CHAPTER 4: ECONOMICS OF FOREST MANAGEMENT

INTRODUCTION

The forests of East Gippsland are not alone in the debate about forest use and forest management. Such issues are of international significance and have been the topic of debate for centuries. Consequently, there is a large body of literature on the economics of forestry which an analysis of forest resource use should consider. East Gippsland's forests are currently managed by government using sustainable yield as its management strategy. Is this socially optimal?

This chapter will develop a comprehensive understanding of the economic theory pertaining to forest management and the associated complications of public ownership. A foundation will be provided for later discussion on the utilisation of forest resources for timber production.

Forest economics analyses the allocation of scarce forest resources. An efficient allocation will be explored as a means of achieving a socially optimal outcome. The efficient economic solution will then be compared to the goal of sustained yield and the principle of internal rate of return. Multiple use management and public discount rates which are crucial to the analysis of a publicly owned forest will be discussed as variations to the efficient market outcome.

Forest Resources

Scarcity

There are insufficient forest resources to meet human wants. Both the forest and the land upon which the forest grows is scarce. Forests compete with agriculture and other economic activities for the use of land. European settlers in Australia cleared large areas of forested land, leaving only a small amount of forested area which is now regarded as extremely scarce. A similar pattern of events has occurred around the world, making Australia's forests an even more valuable resource. Forests are classified as renewable natural resources meaning they can be regrown using the same piece of land. The renewable characteristic of forests means that the relative scarcity between forests and cleared land has the potential to change in the future. Whilst plantation forests can be established on clear land, achieving a forest composition and structure similar to naturally occurring forest is almost impossible. Therefore, the potential to increase forest resources such as those existing in East Gippsland is extremely limited. Use of the East Gippsland forest resources for timber production is a very important and controversial issue because the forests are regarded as scarce in the absolute sense.

Scarcity forces choices to be made about how forest resources should be allocated between various uses. This is the economics of forestry. Gregory's definition gives a little more detail: "Forest economics is the branch of forestry, and of economics, that deals with allocating scarce resources among competing means to satisfy human wants for forest products."[168]

Allocating to maximise social welfare

It would never be possible to satisfy all human wants for forest products but allocating resources to fulfil the most number of wants could be achieved by attempting to maximise society's welfare. The Pareto efficiency criteria will be used as a measure of social welfare maximisation whereby no person can be made better off without someone else being made

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[168] G. Robinson Gregory, *Resource Economics for Foresters* John Wiley and Sons, New York 1987. p. 9.

worse off (or where no more forest products can be produced without reducing the production of other products).

Efficiency ensures that the maximum amount of resources will be available for consumption by society as a whole but does not address the distribution of the resources between members of society or generations.

How is efficiency achieved?

Efficiency in the allocation of forest resources is achieved where the maximum net benefit results from any decision involving forest resources. The market system achieves efficiency by using price as a resource allocator to balance supply from profit maximising producers and demand from utility maximising consumers.

Consumers make decisions about forest products based on utility, income and price. These decisions are made independently from the supply of such products and the resources from which these products are derived.[169]

Producers make decisions about forest products based on profit maximisation. Such decisions in turn will impact upon how forest resources are used. Tietenberg points out that deriving demand for forest resources from the market for forest products is complicated by the fact that trees have the characteristic of being both products and capital. "Trees, when harvested, provide a saleable commodity, but left standing they are a capital good, providing for increased growth the following year." [170] Standing forests also produce commodities such as recreation, conservation, water and biodiversity. Regardless of what products are being produced, the use of forest resources in a market system will depend upon the profit maximising assumption.

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[169] Johansson, Per-Olov and Lofgren, Karl-Gustaf *The Economics of Forestry and Natural Resources* Basil Blackwell Oxford 1985 p. 87.
[170] Tietenberg, Tom *Environmental and Natural Resource Economics* 4th Edition Harper Collins College Publishers, New York 1996. p. 249.

If the forest products market is unfettered, the combination of consumers and producers should result in an allocation which maximises net benefit to society and therefore maximises society's welfare. The market will produce a socially optimal outcome assuming that there are no market failures such as externalities or poorly defined property rights.

FORESTS AS A TIMBER RESOURCE

Most discussions of the economics of forestry consider only timber production as a forest use. Whilst recognising that timber production is not the only use of scarce forest resources, the body of theory which has emerged provides a framework to which other uses can be added. Assumptions associated with a steady state timber production solution, which were used by Johansson, are as follows: [171]

1. It is a competitive model exhibiting no externalities and no multiple use objectives;
2. The capital market is perfect. The interest rate is known over all future periods;
3. All future input and timber prices are constant and known;
4. Future timber yields are known;
5. Forest land can be bought, sold and rented in a perfect market.

Time

Time presents a problem to those considering investing in forests because trees take a long time to grow; much longer than almost any other commodity. This means that capital will be tied up for a very long time before returns are realised. Since it is assumed that people prefer $1 today than $1 in a year's time, the revenue collected on timber harvest at some time in the future will have to not only cover the cost of planting the trees and renting the land, but the opportunity cost of the initial investment. Alternatively, future net revenue streams could be discounted, so that the present value of those streams could be compared with the planting costs which are incurred on day one. The discount rate should reflect the producer's time preference for money which, for the private sector, would normally be the going market interest rate.

[171] Johansson, op. cit. pp. 74-75.

Optimal Rotation

The primary decision which must be made by timber producers is when to cut down a stand of trees. Since the trees can be regrown, the decision affects not only this stand of trees but all future stands. Therefore the real question is: what is the profit maximising cycle of tree harvest, or what is the optimal rotation period?

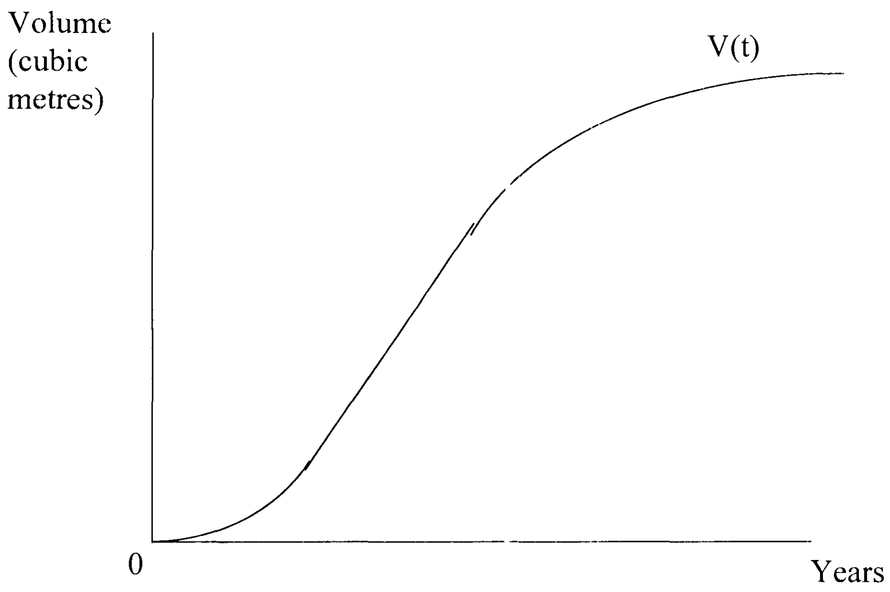
A timber producer will choose a rotation period which will maximise profit. Assuming constant timber prices, this equates to maximising net timber benefit from growing trees. Producers will harvest trees when the total timber benefit from trees less the total costs is maximised.

Benefits

Benefit from the forest is achieved when the timber is sold and is a function of tree volume. In general, the more time that passes, the greater volume of timber the tree produces. Therefore the longer a tree is left standing, the more benefit accrues to the owner. This is a recognition of trees as capital which have the potential to produce forest products. The total benefit curve would reflect the growth pattern of a tree and the resultant volume of timber that it produces, assuming that price per volume of timber remains the same.[172] The total benefit can be represented by the timber volume function V(T) which is usually shaped like Figure 4.1.

[172] Tietenberg, op. cit. p. 249.

Figure 4.1 Model of Tree Growth[173]



The total revenue that a profit maximising producer receives at the harvest date is equal to price per volume of timber P multiplied by the volume of timber harvested V(T). Since the industry is assumed to be perfectly competitive, the total revenue curve PV(T) will also take the shape of the timber volume function.

Benefits can be measured in terms of revenue obtainable on the date of harvest PV(T) or in terms of the present value of those revenues, $PV(T)e^{-iT}$, where e^{-iT} is used to discount the total revenue PV(T) using a continuous discount rate of i over time T.

Costs

Costs can also be measured at two different points in time: the point of harvest (future value) or the point of planting (present value).

[173] ibid. p. 250

Calculating cost at the future value to compare with revenues obtainable on the date of harvest involves measuring in terms of opportunity cost. The future value of planting costs would be the opportunity cost of lending that amount at the going rate of interest for the period of growth. The opportunity cost of standing trees is that amount which could be earned by harvesting the trees, collecting the proceeds and lending them at the market rate of interest. Total cost of a standing forest would increase with time as the opportunity cost of leaving trees standing accumulates.

In addition to the opportunity cost of the current stand of trees, delaying harvest prevents a new stand of trees being grown on the same piece of land. Therefore the full opportunity cost would include all future rotations in addition to the current stand of trees. As noted by Mitra et al: "Once trees are removed from a given area, the land is available for new forest growth. Clearly, the longer the felling of the existing forest is delayed, the longer it takes to acquire revenues from future harvests. The opportunity cost of utilising the forest site for the existing stand of trees must be considered."[174] This was recognised by Martin Faustmann in 1849. The Faustmann solution maximises benefit over the full opportunity cost of using the land for the current stand of trees which includes the present value of all future stands. The Faustmann rotation period is heralded as the "correct" solution to the optimal rotation problem.

Samuelson simplifies Faustmann's solution by adding the cost of renting the land upon which the trees grow to the opportunity cost of the trees themselves for one rotation period.[175] Since it is the land which produces the infinite number of rotations, taking the opportunity cost of using the land for standing trees produces the same result as the Faustmann rule because the rental value of the land should reflect the future earnings of the land.

Measuring costs at present value or at the planting date involves simply accounting for the planting costs, C.

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[174] Mitra, Tapan and Wan, Henry Y. Jr *Some Theoretical Results on the Economics of Forestry* Review of Economic Studies (1985) LII. p. 263.
[175] Samuelson, Paul A. *Economics of Forestry in an Evolving Society* Economic Inquiry Vol. XIV, Dec 1976 p. 472.

Net Benefit

The net benefit can either be measured in future value terms (revenue minus opportunity costs) or in present value terms (present value of revenue minus planting costs). The resulting optimal rotation period will be the same regardless of which method is used. The following analysis uses the present value method.

For one rotation, the present value of the accrued benefits (in this case revenue from timber sales) should be compared to the planting costs to select the optimum time to harvest. This will give a net present value function which can be maximised with respect to time (T):

$$NPV = PV(T)e^{-iT} - C$$

where: P = Price per volume of timber

V(T) = Volume of timber which is a function of time (T)

e^{-iT} = is used to discount the total revenue PV(T) using a continuous discount rate of i over time T.

C = planting costs.

To find the optimum time (T) to harvest this stand of trees, the first order derivative of the above function should be taken with respect to T and set to zero. The resulting time will give the maximum net present value obtainable from the stand of trees. This solution to the optimal rotation problem is not efficient since the benefits and costs of future stands of trees have been ignored. The Faustmann solution remedies this by using the same approach for an infinite number of rotations rather than just one. For an infinite number of rotations, the present value of all future benefits and costs needs to be taken into account rather than just for the one rotation. The net present value function will need to be changed to reflect this:

$$NPV = \left[PV(T)e^{-iT} - C\right]\left[1 + e^{-iT} + e^{-2iT} + e^{-3iT} + ...\right]$$ [176]

which can be rewritten as:

$$NPV = \frac{\left[PV(T)e^{-iT} - C\right]}{\left[1 - e^{-iT}\right]}$$

Here the NPV is higher than for the single rotation case because $[1 - e^{-iT}]$ will always be less than one. This reflects the extra net benefit to be received from many rotation periods.

The time (T) which will give the maximum net benefit can be found by differentiating the above equation with respect to T and setting it to zero. The result will be:

$$PV'(T) = \frac{i\left[PV(T) - C\right]}{1 - e^{-iT}}$$

Marginal Analysis

Decisions about how long to leave a stand of trees standing can more easily be made at the margin. If the benefit of leaving the trees standing for one more period of time exceeds the cost, the trees should be left standing. This would continue until the marginal benefit of leaving trees standing is equal to the marginal cost. Mitra et al summarises: "A stand of trees should be cut at an age at which the increase in the value of the timber content of the standing trees over an additional unit time interval equals the sum of the following two factors (i) the interest that can be earned if the revenue from cutting the trees is invested at an interest rate; (ii) the interest that can be earned on the "site value" [that is, on the present value of the stream of all future revenues on this particular site.]"[177] Any rotation period shorter or longer would lower net benefit.

[176] ibid. p. 479.
[177] Mitra, op. cit. p. 264.

The optimising equation arrived at above can be used to illustrate the marginal approach.

$$PV'(T) = \frac{i[PV(T) - C]}{1 - e^{-iT}}$$

The left hand side of this equation gives the price P times the marginal timber volume or the change in timber volume V'(T). It represents the increase in the value of the timber content of the standing trees over an additional unit time interval. The top part of the right hand side represents the interest that can be earned if the revenue from cutting the trees less initial planting costs is invested at the interest rate i. The bottom part of the right hand side adjusts the interest rate upwards since $1-e^{-iT}$ lies between zero and one. This allows for benefits and costs resulting from infinite rotations and is equivalent to including interest that can be earned on the site value as in point (ii) above.

A more intuitive investment decision is to cut a stand of trees when the rate of growth of the trees just equals the going rate of interest. This compares the rate of return from the forestry investment directly to the alternative rate of return available.

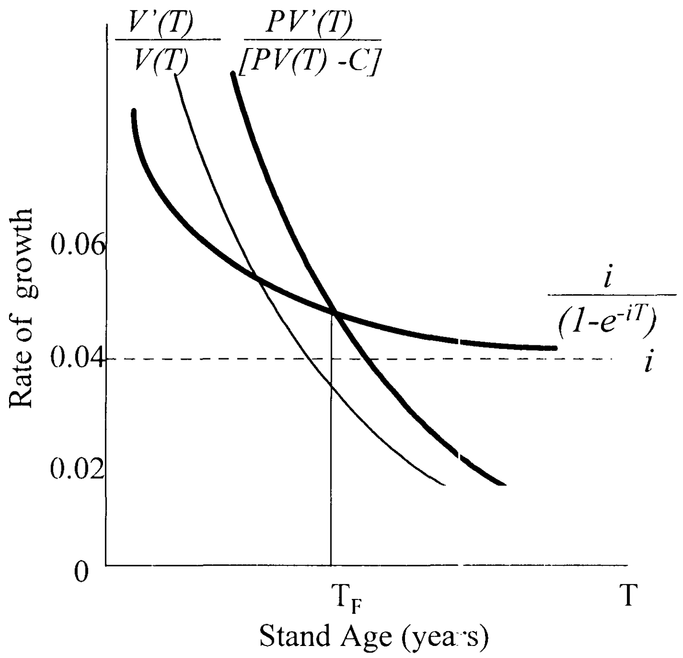
Once again, this simple problem must be adjusted for an infinite number of rotations. Taking the above equation and dividing both sides by [PV(T) - C] gives:

$$\frac{PV'(T)}{[PV(T) - C]} = \frac{i}{1 - e^{-iT}}$$

The left hand side of this equation gives the relative growth rate in the value of a stand of trees. The right hand side gives the adjusted interest rate. This relationship can be seen in Figure 4.2[178].

[178] M. D. Bowes, and J. V. Krutilla, *Multiple-Use Management: The Economics of Public Forestlands* Resources for the Future Washington 1989. p. 00.

Figure 4.2 Optimal Rotation



The $\frac{V'(T)}{V(T)}$ curve represents the growth rate in timber volume and is downward sloping to indicate a slowing in the rate of growth as the stand of trees becomes older. The $\frac{PV'(T)}{[PV(T) - C]}$ curve represents the relative growth rate in the net value of the timber (net harvest revenues) [179] and takes the same shape but lies above the $\frac{V'(T)}{V(T)}$ curve where planting costs are higher than zero (ie where C is positive). The $\frac{i}{1-e^{-iT}}$ curve slopes downward, always lying above *i* which in this case is set at 0.04.

The Faustmann solution to the optimal rotation problem is found at T_F in Figure 4.2 where the two curves intersect.

The Faustmann rule applies whether the stand of trees is a private plantation or a forest which has been inherited by public owner. Since the model assumes that the only use for the forest is timber, the following rule applies: "If the plot of land has initially a standing

[179] ibid. p. 99.

forest .... cut all trees of age T_F or more (where T_F is a solution to the Faustmann problem); thereafter, cut a tree if and only if it is of age T_F."[180]

Timber producers need not be land owners to reap the benefits of forest growth. Producers could purchase the right to harvest a forest from the forest owner at any time during the growth period. Payments should cover all opportunity costs to the forest owner. The forest owner need not wait until the rotation time to reap the benefits of investment because the forest would have an economic value (or price) equivalent to the opportunity costs to date. This price is often referred to as a shadow price. "At any point in time the shadow price of a tree gives the dollar amount that the tree owner would have to receive in order to be persuaded to sell the tree."[181]

Comparative Statics

The three variables impacting on the equilibrium position in Figure 4.2 are: the interest rate (i), the price of timber (P) and the planting costs (C). A change in any one of these variables will cause an exogenous shock and a new equilibrium. An increase in the interest rate will shift the $\frac{i}{1-e^{-iT}}$ curve upwards and shorten the optimal rotation age if all else remains the same. This change is intuitive because a higher interest rate increases the opportunity cost of growing the forest for one more period. An increase in the price of timber (P) will also increase the opportunity cost of leaving the trees standing and invoke a shorter rotation by shifting the $\frac{PV'(T)}{[PV(T) - C]}$ curve downwards. An increase in planting costs (C) will shift the $\frac{PV'(T)}{[PV(T) - C]}$ curve upwards and further away from the $\frac{V'(T)}{V(T)}$ curve. This will lengthen the rotation age because more time will be needed to collect extra revenue to cover the extra planting costs.

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180 Mitra op. cit. p. 264.

181 Hellsten, Martin *Socially Optimal Forestry* Journal of Environmental Economics and Management 15, 387-394 (1988) p. 389.

FOREST MANAGEMENT OBJECTIVES

The Faustmann rule illustrates the socially optimal solution to the forest rotation problem by maximising net benefit to society. This should be compared to other rotation periods which have been selected for different reasons. It is the goals of forest management which differ rather than the calculation of an economically efficient outcome. The debate is important for foresters and timber producers who need to implement such policies and who are faced with decisions which have long term implications.[182] Apart from the Faustmann solution, two other criteria are commonly used to determine the rotation period: sustained yield and internal rate of return.

Sustained yield

Public ownership of forests has brought with it a need to plan for forest resource use rather than allowing the market to allocate resources. Hellsten notes that: "A prime objective of social planners is to even out the pattern of harvests, an objective which is summarised by the term sustained yield." [183]

Samuelson describes maximum sustained yield as follows: "Cut trees down to make way for new trees when they are past their best growth rates. Follow a planting, thinning, and cutting cycle so the resulting lumber output, averaged over repeated cycles .... will be as large as possible." [184] This definition is consistent with the forestry term: Mean Annual Increment (MAI) which is "the average annual income in wood volume for a specified period measured from establishment" [185] and is explained in relation to Figure 4.3[186].

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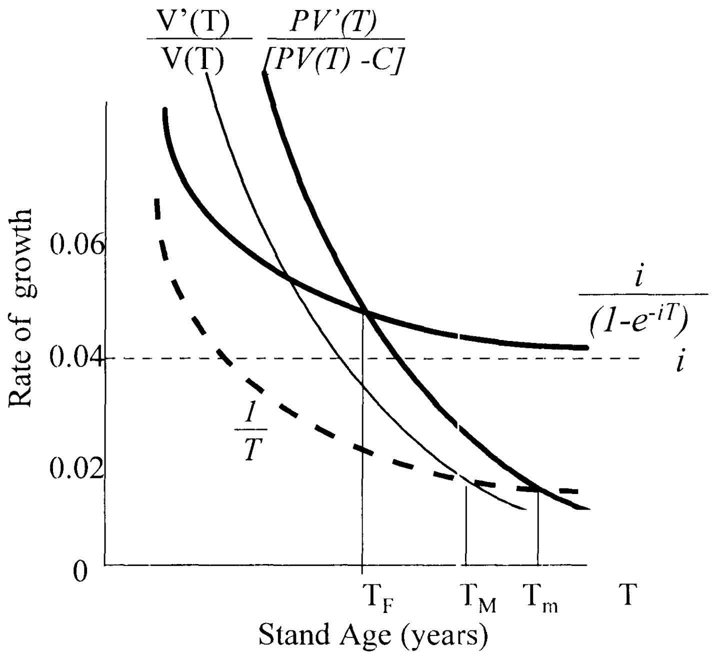
[182] Hagenstein, Perry R. *Forestry, Public Pressures, and Economic Development*, American Journal of Agricultural Economics, 1971, v53(5), 887-893 p. 887.
[183] Hellsten, op. cit. p. 387.
[184] Samuelson, op. cit. p. 476.
[185] Resource Assessment Commission, *Forest and Timber Inquiry Final Report* Volume 1, Canberra p. 519.
[186] Bowes op. cit. p. 103

Figure 4.3 Sustained Yield Solution



Maximum sustained yield occurs at maximum average tree volume. Since marginal equals average at maximum average, maximum average tree volume can be found where it equals marginal tree volume:

$$V'(T) = \frac{V(T)}{T}$$

Dividing both sides by V(T) results in the volume growth rate:

$$\frac{V'(T)}{V(T)} = \frac{1}{T}$$

$\frac{1}{T}$ can be plotted on the previous diagram to find the rotation age which maximises average yearly harvest volume and is shown as T_M in Figure 4.3. This occurs where $\frac{1}{T}$ intersects the $\frac{V'(T)}{V(T)}$ curve.

T_m in Figure 4.3 represents the case where average timber value from harvesting operations is maximised rather than timber volume.

The MAI criteria will choose a rotation period which maximises the average tree growth (or average value) giving the maximum total product over an infinite number of rotations. This is regarded as socially suboptimal because the opportunity cost to society of the standing trees has been ignored. Samuelson explains: "To wait until each tree slowly achieves its top [average] lumber content is to fail to realise that cutting the tree to make the land available for a faster-growing young tree is optimal."[187]

Given the assumptions stated, the general conclusion that can be drawn is that a sustained yield rotation period will be longer than a Faustmann socially optimal period when a positive rate of interest prevails.[188] The Faustmann solution will lengthen as the interest rate falls and $\frac{i}{1-e^{-iT}}$ will approach $\frac{1}{T}$ as i approaches zero. Therefore, the only time that the Faustmann solution will agree with the maximum sustained yield solution is when the interest rate is zero.

The East Gippsland forest management plan uses the term *sustainable yield* which means "the estimated rate of sawlog harvesting that can be maintained for a given period without impairing the long-term productivity of the land, taking account of the structure and condition of the forest."[189] The calculation gives an annual volume of timber that can legally be extracted from the forest area (the sustainable yield is set in legislation) which allows sawlog licences to be issued. The rotation age is set on the MAI of an even aged nominal forest and has an influence on sustainable yield calculations. Nominal rotation lengths in the FMA vary from 80 years to 120 years depending on the forest type. For forest types other than Coastal Mixed Species the rotation age is 80 years while for Coastal Mixed Species the rotation age is 120 years. To even out wood flows, it is often necessary

[187] Samuelson, op. cit. p. 477.
[188] Johansson, op. cit. p. 90.
[189] Department of Conservation and Natural Resources *Proposed Forest Management Plan East Gippsland Forest Management Area*, Melbourne, February 1995, p. 37.

to vary the age at which some stands are scheduled for harvesting above and below the nominal rotation age. The minimum cutting age in the coastal mixed species forest type has been set at 100 years and for all other forest types it is 65 years.[190].

The practical application of sustainable yield in the FMA means that harvesting of the available older forests will be staged, so that they last until regrowth forests (from earlier harvesting and wildfires) are old enough to harvest. Consequently, most sawlog harvesting will occur in older forest until around 2030 when large areas of regrowth forest begin to become suitable for harvesting.[191]

Internal Rate of Return

"A project's internal rate of return (or IRR) is the rate earned on all project costs by the anticipated revenues .... which means it is the discount rate that makes the net present value of a project equal to zero."[192] This is different from the Faustmann rule where the present value of the net benefits are maximised and where the discount rate would normally be the market interest rate to cover the opportunity cost of operation. It should be noted that the IRR does not include the cost of land rent in its cash flow. This means that revenue from tree growth would cover costs of production more quickly, negating the need to leave the trees standing longer to collect more revenue. Samuelson pointed out the limitations of the IRR criteria, "...ignoring land rent and maximising the internal rate of return will give you so short a rotation period that, at the postulated interest rate, you will not be able to pay yourself the positive land rental set by competition."[193]

IRR will fall if land rental is included because the revenue will have more costs to cover and therefore will not earn as much. The IRR could be reconciled with Faustmann's rotation period if the cost of land rental was included in the cash flow. Then, the discounted revenue would just cover the full discounted costs maximising the rate of return from the full costs of the operation.

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[190] Department of Conservation and Natural Resources, *East Gippsland FMA - Statement of Resources, Uses and Values*, Melbourne, January 1993, p. 134.
[191] Department of Conservation and Natural Resources *Proposed Forest Management Plan East Gippsland Forest Management Area* op. cit. p. 37.
[192] Gregory, op. cit. p. 250.
[193] Samuelson, op. cit. p. 472.

PRIVATE OR PUBLIC FOREST RESOURCES?

The decision of when to cut down a stand of trees would be relatively simple to implement for a private land (forest) owner who has a clear idea of timber and other values which are placed on the forest. If the market operates successfully based on the assumption of such private ownership, all private land owners acting in a profit maximising way would lead to a socially optimal outcome.

Many of the world's forests are not subjected to such market based management but are publicly owned and managed. The reason for such ownership may be historical or due to the inadequacies of the market in dealing with allocation of such a sensitive national resource. Despite the reason, a public forest is technically owned by members of the public so should reflect the timber and other values placed on the forest by the whole society. Public ownership with multiple use objectives requires breaking down some of the assumptions of the previous Faustmann analysis and therefore may result in alternative outcomes for forestry and society. The issues of the appropriate rate of discount to be used and other forest management objectives will also be explored within the context of public forest ownership.

Which discount rate?

It is the extensive time that trees take to grow which makes the discount or interest rate so important. The time factor and resulting opportunity cost far outweighs the tangible costs of planting and harvesting trees. The imbalance is so great that tangible costs can almost be disregarded in the decision making process because even when changed significantly make very little difference to the rotation decision. [194]

The discount rate significantly influences the optimal rotation period. Higher rates of discount shorten the rotation period because they increase the opportunity cost of leaving

[194] Tietenberg, op. cit. p. 253.

the trees standing. In figure 4.1, a higher discount rate would shift the $\frac{i}{1-e^{-iT}}$ curve up, shortening the rotation period. Similarly, a lower rate would lengthen the rotation period.

The are some questions which are crucial to decision making about forest resource use for timber production. Which discount rate should be used to discount future revenues in order to conduct cost benefit analysis and therefore determine the optimal rotation of a forest? Should there be a different discount rate for public forests as opposed to private forests; forests as opposed to other investment goods?

Individuals have time preferences for money which influence their investment decisions The discount rate should reflect these preferences. One indicator of private time preferences would be the going market interest rate.

Most investment decisions about forest use are not made by individuals but by the government in terms of forest rotation policy. There has been much discussion on whether individual time preferences of the public can be aggregated to arrive at a social discount rate which represents public time preferences. There may be some investment projects of lower return than the private sector will accept, that the public sector could take on because it is concerned for the welfare of future generations.

Marglin broaches three possible ways that a social discount rate could be developed and concludes that it is the combination of interdependence between individuals and the coercive power of the government which allows a social discount rate to be developed. The interdependence between individuals means that public investment will go ahead only if everyone bears a share of the investment burden, otherwise individuals will not expose themselves to the risk of investing. The government has the power to ensure that each person bears his or her share of the risks and investment burden.[195]

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[195] Stephen A Marglin,. *The Social Rate of Discount and the Optimal Rate of Investment* Quarterly Journal of Economics V77, 1963 pp. 103-104.

These observations allow a distinction to be drawn between a private rate of discount and a social rate of discount. Marglin explains: "My marginal private rate of discount is the net marginal rate of substitution of future consumption for my own consumption on the assumption that the trade is a unilateral venture. My marginal social rate of discount, on the other hand, is my net marginal rate of substitution of future for present consumption on the assumption that my sacrifice is accompanied by sacrifices by everybody else." [196]

If everyone in a democratic society bears their share of the public investment, the risk encountered by each person would be minimal. Therefore, the normal risk premium that would be added to the expected return by an individual is unnecessary in the case of public investment.[197] According to Arrow: "What has been shown is that when risks are publicly borne, the costs of risk-bearing are negligible; therefore, a public investment with an expected return which is less than that of a given private investment may nevertheless be superior to the private alternative."[198]

The distinction between a private and social discount rate seems clear when the net benefits of a public investment are spread evenly amongst members of society. Arrow recognised that not all benefits and costs from a public investment project accrue evenly to all members of society. "Therefore, in calculating the present value of returns from a public investment a distinction must be made between private and public benefits and costs. The present value of public benefits and costs should be evaluated by estimating the expected net benefits in each period and discounting them, using a discount factor appropriate for investments with certain returns. On the other hand, private benefits and costs must be discounted with respect to both time and risk in accordance with the preferences of the individuals to whom they accrue."[199]

This combination of private and social discount rates is likely to lead to a generally higher discount rate on cost/benefit analysis than using only a social rate.

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[196] ibid. p. 106.
[197] Kenneth J Arrow,. and Robert C Lind,. *Uncertainty and Evaluation of Public Investment Decisions* The American Economic Review V60 1970 p. 366.
[198] ibid. p. 375.
[199] ibid. p. 377.

If a lower discount rate exists for public as opposed to private investment projects, some reallocation of resources will occur towards the public sector since the public sector will accept projects that the private sector cannot afford to. This is viewed as acceptable if there is a socially desirable project yielding future returns too low to be undertaken by the private sector[200], and socially optimal if the investment displaces a private sector investment yielding a lower return than the public investment when adjusted for risks.[201] In other words, the return to the public investment need only cover the risk free opportunity cost to the private sector to be optimal.

Baumol disagrees with this conclusion, stating that "the appropriate rate of discount for public projects is one which measures correctly the social opportunity cost."[202] The transfer of resources from the private to the public sector should therefore only be undertaken whenever a potential project available to the government offers social benefits greater than the loss sustained by removing these resources from the private sector.[203] The loss sustained by transferring the resources is the return that would otherwise have been obtainable by the private sector which includes a premium for risk. Therefore, the social discount rate should equal the private discount rate.[204]

The general conclusion seems to be that at least benefits and costs accruing to the private sector should be discounted at the private rate if not all of them. The implications for public forests are that if a higher discount rate is used in preference to a lower (social) rate, then rotation periods will be shorter. Figure 4.3 shows that a sustained yield criterion effectively uses a discount rate which is very low (approaching zero), meaning that forests which are currently managed using this criteria are far from covering the social opportunity cost.

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[200] Marglin, op. cit. p. 111.
[201] Arrow, op. cit. p. 375.
[202] Baumol, William J. *On the Social Rate of Discount* American Economic Review V58 1968 p. 789.
[203] ibid.
[204] ibid. p. 795.

Forests can be strongly associated with investment which needs to be undertaken by the public sector for the benefit of future generations. Baumol concluded: "Investment in the preservation of such items then seems perfectly proper, but for this purpose the appropriate instrument would appear to be a set of selective subsidies rather than a low general discount rate that encourages indiscriminately all sorts of investment programs whether or not they are relevant." [205]

There is some suggestion that the growth rate of the forest will never be high enough to encourage profitable, sustainable market based investment. That is, continued forestry becomes unprofitable when the interest rate exceeds the growth rate of timber value so the forest will be harvested and the land possibly put to a more profitable use.[206] The solution offered is to reduce profit rates across the whole financial system (and therefore market interest rates) by accounting for environmental externalities. "Far from being a disaster for the market, the reduction in profit rates would facilitate the achievement of sustainable financial equilibrium."[207] This suggestion is consistent with the idea of subsidising private investors to reduce the risk premium required for market based investment. The environmental externalities would be accounted for in this arrangement because the social opportunity cost would approach the social preferences of a society concerned for a sustainable future.

Multiple Use Objectives

A forest full of standing trees may have more uses than just timber production. The forest is a resource which can also produce positive values when used for leisure, water flow, biodiversity, grazing, conservation and other non-timber uses. Recognition of these multiple uses has influenced decision making about forest use, in particular the management of public forests. Public forests throughout the world are now managed for a variety of uses in addition to timber production. Efficient management involves selecting a

[205] ibid. p. 801.
[206] Frank Ackerman, *The natural interest rate of the forest: Macroeconomic requirements for sustainable development* Ecological Economics Vol. 10 (1994), p. 23.
[207] ibid. p. 25.

sequence of harvests and stocks over time so as to maximise the net present value from all current and future flows of harvests and resource services of the area.[208]

The Faustmann rule can be adapted for the multiple use management problem and was done so by Hartman. Hartman suggests that the asset value of the land upon which a forest grows depends not only on the present value of the future timber which will stand on the land but the present value of the future amenity services which would be produced by the standing forests.

The set of assumptions used to frame the Faustmann solution needs to be amended to include multiple uses. In particular, the first assumption needs to be amended to allow multiple use objectives and an extra assumption must be added: "the flow of net benefits from the nontimber services can be expressed as a function of stand age."[209]

If this is possible, then amenity values can easily be included in the previous (Faustmann) analysis. The relationship between amenity values and stand age will depend upon the relationship of each nontimber use of the forest with the age of the forest. For example, grazing may have a negative relationship with stand age while conservation based recreation may have a positive relationship. There are other uses such as hunting and water flow which will have a varying relationship over the stand age.

Recalling that a delay in harvest gave a marginal benefit value of $PV'(T)$ for timber only values, we have:

$$PV'(T) = \frac{i[PV(T) - C]}{1 - e^{-iT}}$$

Since the value of an infinite number of rotations is equal to considering the rental value on the land for one rotation period, the above equation can be rewritten as:

208 Bowes, op. cit. p. 124.
209 ibid. p. 104.

$$PV'(T) = i[PV(T) + \lambda^*]$$

where λ^* may be viewed as the value of an acre of land under forestry management for timber only values.[210] The interest rate i multiplied by the land value will give the opportunity cost of using the land for one more period of time. Add to this the opportunity cost of leaving the forest standing for one more period *i[PV(T)]* and the optimal solution becomes clear: that the marginal benefit of delaying harvest, $PV'(T)$ should equal the marginal opportunity cost, $i[PV(T) + \lambda^*]$.

Including nontimber values will have two effects on the above solution. The first is an adjustment in the flow of benefits from a delay of harvest on the left hand side of the equation, a(T). Delaying harvest may increase or decrease value flowing from a standing forest over a given period as discussed above. The second effect is that the asset value of the land will be adjusted to encompass the amenity values.

$$PV'(T) + a(T) = i[PV(T) + \phi^*]$$

where ϕ^* "is the overall asset value of an acre of land."[211] Although not used further for this study, the overall asset value includes $\lambda(T)$ for timber values and $\psi(T)$ for amenity values.

Hartman concludes by stating: "The basic conclusion of this analysis is that the presence of recreational or other services provided by a standing forest may well have a very important impact on when or whether a forest should be harvested. Those models which consider only the timber value of a forest are likely to provide incorrect information in the many cases where a standing forest provides a significant flow of valuable services." [212]

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[210] ibid. p. 96.
[211] ibid. p. 104.
[212] Richard Hartman, *The Harvesting Decision When a Standing Forest Has Value* Economic Inquiry Vol XIV, March 1976 p. 57.

The result is likely to be a longer rotation period with the inclusion of most amenity services, even to the extent of leaving the forest uncut if the amenity services add a sufficient amount to the asset value of the land over time. One severe limitation of this approach is that many amenity values are not the result of commercial activities and are therefore more difficult to measure than timber which has a clear commercial value.

Various attempts have been made at estimating the amenity value of forests. This continues to be a large area of research which includes such methods as contingent valuation and hedonic price modelling.[213] The outcome of such research serves only to change the accuracy of predictions such as Hartman's, not the basic concepts upon which the above analysis is based.

One final point made by both Hartman and Bowes and Krutilla is the extent of the interdependence between forest stands or plots of land. "For many plots of forest land which could reasonably be taken as units for making cutting decisions, what happens on one plot will clearly affect the value of a standing forest on other plots."[214] The implication is that multiple use management decisions cannot be made about one stand of trees without considering the impact on the rest of the forest.

Management of forests using multiple use objectives is a deeply complex and daunting task especially if economic efficiency is to be the primary goal. Linear programming is a tool which has been used in an attempt to encompass this complexity; an example of a forestsry application is FORPLAN.[215] FORPLAN is not used for analysis in this study due to the timber only focus and the methodology used.

Extensive or Intensive Forest Management?

Selecting a rotation age which reflects multiple uses assumes an extensive management approach where every hectare of land will be managed for a variety of uses. Whether this

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[213] Guy Garrod, and Ken Willis, *The environmental economic impact of woodland: a two-stage hedonic price model of the amenity value of forestry in Britain* Applied Economics V24 1992 p. 716
[214] Hartman. op. cit. p. 57.
[215] FORest PLANning Model

approach is actually the best use of the land can also be analysed using efficiency criteria. Most public forests cover large, contiguous areas like those found in East Gippsland. Such forests need to be managed as a whole and decisions need to be made for operational purposes as to how much land is available for various uses.

Whether to have specialised or integrated land allocation is one of the key decisions to be made when managing public forests for multiple uses. The joint production framework can be used to give considerable insight into this problem, even if only on a conceptual basis. Two dimensional geometry limits the discussion to two outputs at one time. In practise, complex linear programming models are used to solve the multiple use management problem. Whilst it would be possible to work through paired combinations of outputs such as timber, watershed, conservation and recreation, the following analysis will concentrate on the two most contentious uses: timber and conservation.

Given an area of public forest, the forest manager must decide how to allocate the forest resources to meet both conservation and timber needs in the most efficient manner. The dynamic analysis tends to assume that the whole area will need to be used for both and so the rotation age for the whole forest should reflect both uses. An alternative is to designate certain sites for conservation only and others for timber production only. Then the rotation criteria need only be applied to the timber area. The allocation for conservation and timber seems to be an intuitive case for specialised production but the precise conditions will allow a more reasoned approach to the problem.

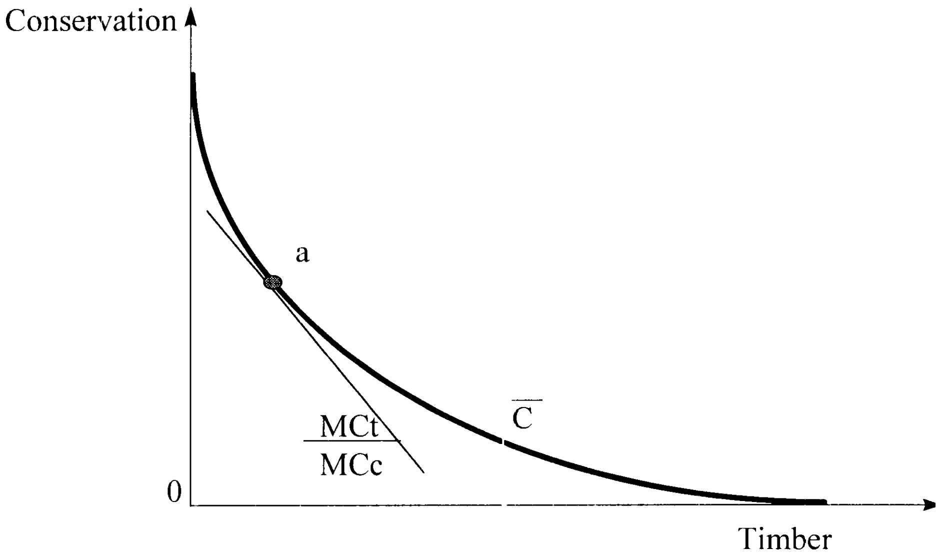
The decision to allow specialised production is favoured by diseconomies of jointness, by economies of scale and by differences in site productivity.[216] The relationship between two jointly produced products including economies of jointness can be illustrated using an output isocost curve for a forest site.

The technical production details are contained in the output isocost curve if the total cost function accurately reflects the underlying production function. The output isocost curve is analogous to a product transformation curve but the restriction is a given level of cost

[216] Bowes, op. cit. p. 64.

rather than a given level of resources. This is more appropriate when examining a public organisation who has a set budget from which to work and in a world where cost data is more readily available and measurable than resource data. The slope of an output isocost curve indicates the technical rate at which a producer is able to substitute one output for another in production while holding cost constant. The slope of the output isocost curve therefore equals the ratio of marginal costs.[217] The output isocost curve can be expected to be downward sloping because increasing timber production on a particular site will reduce conservation for the same total cost. Any attempt to maintain conservation in the face of increased timber production will almost certainly result in an increase in total cost and a shift to a higher output isocost curve.

Figure 4.4 Output Isocost Curve



The exact shape of the downward sloping output isocost curve illustrates the production relationship between the two joint products. Figure 4.4 shows that moving down along the output isocost curve from left to right increases timber production and reduces conservation. The slope of the output isocost curve becomes flatter indicating a relative increase in the marginal cost of conservation as timber production increases. The amount

[217] ibid. p. 61.

of this increase and therefore the shape of the output isocost curve will depend on the magnitude of the timber-conservation cross partial derivative: C_{tc}.

The cross partial derivative indicates the amount of increase in the marginal cost of conservation with a one unit increase in timber production when total costs are held constant. The cross partial derivative is a local measure, providing information only about a particular point such as point *a* in Figure 4.4. The sign of the cross partial derivative $C_{tc}(Q)$ at any output mix Q, indicates whether the products are complements, substitutes or independent in production. "Substitutes are those output pairs for which an increase in production of one leads to an increase in the marginal cost of the other. That is, products *t* and *c* are substitutes at output Q if $C_{tc}(Q) > 0$."[218] The corresponding output isocost curve would be convex to the origin over that range of output and the slope would be decreasing as more timber was produced as illustrated in Figure 4.4. "Complements are those output pairs for which an increase in production leads to a decrease in the marginal cost of providing the other. That is, products *t* and *c* are complements at a given output mix Q if $C_{tc}(Q) < 0$."[219] The corresponding output isocost curve would be concave to the origin over that range of output because the slope would increase as more timber was produced.

Curvature of the isocost curve is a major determinant of whether specialised or integrated production is least costly.[220] The two products would not necessarily be complements or substitutes over the whole range of output. Consequently, the isocost curve may not be concave or convex over the whole range of output possibilities but some combination of the two shapes.[221] It is quite likely that Conservation and Timber will be substitutes at every level of output indicating that they may be global substitutes. If this is the case, as Figure 4.4 suggests, both cross partial derivatives will be positive over the full range of output, giving diseconomies of jointness and supporting the intuitive conclusion that specialisation in production will be the least cost alternative. Diseconomies of jointness refers to the situation where producing two products jointly costs more than producing

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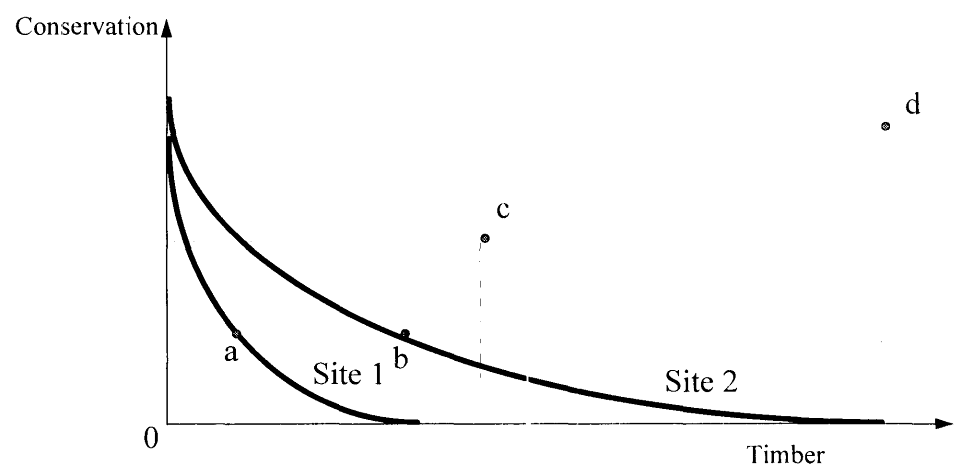
[218] ibid. p. 57.
[219] ibid. p. 57.
[220] ibid. p. 61.
[221] ibid. p. 58.

them separately. That is: C(Qt,Qc)>C(Qt,0) + C(0,Qc)[222]. To illustrate this, both site productivity and social preferences need to be considered.

The position of the output isocost curve in output space would indicate a site's productivity relative to other sites. The forest manager must allocate resources for the whole forest in the most efficient way. Efficiency in this context can be measured in the total amount of output for the given cost represented by the output isocost curve. Therefore the rule of comparative advantage would apply, requiring that each site specialise in the product in which it is relatively more productive. Such specialisation assumes that each product has positive value in consumption, and that more is preferred to less by society. This assumption will be qualified in the discussion on social preference.

Figure 4.5 shows that more of both products will be available for consumption if the sites specialise in the product of its comparative advantage. This will be so as long as the two sites have different productivity, even if one particular site is absolutely more productive in both products.

Figure 4.5 Differing Site Productivity



[222] ibid. p. 69.

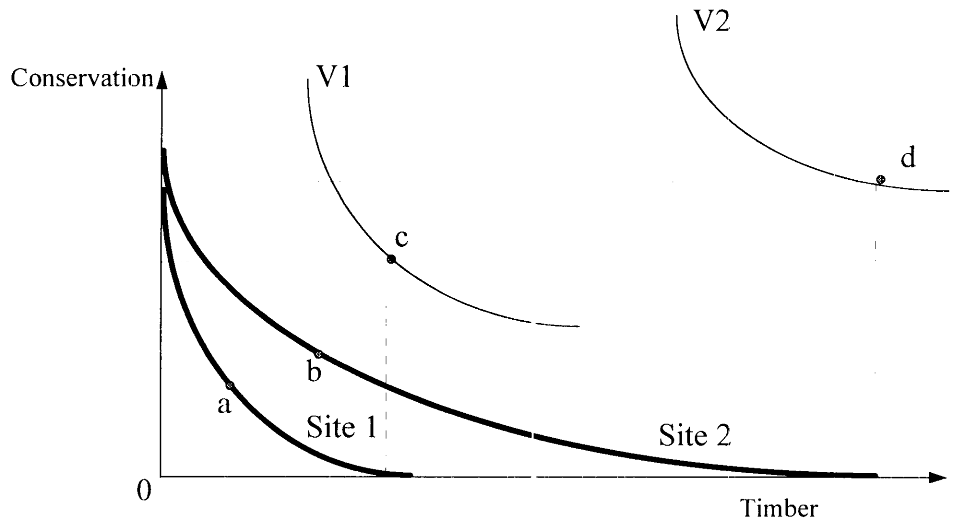
Figure 4.5 shows that Site 2 is absolutely more productive at producing both timber and conservation for a given cost but is relatively better at producing timber when compared with Site 1. If each site produces approximately even amounts of each product in an integrated operation such as points a and b, the combined production will be point c. For the same cost, a much higher combined production point (such as point d) can be obtained if each site specialises completely in its comparative advantage product. This is because as Site 2 approaches the maximum production of timber, MC_t/MC_c is at the lowest point and as Site 1 approaches the maximum production of conservation, MC_c/MC_t (MC_t/MC_c) is at its lowest (highest) point. It is easy to see that Site 2 can produce more timber at a lower marginal cost than can Site 1 so it would therefore be more cost effective for Site 2 to specialise in timber production.

Whether point *d* is actually preferred to point *c* by society depends upon social preferences represented by an isovalue curve. The isovalue curve represents combinations of the two products which will give equal benefit to society.[223] In the case of privately owned forest which is set aside solely for timber production, the isovalue curve may be the same as an isorevenue curve. However, in a public forest which may produce more benefits than just revenue from timber, the term isovalue is more appropriate. Similar to the isocost, the isovalue curve is expected to be downward sloping indicating that there is some substitution in consumption. It is often also expected that the isovalue curve will be convex to the origin exhibiting diminishing marginal valuation of both products (marginal values are positive but declining). However, the exact shape and position of the isovalue curve depends upon the marginal valuation of each product and the structure of the industry in which the products are produced. For example, a linear isovalue curve will occur where the industry structure is perfectly competitive while a positively sloping isovalue curve will occur where one product has negative marginal value. In the case of timber and conservation, both can be assumed to have positive value, ruling out an upward sloping isovalue curve. If all of the land is publicly owned and managed, the possibility of a perfectly competitive situation is minimal. It could therefore be cautiously concluded

[223] ibid. p. 39.

that the isovalue curve for conservation and timber would be convex to the origin making point d superior to point c as shown in Figure 4.6.

Figure 4.6 Preferences



Efficient forest management would aim to produce a combination of products such that the highest isovalue curve is reached for a given cost (or that cost is minimised for a certain level of output). In figure 4.6, this condition is achieved by point d on V2 where each Site is completely specialised in its comparative advantage good. Figure 4.6 also illustrates that the isovalue curves would have to be quite sharply upward sloping in order for point *d* to be on a lower isovalue than point *c*.

For conservation and timber production as illustrated in Figure 4.6, the combination of convex output isocost curves and a large difference in site productivity makes specialised production the most efficient solution to this forest allocation problem. The conservation/timber example seems reasonably straight forward, but the complexity of also including watershed, recreation and other nontimber uses is evident. In East Gippsland, the specialised approach is taken with the forest management zoning system. It is not clear whether the decision to zone the land is based on efficiency or on administrative convenience. Large areas are reserved for conservation in National Parks, smaller areas are set aside in special protection zones to protect wildlife corridors and water catchment areas. The remaining areas are managed solely for timber production with logging prescriptions providing for conservation and water catchment values. Recreation and tourism are not specifically provided for in East Gippsland, but National Parks cater for nature based recreation while other recreators have access to State forest for hunting and horse riding.

The land zoning system in East Gippsland allows specialised timber production and logging prescriptions are supposed to ensure ecologically sound harvesting practice. Given the constraints necessary to protect wildlife, heritage and water catchment values, it seems appropriate to manage the General Management Zone intensively for timber rather than extensively for all multiple uses. Chapter 5 will explore the intensive management option by calculating an economic rotation for the net productive area of the General Management Zone.

CONCLUSION

The market based optimal rotation solution gives a foundation from which to discuss issues of multiple use, discount rates and market failure. The economic rotation also gives some benchmark against which to measure the efficiency of current operations in East Gippsland and the resulting return to the public for the commercial utilisation of the forest.

CHAPTER 5: FOREST MANAGEMENT IN EAST GIPPSLAND

INTRODUCTION

Primary decisions about forest resource use for timber production in East Gippsland begin at the planning or forest management level. The rotation age which is set at this stage of production will determine the volume, quality and availability of timber for commercial use.

Chapter 5 will apply the economic theory of forest management to the particular case of East Gippsland.

An economic solution to the forest rotation problem will be calculated for East Gippsland. The implications of this timber-only solution for sustainability and multiple uses will be addressed. Finally, a simulation using actual inventory data will explain how the economic solution translates to harvest scheduling decisions.

ECONOMIC SOLUTION FOR FOREST MANAGEMENT

Maximising Return to Public

The economic solution for forest management prescribes a forest rotation period which maximises return on the forest investment rather than maximising annual timber volume as is calculated for sustained yield. As was shown in Chapter 4, the economic rotation will always be shorter than the sustained yield rotation unless the prevailing interest rate (discount rate) is zero.

Leaving arguments about the appropriate rate of discount aside, the economic rotation will be shorter than the sustained yield rotation in Victoria due to the State Government's requirement of 4% real return. The 4% requirement is applied to all State Government investments and gains support from the international 10 year bond yield which is approximately 5 % when averaged over the past two decades.[224] The international 10 year bond yield would be an acceptable proxy for a social rate of discount as it measures the opportunity cost of society's investment in any capital project.

It may be recalled from Chapter 4 that a sustained yield rotation has the aim of maximising timber volume (or value). This is different to the economic rotation which aims to maximise profit from timber operations. Figure 4.3 in Chapter 4 shows that with a discount rate of more than 0%, the sustained yield solution will always produce a longer rotation than the economic solution and consequently will always yield less than maximum profit. The discount rate in Figure 4.3 of Chapter 4 is set at 4% which is consistent with the Victorian State Government's investment return requirements. Profit is maximised at rotation T_F after the opportunity cost of delaying harvest has been accounted for, given a discount rate of 4% per annum. This time cost is the major cost component in forestry with planting or regeneration cost variation making very little difference to the final outcome. It would therefore be impossible to earn 4% per annum using a sustained yield rotation which is longer than the economic rotation.

The current sustainable yield management technique seems to have evolved as the solution to the forest allocation problem and meets the historical need to sustain the industry for the benefit of the region. In recent years, returns to the public from utilisation of forest resources has become important, with royalties being increased to better reflect market prices. Consequently, the revenue collected for timber production in any one year may outweigh the costs, giving the impression that a reasonable return is being made. This result only guarantees a return on current expenditure and does not account for the use of a public asset for 80-120 years. This seems to be true for most regions in Australia as confirmed by an ABARE study: "The State forest services appear to achieve either 'normal' or less than 'normal' returns on investment in labour and capital equipment used

[224] pers. comm. Michael Crowley, Monash University September 1997.

in native forests, but have generally not claimed financial returns on the capital value of the standing forest."[225]

In a submission to the Victorian Timber Industry Inquiry, this observation was made by FORTECH in 1984: "To make gains in efficiency, the government has commenced reform in the management of the public sector, particularly in relation to economic and financial management. It has adopted investment and pricing policies to achieve a minimum of 4% per annum real rate of return. It intends to eliminate cross-subsidies by relating prices to the costs of supply, and for some scarce resources it is aiming at taxes to price them at their opportunity costs."[226]

In 1993, the Victorian Auditor General completed an audit of the implementation of Victoria's Timber Industry Strategy, and drew the following conclusions about the success of the government's plans with regard to efficiency in forest management: "As a Balance Sheet for native State forests is yet to be prepared, there is currently no basis on which to assess the rate of return in this area. Nevertheless, the statements prepared to date indicate that the return from forest operations is still far from the Strategy target of 4 per cent. In fact, the loss made on native forest operations would indicate that some degree of subsidy is currently provided to industry in this area."[227] It should be noted that this conclusion referred to the whole of Victoria, not just the East Gippsland Forest Management Area.

The economic method of calculating an optimal forest rotation specifically takes account of returns on the capital value of the forest and land by maximising net revenues over time.

Economic Rotation

Just as with the sustained yield calculation, the lack of data available on the growth rates of native forests prevents an accurate calculation of the economic rotation. The East

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[225] ABARE, Forestry and conservation: an examination of policy alternatives Submission to the Resource Assessment Commission, Commonwealth of Australia, June 1990, p. 22

[226] FORTECH A Report on the Efficiency of Resource Use for Supplying Wood Commissioned Paper of the Board of Inquiry into the Timber Industry in Victoria September 1984 p. 8

[227] Victorian Auditor-General's Office Special Report No. 22 Timber Industry Strategy Melbourne May 1993 p.135

Gippsland Statement of Resources, Uses and Values recognises that this is a limitation to accurate planning. "Knowledge of growth rates for East Gippsland forests is poor since there has been only limited local research on specific species, primarily Silvertop (E. sieberi). Much of what is known is based on extrapolation from similar forest types in other areas."[228] Using what is available, the suggested economic rotation for a high-sawlog productive forest is approximately 50 years. The margin for error in this calculation is high but not significant for the overall conclusion. The purpose of the economic rotation calculation is to illustrate that forest resources will be more efficiently used if an economic rotation is adopted, than with the current sustained yield rotation. The explicit outcome of the calculation is not designed to be prescriptive, but rather to illustrate the process of implementing the concept of an economic rotation.

In general terms, the Faustmann economic rotation explained in Chapter 4 results in a shorter rotation than the timber maximising sustained yield. It can therefore be concluded that a sawlog-only economic rotation will be shorter than the current sustainable yield rotation age of 120 years for Coastal and Alpine Mixed Species, and 80 years for all other forest types.

A private forest owner would usually plant the same species of trees in each area of land as a plantation. This means that the same volume function could be used over the whole plantation or part of the plantation to represent each species which is grown in constant conditions. While some areas of native forest in East Gippsland are set aside for timber production only, they cannot be compared directly to a plantation because of the natural composition of species and density. Most forest in East Gippsland is comprised of mixed species and varying size and quality according to the growing conditions. Regrowth stands also carry these characteristics because the regeneration process attempts to maintain the natural features of the forest. Therefore the same coupe could yield several different species of tree or the same species could yield different volumes in different coupes, potentially giving a different volume function for every species in each coupe.

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[228] Department of Conservation and Natural Resources, *East Gippsland FMA - Statement of Resources, Uses and Values*, Melbourne, January 1993 p. 133

Extensive growth and volume analyses have been completed for the Douglas Fir species in the United States. Although growing time and timber yield could obviously be quite different for East Gippsland eucalypt forests, it would be reasonable to assume that the pattern of growth is much the same. Opie et al describe the growth pattern of the eucalypt species: "Compared with many other forest species, the eucalypts are capable of very rapid height growth at an early age. The majority of eucalypts achieve their largest annual height increment between the ages of 5 and 10 years. For example, E. regnans [Mountain Ash] achieves half its final stand height by age 20 years.....Most even-aged stands of the fast growing eucalypts attain maximum current annual increment (CAI) in basal area by 10 years, and in volume by age 20 years. Maximum mean annual increment (MAI) in volume usually occurs by age 50 years."[229]

The following depiction of forest volume over time is derived from a third degree polynomial function used by Clawson for Douglas Fir.[230] The function was arbitrarily adjusted to fit the volume data and mean annual increment of East Gippsland forest types having an 80 year rotation.

The Faustmann analysis simply equates marginal benefit with marginal cost. A delay in harvest gives a marginal benefit of $P_sV_s'(T)$ for sawlog only values.

$$P_sV_s'(T) = \frac{i[P_sV_s(T) - C]}{1 - e^{-iT}}$$

The right hand side of this equation gives the marginal sawlog cost of leaving the forest standing for one more period of time. Dividing both sides by $P_sV_s(T) - C$ gives the following relationship and diagram explained in Chapter 4:

$$\frac{P_sV_s'(T)}{[P_sV_s(T) - C]} = \frac{i}{1 - e^{-iT}}$$

[229] J.E. Opie, R.A. Curtin and W.D. Incoll Stand Management, Chapter 9 in W.E. Hillis and A.G. Brown (Eds) Eucalypts for Wood Production, CSIRO Australia, Academic Press, Melbourne 1984, p. 185
[230] Tietenberg, Tom Environmental and Natural Resource Economics 4th edition Harper Collins College Publishers, NY 1996 p. 249

This equation means that the trees should be harvested when the rate of growth in revenue is equal to the adjusted interest rate being the opportunity cost of leaving the forest standing for one more period of time. The optimal rotation for sawlog only is shown in Figure 5.1 as the thin solid line given the following assumptions:

$$V = 0.5T + 0.05T^2 - 0.00035T^3$$

The volume function is rather arbitrary except for its origins in a Douglas Fir function. It does, however, fit the actual volume and mean annual increment which occurs in East Gippsland at the sustained yield rotation age of 80 years. The precise behaviour of the function at earlier ages may not be accurate but, as mentioned earlier, is of little consequence. The volume describes sawlogs of D+ quality so assumes that the logs will be at least of D grade merchantable quality regardless of the rotation age.

C = 1000

Costs of $1000 may seem quite high but must include the cost regeneration (planting) and the costs of meeting the logging prescriptions. For example, seed and habitat trees need to be identified before logging can begin, wildlife corridors and streamside buffers need to be left undisturbed.

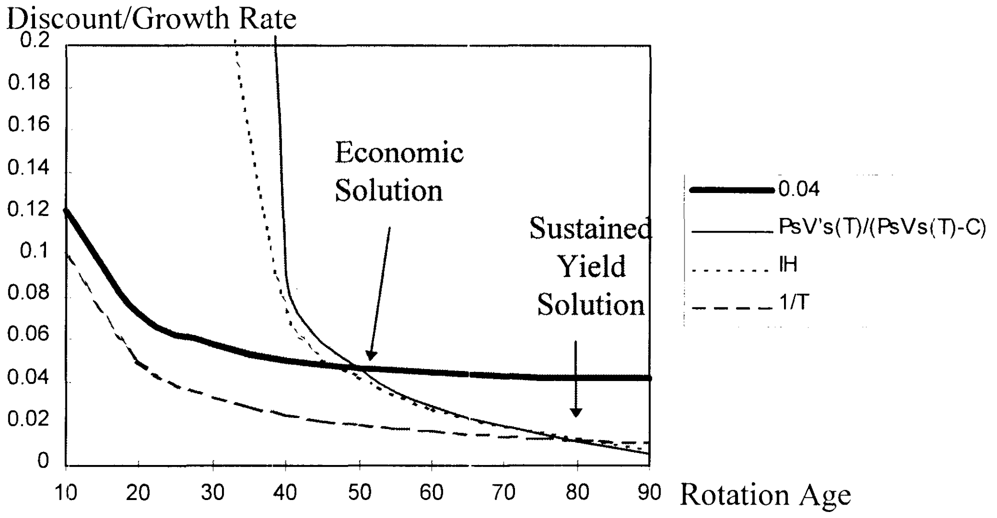
i = 0.04

The discount rate of 4% is set by the State Government of Victoria.

P = 20

The price is a conservative average of current sawlog prices.

Figure 5.1 Comparison between Economic Rotation and Sustained Yield Rotation



The assumed information gives the sustained yield rotation of 80 years where the sawlog function PsV's(T)/(PsVs(T)-C) intersects with 1/T and an economic rotation of approximately 50 years where the sawlog function intersects with 0.04. The mean annual increment is maximum at 80 years being 2.58 m^3 per hectare per year which is approximately consistent with the forest types having an 80 year rotation. The absence of accurate growth data, knowledge of future prices and exact costs make this calculation no more accurate than the existing sustained yield projections. The IH curve in Figure 5.1 represents the integrated harvesting case, the discussion of which occurs in the next section.

The results are similar to those concluded in the economic study completed for the Young Eucalypt program by the CSIRO. The purpose of the Young Eucalypt Program was to "examine the implications of different ways of managing some of the faster-growing, ash-type eucalypts and of using the young wood."[231] The focus of the study was on thinning as a silvicultural method to increase the useable wood produced by a forest area. Part of the study was an economic analysis of the costs and benefits of alternative management

[231] Kerruish, C.M. and Rawlins, W.H.M. (Eds) The Young Eucalypt Report - some management options for Australia's regrowth forests, CSIRO Australia 1991 p. 2

regimes. The conclusion drawn from the economic analsysis was that: "The thinned regimes have higher NPVs than the unthinned regime and this ranking is insensitive to changes in key parameters which were the subjects of the research projects. NPV calculations present here suggest that there may be significant financial gain from thinning regrowth forests."[232] Closer examination of the study reveals that the management regime with the most amount of thinning also assumes the shortest rotation. It is likely that the short rotation of 50 years is the reason for the highly thinned stand having the highest NPV when compared with the other regimes assuming rotations of 60, 65 and 80 years. The fact that "the simple effects of bringing forward the clearfelling operation by 30 years when real interest rates are 4% per annum is a major economic advantage" is recognised in the report but not emphasised.[233]

The practice of thinning and the consequent economic analysis in the Young Eucalypts Program appear to be as much devoted to maintaining timber volume and sawn timber quality as maximising economic return. It seems that the rotation period was only able to be shortened if the thinning resulted in an equivalent timber volume. This may explain the acceptance in East Gippsland of thinned foothill mixed species which are able to be harvested at age 55 years.[234]

Additional support for a shorter rotation can be found in Opie et al where a number of alternative stand regimes are suggested. A regime exhibiting long rotations for sawlogs without thinning has a rotation of approximately 60 years. However, the following qualification is given: "Hastings and Opie (1974) showed that for both E. regnans and E. delegatensis the profitability of such a regime depended very much on initial density, which should be as low as possible commensurate with minimum requirements for tree form and site occupancy. With significantly higher initial densities, rotations of 80 years and more are required to produce sawlogs having the size distribution required currently by the industry. The regime, possibly with a longer rotation, may be appropriate where one of

[232] ibid. p. 6.
[233] ibid. p. 266
[234] DNRE Review of Sustainable Sawlog Yield East Gippsland Forest Management Area Forest Service Technical Reports 96-2 Victoria November 1996 p.12.

the main objects is to manage for nonwood benefits such as water or fauna."[235] Both the initial densities and the nonwood objectives may be reasons for longer rotations in East Gippsland. These factors do not, however, change the basic conclusion that an economic rotation provides a higher return to the public than sustained yield criteria.

Integrated Harvesting

It is almost inevitable that integrated harvesting will be undertaken in East Gippsland in the future, if only for the silvicultural benefit of making regeneration more effective. It is therefore necessary to briefly consider the impact of integrated harvesting on the economic rotation.

When looking at the overall forest resource, many studies have concluded that short rotation for pulpwood only would be the optimal economic solution. This may be true but is not feasible from a political or an industry adjustment point of view. The East Gippsland timber industry is currently geared towards mature and overmature stands for sawing. Sawing younger timber requires different production technology than is currently used in East Gippsland. Although some adjustment will occur as regrowth forest becomes available for harvest, it would not currently be feasible for industry to switch to pulpwood only production due to high investment costs.

The Victorian Timber Industry Strategy has clearly averted the short rotation pulpwood only option by insisting on the 'sawlog-driven concept' of forest management. For East Gippsland this means a strong adherence to the log grading system with no possible substitution between sawlogs and residual logs.

The log grading system fixes the proportion of residual log to sawlogs in any one hectare at any one time. This does not mean that the proportion would not change over time or over the whole forest management area. Giving preference to sawlogs in production means that large amounts of residual log will only become available after sawlog quality begins to deteriorate with age.

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[235] Opie et al, op. cit. p. 194

The precise impact that integrated harvesting has on the rotation length when compared with the sawlog-only rotation can be predicted using the same approach as Hartman did with multiple use forestry. The log grading system potentially gives information about five different products and prices for sawlog grades A to D and Residual Log. The analysis will be limited to two products: sawlogs and residual logs.

The sawlog only solution is determined (as above) by:

$$\frac{P_s V_s'(T)}{\left[P_s V_s(T) - C\right]} = \frac{i}{1 - e^{-iT}}$$

The sawlog volume function $V_s(T)$, cannot be altered to include residual log merely by allocating a proportion of the tree growth to residual log production. A separate volume function is required for residual log to illustrate its unique relationship with time and so that the separate residual log price can be applied to the volume when calculating revenue.

The residual log category is defined as anything which is too small or defective to meet sawlog specifications.[236] This includes branches, crooked sections of trees and severely defective trees.

The yield curve of residual log is likely to be much flatter than that for sawlog only. Figure 5.2 shows that the proportion of sawlog to residual log is quite low in the very early years of forest growth because very few trees would have the size to be classified as sawlogs while almost all would suffice as residual log. It is unlikely that either the volume or the value would be sufficient to harvest at this stage. As the trees begin to grow more quickly, sawlog production would increase relative to residual log production as the trees become larger leaving only branches for residual log. In the later stages of tree growth, sawlog production will stabilise and eventually decline as trees deteriorate and acquire growth defects. During this phase, some of the sawlogs may become residual log and more

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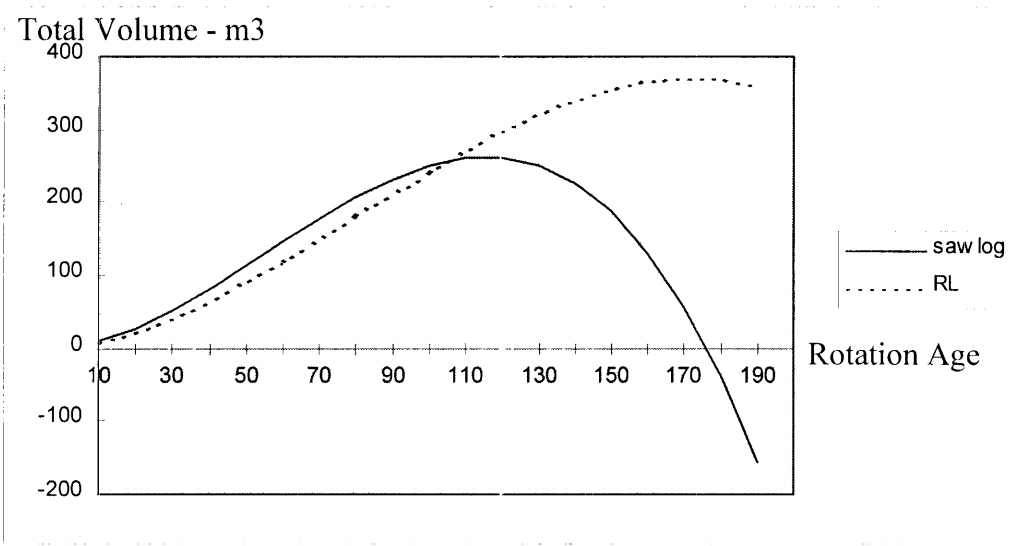
[236] Comprehensive Regional Assessment East Gippsland Resource and Economics Report Joint Commonwealth and Victorian Regional Forest Agreement (RFA) Steering Committee July 1996 p. 36

insignificant undergrowth will occur, thereby increasing the proportion of residual log to sawlog. This situation can clearly be seen by the mature forests of East Gippsland yielding a significantly higher proportion of residual log to sawlog than the younger regrowth forests. The East Gippsland Statement of Resources, Uses and Values supports this: "Harvesting operations in regrowth forests above the minimum rotation age generally yield equal volumes of C+ and D- log, whereas mature/overmature forests generally yield C+ to D- log in the ratio 1:4.5."[237] This can be seen in Figure 5.2 where the volume of sawlogs has declined while the volume of residual log still continues to increase.

Figure 5.2 Stand Volumes for Integrated Harvesting



The two volume functions could be added together to determine total yield from the forest coupe but its usefulness would end there. It is the revenue and costs of the integrated operation which is of most interest. Revenue is determined by the price and volume. Residual logs attract a different price to sawlogs, so the volume of each must be multiplied by the respective prices to determine total revenue. The benefit of leaving the forest standing for one more period can be calculated by multiplying the marginal increase in each of residual log and sawlog volume with their respective prices. If this is higher than the marginal cost of leaving the forest standing, it would be beneficial to delay harvest until

[237]Department of Conservation and Natural Resources, *East Gippsland FMA - Statement of Resources, Uses and Values* op. cit. p. 135

the marginal benefit equals the marginal cost. Including residual log production in the product mix increases both marginal revenue and marginal cost because while extra revenue is drawn from the harvest, there is extra opportunity cost involved because the forest is now also valued for its residual log production. The following equation shows this by including residual log revenue in the right hand side along with sawlog revenue:

$$P_sV_s'(T) + P_rV_r'(T) = \frac{i\left[P_sV_s(T) + P_rV_r(T) - C\right]}{1 - e^{-iT}}$$

The jointness in production means that sawlog-only production assigns all of the joint cost, C, to sawlogs. There are very few regeneration cost differences between sawlog-only and integrated harvesting, meaning that planting costs, C, would be the same as those in the sawlog-only function. The impact can be seen by rearranging the above equation and comparing it to the sawlog only case as in Figure 5.1. The integrated harvesting rotation can be seen in Figure 5.1 where the IH curve intersects the 0.04 curve.

$$\frac{P_sV_s'(T) + P_rV_r'(T)}{\left[P_sV_s(T) + P_rV_r(T) - C\right]} = \frac{i}{1 - e^{-iT}}$$

The results indicate that integrating harvesting makes very little difference to the rate of growth in the value of the forest over time as long as the price of sawlogs is higher than residual logs. As the price of residual logs is increased relative to sawlogs, the rotation is lengthened, as a longer growing period produces relatively more residual log under the log grading system. It is unlikely that a significant change in price would occur in East Gippsland unless a large processing plant required large volumes of residual log over a long period of time and therefore increased the value of residual log. If this were to occur, the merits of the log grading system would surely come into question, allowing the lower grade sawlogs to be used for residual log purpose and therefore shortening the rotation.

Given the apparent insignificance of integrated harvesting in determining the economic rotation and the general paucity of data from East Gippsland, no alteration will be made to the economic rotation calculated above.

SUSTAINABILITY

The general understanding of sustainability refers to retaining resources so that future generations are able to make decisions about the resources for themselves. "The sustainability criterion suggests that, at a minimum, future generations should be left no worse off than current generations."[238] The general problem surrounding sustainability of how much of our forests to use now and how much to leave for future generations is complicated by the renewable aspect of forests for timber production.

The term 'sustained yield' refers more to the sustainability of the timber industry and timber supply than of the forest from which the timber was sourced. Sustained yield results in a continuing supply of timber to the industry which specifically translates to the maximum possible annual yield from the forest. In order to achieve this result, the forest must be regenerated after harvest. The Comprehensive Regional Assessment carried out for the East Gippsland Regional Forest Agreement questioned whether the current sustainable yield estimates were adequate for forest planning in East Gippsland. Melbourne University consultants assessed the methodology for estimating sustainable yield as being "simple yet adequate given the extent and quality of available data."[239] This assessment validated the methodology of the calculation but did not make comment on the appropriateness of sustainable yield as a forest management tool.

Some land (such as native forest) has its economic value in growing forest over other agricultural or development uses. If this is true, there is every reason for the land manager to regenerate the forest site. In fact, one of the main features of an economic rotation is that time is important and the very reason that the rotation is shorter is because slower

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[238] Tietenberg, loc. cit.
[239] Appendix A: *Comprehensive Regional Assessment East Gippsland Resource and Economics Report* Joint Commonwealth and Victorian Regional Forest Agreement (RFA) Steering Committee July 1996 p 21

growing older regrowth is taking the space of faster growing newer regrowth. This gives even less weight to the argument that a forest manager using economic principles would not regenerate a forest site after harvesting. Therefore, if the general idea of sustainability is to leave substantial resource for future generations, then regeneration carried out by a manager using economic principles must be equivalent to regeneration carried out using sustained yield criteria.

Proponents of the sustained yield approach advocate that even timber flow is a specific outcome of sustained yield management. This concept is often linked to sustainability. For example: If the trees in the forest on average grow at 1 m^3 per year and the timber maximising rotation is 100 years, then cutting 1/100th of the total forest area each year will not only provide the same maximum yield to industry each year but will harvest only what the forest (on average) can replace with regrowth.

Firstly, matching the rate of harvest with the average rate of regrowth is only important if trying to maximise timber volume. The economic solution is less interested in volume and more interested in return, so therefore will harvest the forest at its maximum marginal growth rate. There is no violation of the general concept of sustainability here as the forest is still replacing itself.

Secondly, the even flow of wood is clearly important to industry but it does not only result from a sustained yield management regime. Regardless of the rotation chosen, when faced with a whole standing forest, the forest manager has the choice of harvesting the whole forest at once, or harvesting a portion of forest each year. If an even flow of wood is desired, then the whole forest area can be divided by the number of years of the rotation, and only that area harvested each year. When the whole forest area has been harvested once, the even flow of wood will be the natural result as each year one forest plot reaches the rotation age. With an 80 year rotation, the total forest area would be divided into 80 blocks and one block harvested each year. An economic rotation does not preclude the outcome of the area being divided into 50 blocks and one harvested each year. Under an economic rotation, each block would be larger and harvested more often than under a sustained yield management regime.

The only question about sustainability using an economic rotation is that of land (soil) productivity. Shorter rotations mean that the soil is used to support the fastest growing period of each rotation more frequently than would occur under a longer rotation period. This problem would be solved in economics when the lower soil productivity resulted in slower growing trees and would therefore reflect in the tree volume function, ultimately feeding through to a longer optimum rotation.

MULTIPLE USES

In a forest managed extensively for multiple uses, all uses of the forest would be given due consideration and the rotation of the forest for timber purposes be adjusted accordingly. Such an approach assumes that the whole forest area should be managed for all possible uses, timber being just one of them. Genuine extensive forest management in the East Gippsland FMA would involve fewer National Parks and conservation reserves and consideration of all forest values at the base planning level. Timber would not be given preference over other forest values unless complete specialisation was the optimal outcome. A longer economic rotation period is the likely outcome of true extensive management due to the extra net benefits of non-timber uses, many of which increase with time. The timber only calculation is validated in this study due to the intensive nature of forest management. The multiple uses in East Gippsland's forests have demanded specialised land allocation for conservation and timber resulting in a land zoning system which gives dominance to one use over another. The result is that some forest uses are not specifically considered, but timber and conservation are given exclusive rights in their respective zones.

The land zoning system in East Gippsland allocates areas for conservation in National Parks and the Special Protection Zone. Timber production is given priority in the net productive area of the General Management Zone. This type of land use system is consistent with the theoretical concept of specialisation in joint production as illustrated in Figure 4.6 of Chapter 4.

Timber is the dominant use of forests in the East Gippsland General Management Zone (GMZ). The Timber Production Subzone of the GMZ covers 332 600 ha of forest accounting for 52% of state forest and 32% of public land. Forest in this zone will be managed for the production of sawlogs. Secondary aims of the whole GMZ include protection of landscape, provision of recreation and educational opportunities, fire protection and conservation to complement adjacent zones.[240]

Multiple uses have been considered by specialising production across the forest management area and prescribing strict logging procedures to minimise environmental impact, leaving no reason to explicitly consider non-timber uses in the management of the GMZ. Therefore, the net productive area of the GMZ could be managed intensively for timber production in much the same way as is a private plantation. The Victorian Code of Forest Practice contains logging prescriptions for both private and public forests. The requirements are somewhat more stringent for public native forests than for private plantations and this generally feeds through to the costs of production. Therefore, an economic rotation which considers these costs and which has already set aside conservation zones, streamside buffers and wildlife corridors, fully takes account of the conservation use of those forest zones.

Despite this observation, relatively long rotation periods of 80 and 120 years are used in East Gippsland which is in conflict with managing the forest intensively for timber. The conflicting practice of long rotations combined with specialised production may be due to the extreme political sensitivity of public forest management or may simply be due to the historical yield maximising approach to forestry.

MORE EFFICIENT HARVEST SCHEDULING

Shortening the rotation of East Gippsland native forests will make some regrowth forest available now for harvest. This will relieve the pressure on mature stands of forest to meet the sawlog commitments during the next 30 years.

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[240] CNR *Proposed Forest Management Plan East Gippsland Forest Management Area* Conservation and Natural Resources February 1995 p. 8

Preliminary calculations using the East Gippsland forest inventory indicate that some 1.4 million cubic metres of D+ sawlog do not need to be harvested from mature/overmature forest if efficiencies in forest management are achieved. Some basic assumptions underpin these calculations:

1. The economic rotation for Coastal and Alpine Mixed Species is 80 years and 50 years for all other forest types.
2. The mean annual increment for the different forest types at the sustainable yield rotations were[241]:

Alpine Ash	2.75 m^3/ha/year
Mountain Ash and Shining Gum	3.30 m^3/ha/year
Mountain Mixed Species	2.40 m^3/ha/year
Foothill Mixed Species	1.80 m^3/ha/year
Alpine Mixed Species	0.60 m^3/ha/year
Coastal Mixed Species	0.60 m^3/ha/year

3. The yield achievable at the economic rotations is 70% of that achievable at the sustainable yield rotations of 120 years and 80 years respectively. This is based on rotation variations in Sharp et al. [242]
4. The conversion rate from gross harvest to net harvest is 0.8 m^3 of net for every 1 m^3 of gross. This conservative estimate is based on the conversion rates for the different grades of logs: B - 0.96, C - 0.87 and D - 0.73.[243]

[241] DNRE *Review of Sustainable Sawlog Yield East Gippsland Forest Management* op. cit. p. 10.
[242] Sharp, Richard *Regeneration Costs Under Alternative Silvicultural Systems in Lowland Schlerophyll Forest* VAUS Project Department of Conservation and Natural Resources May 1993, p. 27.
[243] pers. comm. Gary Featherston Department of Natural Resources and Environment, Orbost, 14-1-97

The following process was applied to the available area of the inventory data in order to arrive at the preliminary calculations:

1. The D+ gross sawlog inventory values were converted to net values.
2. The regrowth was extrapolated using the mean annual increment for the sustained yield period.
3. The regrowth yield was then discounted by 30% to reflect the shorter rotations.
4. The economic rotations were applied to the inventory to determine which years the regrowth would be available for harvest.
5. Harvest of regrowth was scheduled for the soonest possible date.
6. Mature and Overmature forest was used to make up the balance of the annual sawlog commitment of 250 000 m^3.

Table 5.1: Proposed harvest schedule using economic management criteria. Volume (m^3) of D+ Sawlog able to be harvested in each period.

Forest Type	1995	2005	2015	2025	TOTAL
AA RH	69770.4		18788	256872	
AA RL					
MASHG RH	3755.92		24024	138784.8	
MASHG RL					
MASHG UNES	1232				
MMS RH	394497	150310.2	279207.6	740174.4	
MMS RL	924	1551.2	37646	20880.16	
MMS UNES	27700.8				
FMS RH	243488	169288	452797.5	737458.4	
FMS RL	2419.2	12146.4	14252	17640	
FMS UNES	60890.4				
CMS RH			2872.8	16884	
CMS RL					
CMS UNES	231434.4				
Total RH	711511	319598	777690	1890174	3698973
Total RL	3343	13698	51898	38520	107459
Total UNES	321258	0	0	0	321258
Total Regrowth	1036112	333296	829588	1928694	**4127690**
Mature/om	1463888	2166704	1670412	571306	**5872310**
Total Harvest	2500000	2500000	2500000	2500000	10000000

The following notation applies to Table 5.1:

AA - Alpine Ash
MASHG - Mountain Ash and Shining Gum
MMS - Mountain Mixed Species
FMS - Foothill Mixed Species
CMS - Coastal Mixed Species
RH - Regrowth forest of high sawlog productivity (>40 m^3/ha)
RL - Regrowth forest of low sawlog productivity (<40 m^3/ha)
UNES - Uneven aged stands carrying sawlog volume

Table 5.1 indicates the harvest yields using economic forest management guidelines. Regrowth forests have been scheduled for harvest according to the economic rotation with the remainder of the annual yield made up of mature and overmature stands. The harvest periods cover 10 years. Therefore all stands harvested would have the economic rotation as the minimum. Low productivity regrowth forests are given logging preference over mature/overmature stands. The table extends to the 10 year period following 2025. After this point, the harvest of mature/overmature stands would not be necessary and the yield would be higher than 250 000 m^3/year of D+ net sawlogs. The table shows that the current annual sustainable yield can be achieved by harvesting only 5 872 310 m^3 of sawlogs from mature/overmature forest. This is 1 418 591 m^3 less than the 7 290 902 m^3[244] required to be logged under the current sustainable yield management criteria. The current sustainable yield regime will use large areas of mature/overmature forest until the year 2048 with the long term sustainable yield volume not being reached until the year 2148.[245] The spreadsheet used to calculate the data in Figure 5.1 is contained in the Appendix - Economic Harvest Schedule.

The more efficient outcome is the clear result where the same yield of timber is available from a reduced area of land. The result could be viewed as a way of increasing input to

[244] DCNR Hardwood Timber Resources in the East Gippsland Forest Management Area Areas and Volumes report Resource Assessment Report No 93/01 Summary Statement of Hardwood Forest Resources, Melbourne 1993 pp 1-3

[245] DNRE Review of Sustainable Sawlog Yield East Gippsland Forest Management op. cit. p. 17.

industry by harvesting the extra timber or a way of contributing more land to conservation reserves. It is unlikely that this extra timber would be harvested because even with the more efficient outcome, foresters will be forced to log uneconomic forest sites just to meet the existing 250000 m^3/year sawlog commitment. The extra cubic metres of timber would ease the pressure on harvest scheduling so that the lowest productivity sites could be left unharvested. For example, logging could be ceased in the low productive Coastal Mixed Species where 955 915 m^3 of D+ sawlog stand and 27% of the low productive Foothill Mixed Species would not be logged, making up the remaining 462 676 m^3 of D+ sawlogs. If this option was selected, 51845 hectares of forest would not be logged from the Coastal Mixed Species forest type and 20218 hectares would not be logged from the Foothill Mixed Species type. This is a significant proportion of land given that the Regional Forest Agreement process only returned a net area of 8300 hectares to reserves and still had a small reduction in sustainable yield. A more likely outcome to the economic solution is that the least productive sites would be left from each forest type.

Just as each forest site is not equally as productive for timber, different forest sites carry different conservation values. Therefore taking the lowest productive timber producing sites and offering them as conservation reserves may not result in an increase in conservation values. An ABARE study recognised that: "The greatest potential for conflict exists in old-growth forests which have high conservation values and high potential wood productivity. As Cameron and Penna (1988) point out, the species composition of such forests may not be replicated in regrowth. Some of those forest may also have distinctive site values, as wilderness, which are dependent on non-disturbance."[246] Despite this observation, having some mature/overmature standing forest to spare should allow for more flexibility regarding the size of conservation reserves than the current system offers.

The sawlog licences making up the sawlog commitment of 250 000 m^3/year are a maximum of 15 years long. This means that the annual yield from the forest could be dropped long before the year 2035. If this was possible, all forest sites which could not return 4% over the longer term could be removed from the net productive area of forest and

[246] ABARE op. cit. p. 32

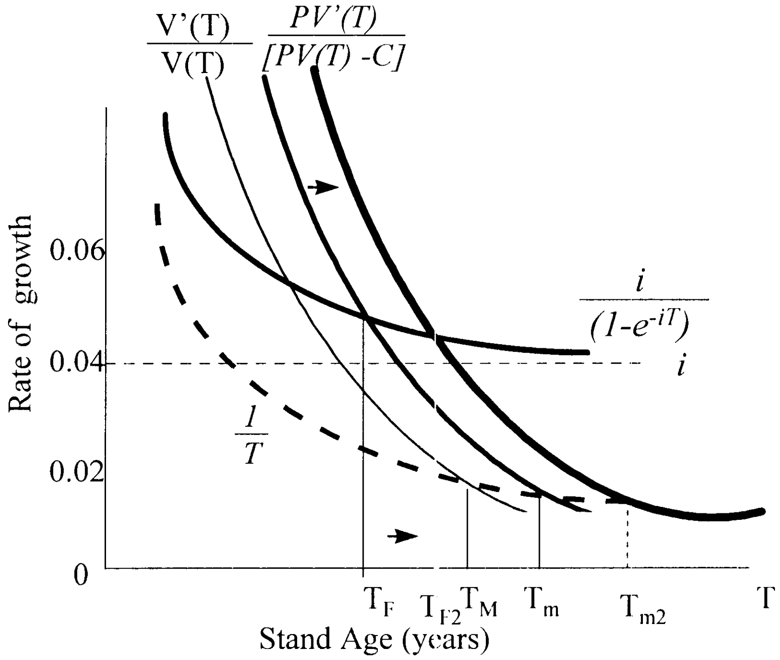
the annual yield recalculated to reflect the economic area to harvest using economic rotations. The result would be a smaller, more intensively managed forest.

LIMITATIONS OF ANALYSIS

The lack of local and relevant stand growth information is a severe limitation of the analysis, but not of the framework which has been used.

A limitation of the analytical framework is that price is considered to be constant throughout the rotation cycle. The explanation of comparative statics in Chapter 4 allows for changes to the optimal rotation age when price, the interest rate and regeneration costs change. The treatment of price in this way assumes that the same price can be obtained regardless of the quality of the sawlog. Since the quality of a sawlog may be associated with time (maturity), the price of a sawlog may also have a relationship with time. This problem could be overcome by making price a function of time within the optimal rotation calculation. It is beyond the scope of this study to test the theoretical validity of such an inclusion and to establish some empirical relationship between price and time. It is possible, however, to consider how a variable price may change the outcomes concluded above.

Figure 5.3 Economic and Sustained Yield Rotation



The comparative static explanation in Chapter 4 concluded that a decrease in price would lengthen the optimal rotation because the opportunity cost of leaving the trees standing is lower than if the price is high. The impact can be shown in Figure 5.3 if the PV'(T)/[P'V(T)-C] curve shifts up, thereby moving the T_F solution further to the right to T_{F2}.

Suggesting a shorter rotation than the current sustained yield solution may attract a lower price per m^3 of sawlog because the timber would be younger and possibly of lower quality. If this is built back into the model, what initially appeared to be a much shorter economic rotation than the sustained yield rotation, may be lengthened by this decrease in price. It can be seen that if T_M is the sustained yield solution, it would be possible for the economic solution to approach the sustained yield solution as the price became lower. (T_{F2} is closer to T_M than T_F). This would not be the case, however, if the aim of sustained yield was to maximise value from timber production at the T_m solution because T_m would move to the right along with T_F. After the shift in PV'(T)/[P'V(T)-C], Tm2 is the new value maximising solution. This should be compared with TF2 to see that if value is maximised for a sustained yield solution, a change in price makes no difference to the general conclusion that economic rotation will always be shorter than sustained yield rotation. The sustainable yield management regime used in East Gippsland maximises timber volume although the motives behind this decision are not clear. It could be that volume is maximised in the belief that higher volume is consistent with higher value.

This simple explanation by no means solves the problem or negates the complication. Another way of dealing with this is to predict the different mixes of sawlog products at various stand ages and the prices which can be obtained for each product (quality). The integrated harvesting model could then be extended to include five products instead of two and the importance of price would show through in the model. If, for example, the ratio of B grade sawlogs to the other grades of log was extremely high and the forest needed to stand longer to grow B grade quality logs, this may influence the optimal rotation by lengthening it. Once again, there is no scope in this study to test for accurate application.

Despite the limitations, it seems that the goals of forest management, rather than the exact outcome, should be brought into question. The public owns the forest and it has been decided to use some of that forest for timber production. It must be in the public's interests to maximise return from that production, rather than maximise timber volume. It is this fundamental change in thinking that is required before further progress can be made towards incorporating more complex issues.

CONCLUSION

Preliminary calculations confirm the theoretical result that an economic rotation will give a more efficient use of forest resources for timber production than the current sustained yield criteria. The economic criteria does not violate the general concept of sustainability nor the does it preclude the possibility of an even annual flow of wood from the forest. Integrating the harvesting of sawlogs and residual logs does not influence the rotation calculation unless the current ratio of sawlog to residual log prices changes significantly. The integration of harvesting does have important implications for the utilisation and allocation of forest resources. This will be discussed in chapters 6 and 7.