands on fertile farm sites) throughout New Zealand. A range of growth and height models are therefore available to describe stand yield and return for most sites. In addition, key parameters and functions, such as basal area increment equation, can be calibrated using site specific data.

3. MODEL SPECIFICATION AND DATA SOURCE

The reservation price model was applied to a stand of *Pinus radiata* forest planted on Massey University's hill country farm near Palmerston North. The growth of the stand was modelled using Forest Research Institute's STANDPAK package for two regimes designed to produce pruned and unpruned saw logs for the domestic market. The characteristics of the site and schedule of treatments used in STANDPAK are summarised in Table 1. The pruned stand regime is pruned three times and thinned once to a final stocking of 300 stems /ha. The unpruned stand is thinned once at age 12.6 years to a final stocking of 400 stems /ha.

Table 1: Tending operations used to simulate Radiata pine growth in STANDPAK.

A 'Pruned'

Schedule of tending operations used for the production of pruned sawlogs

PRUNED (DOS) 330 stems/ha to leave 2.0 m. of crown at age 4.7 years
PRUNED (DOS) 300 stems/ha to leave 2.2 m. of crown at age 6.5 years
PRUNED (DOS) 300 stems/ha to 6.0 m at age 9.2 years
THINNED stand (least prnd) to waste leaving 300 stems/ha at age 9.2 years
SWITCHED to later model set from G23 H26 V22 M6 at age 15.9
END Rotation at age 40 years

B. 'Unpruned'

Schedule of tending operations used for the production of unpruned sawlogs

THINNED stand (least prnd) to waste leaving 400 stems/ha at age 12.6 years
SWITCHED to later model set from G23 H26 V22 M6 at 15.9 years
END Rotation at age 40 years

The estimated growth is shown in Figure 1. The unpruned sawlog produces a higher volume of wood and has a higher mean annual increment (MAI) that than the pruned sawlog. In both regimes the peak MAI falls between ages 30 and 37 years. It is therefore likely that harvest will take place before the stand reaches 37 years.

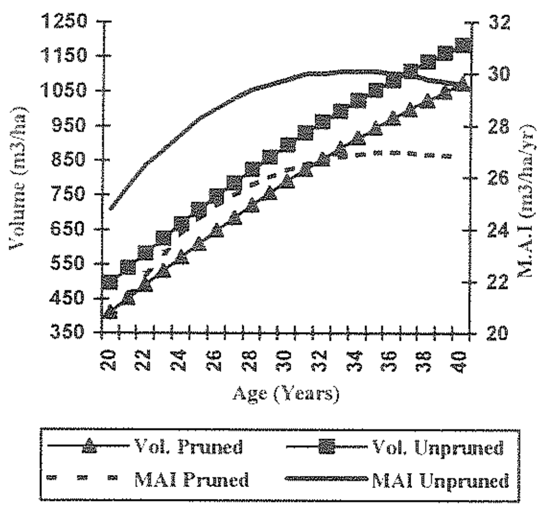

Figure 1: Standing volume and mean annual increment (M.A.I) of Radiata pine - site index 23

The value of logs recovered from the stand is higher for the pruned sawlog regime. This is shown in Tables 2 and 3 at age 30 years for the minimum and maximum prices recorded between 1993 and 1997 [Edmonds, 1996; Massey University, 1997]. At age 30 years the stumpage consistent with log grade prices, and felling, transport and roading costs range from $37 /m^3$ to $158 /m^3$ for the pruned sawlog, and $12 /m^3$ to $94 /m^3$ for the unpruned sawlog regime.

Table 2: Log grade recoveries at clearfell age of 30 years

Log grade	Minimum log price for NZ domestic grades at wharf gate or mill door	Maximum log price for NZ domestic grades at wharf gate or mill door	Pruned		Unpruned	
			Volume	Outturn	Volume	Outturn
	($/m³)	($/m³)	(m³)	(%)	(m³)	(%)
P1	148	370	223.9	31.7	0	0.0
P2	111	370	41.6	5.9	0	0.0
S1	90	200	2.6	0.4	72.5	8.5
S2	70	170	5.3	0.8	74.9	8.7
S3/L3	58	130	69.4	9.8	130.7	15.3
L1/L2	56	150	282.4	40.0	479.3	56.0
PULP	35	75	80.0	11.3	99.2	11.6
Total			705.2	100	856.6	100

Table 3: Stumpage at clearfell age of 30 years of Radiata pine (using log grade recoveries and prices shown in Table 2)

	Pruned		Unpruned	
	Min.	Max.	Min.	Max.
Standing Volume(m³)	791	791	896	896
Revenue at wharf gate or mill door($)	61,002	157,041	49,660	123,557
Cost –felling, roading and transport ($)	32,138	32,138	38,946	38,946
Net revenue ($)	28,863	124,902	10,714.0	84,610
Stumpage ($/m³)	36.5	157.9	12.0	94.4

The assumed minimum and maximum stumpage used in this study were:

Pruned regime: $35/m^3$ - $160/m^3$
Unpruned regime: $10/m^3$ - $95/m^3$

The distribution of stumpage was modelled as a Beta distribution, which uses two parameters to describe the shape of the distribution. The Beta distribution is flexible since it can be used to describe a large range of shapes by simply modifying the shape parameters

[Anderson *et al.*, 1977]. The future probability distribution of stumpage is unknown. A uniform distribution (Beta shape parameters 1,1) was assumed for the purpose of this study, with the minimum and maximum stumpage shown above.

Two discount rates, 7% and 10% real, were used and an opportunity cost of $2000 /ha was assumed for land, which is approximately the current selling price for a hill country sheep and beef cattle farm. (This is obviously a simplification since the opportunity of cost land that is to be replanted into forestry may be different from the value of land in pastoral production).

The model is solved backward from age 40 years which exceeds the age of maximum mean annual increment (See Figure 1). It was assumed that at this age the stand would sell at any price on offer. In this case the minimum stumpage is the optimal reservation price.

The model was programmed in Microsoft Excel and Visual Basic, and the optimal price and value for (1) and (2) were solved numerically and backward in time from age 40 years to age 20 years.

4. RESULTS

The optimal reservation price is shown in Figure 1 for the pruned and unpruned saw log regimes, and for 7% and 10% discount rates. As expected the optimal reservation price (stumpage) decreases with age, and is higher for the pruned than unpruned saw logs. The reservation price reduces as the discount rate increases.

The reservation price is fairly constant between age 26 to 34 years (about $\$130/m^3$ for pruned sawlogs). This indicates a high probability that the forest stand will be harvested between these ages.

5. CONCLUSION

An advantage of forestry over other cropping or pastoral farming systems is that the forest need not be harvested at any given age if the price on offer is too low. The forest should not be harvested unless the offered price exceeds the optimal reservation price for that age class. If the offered price exceeds the reservation price then the stand should be sold. Therefore, the optimal rotation length depends on the distribution of stumpage and the growth characteristics of the forest. This approach also provides a method for valuing a young forest stand that has been subjected to a range of silvicultural treatments when price is stochastic.

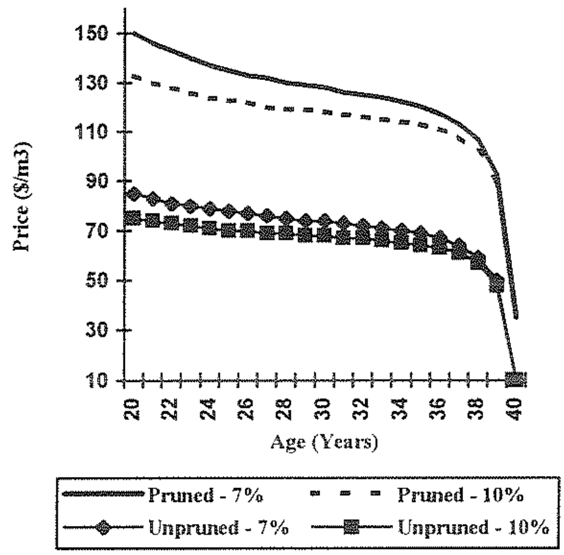

Figure 2: The optimal reservation price (stumpage) at 7% and 10% discount rate of Radiata pine.

The optimal present value of the forest stand is shown in Figure 2. As expected the present value of the forest decreases with age, and increases with discount rate. At the 7% discount rate it is best to prune, and at 10% real discount rate it is best not to prune.

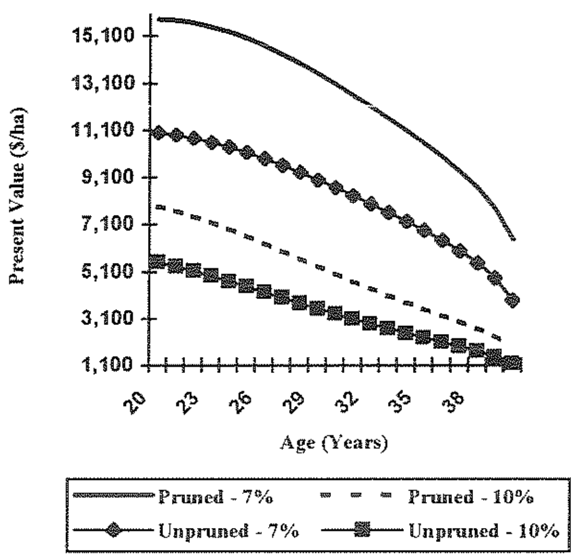

Figure 3 The optimal expected present value at 7% and 10% discount rate.

6. ACKNOWLWDGMENT

The silvicultural regimes used for this study were developed by James Millner and Jason Blair, Plant Science Department, Massey University. Their assistance is gratefully acknowledged.

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