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FINANCIAL MATURITY OF TIMBER AND MAXIMUM NET PRESENT VALUES

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Simple financial maturity guidelines recommend harvesting timber when its rate of value growth becomes less than or equal to the highest rate that can be earned in other investments of equal risk. Several authors have shown that financial maturity guides are consistent with maximizing economic criteria such as net present value, but their results are sometimes accepted by foresters and land managers without being fully understood. In this article, financial maturity guides are derived in a way that is easily understood, simply by maximizing the present value of all future net income.

1. INTRODUCTION

The concept of financial maturity of timber is familiar to an entire generation of foresters and other land management professionals. Since an early presentation by Duerr *et al.* (1956), the concept of comparing timber value growth with an alternative rate of return has been widely applied in the field and widely discussed in the literature.

A particularly important aspect of financial maturity is the guideline's consistency with maximizing present net value or other economic criteria. If, for example, we cut a tree or a stand when its rate of value growth equals our alternative rate of return, are we cutting at the age that maximizes net present value? This question and other closely related issues have been discussed by several authors. Among the most cited references are Gaffney (1957), Bentley and Tegaarden (1965) and Samuelson (1976).

In this article, the consistency of financial maturity guidelines is addressed from a different standpoint: by maximizing a single economic objective. Although the results are not new, they are very easily demonstrated and understood with this approach.

2. SYMBOLS

The following symbols are used:

r = rotation age (years),

HV_r = net harvest value at rotation age r (dollars), including compounded costs,

i = interest rate representing the alternative rate of return (decimal percent),

e = base of the natural logarithms,

n = year of final harvest for an existing stand, and

C = a constant representing income obtained following a stand's removal (dollars discounted to year n).

3. MAXIMIZING AN ECONOMIC OBJECTIVE

Throughout this article, a single economic objective is assumed:

Timberland will be managed so that the present value of all present and expected future net income is maximized.

Timberlands are divided into two categories for discussion, those *with* and those *without* existing stands. Each group is considered with regard

to maximizing the objective above. For simplicity, indivisible timber capital is assumed (Duerr 1984), i.e., we want to determine the optimal time of harvest for an indivisible, even-aged stand of trees.

3.1 Lands Without an Existing Stand

For the bare land case, we want to establish the best level of investment and management regime based on maximum net present value. If only one rotation of timber is considered, the present value of future income is:

$$\frac{HV_r}{e^{ir}} \quad (1)$$

Although (1) does not consider *all* future timber income, the expression leads to a frequently used financial maturing guideline. To determine the age of harvest that maximizes (1), we set the first derivative of (1) with respect to r equal to zero:¹

$$\frac{e^{ir} \left(\frac{dHV_r}{dr} \right) - HV_r (e^{ir} i)}{e^{2ir}} = 0. \quad (2)$$

Solving equation (2) for i yields the simple, unadjusted financial maturity guideline:

$$\left(\frac{dHV_r}{dr} \right) / HV_r = i. \quad (3)$$

The guideline tells us to cut timber when the change in harvest value on a percentage basis is equal to our alternative rate of return. We know this is consistent with setting a rotation age which maximizes the net present value of future income from a single rotation. Economists, of course, recognized that the simple financial maturity guide did not recognize *all* potential future income and the following adjustments were made.

¹Continuous discounting is used to simplify derivatives. Second order conditions for maxima are fulfilled for the examples in this article for harvests within the economic range of production (when harvest values are increasing at a decreasing rate).

To reflect all future net income, we can assume identical net harvest values for an infinite *series* of rotations. The present value of a perpetual periodic series of such harvests is:

$$\frac{HV_r}{e^{ir} - 1} \quad (4)$$

This value is commonly referred to as soil or land expectation value, and can also be maximized with respect to r . Setting the first derivative of (4) with respect to r equal to zero yields:

$$\frac{(e^{ir} - 1) \left(\frac{dHV_r}{dr} \right) - HV_r (e^{ir}) i}{(e^{ir} - 1)^2} = 0. \quad (5)$$

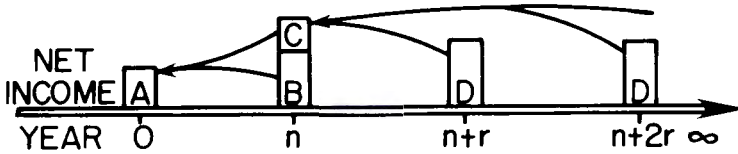
Solving equation (5) for i yields the *adjusted* financial maturity model for harvesting timber:

$$\left(\frac{dHV_r}{dr} \right) / HV_r = i \left(\frac{e^{ir}}{e^{ir} - 1} \right) \quad (6)$$

Adjusted financial maturity tells us to harvest timber when the percentage change in harvest value is equal to our alternative rate of return multiplied by an adjustment factor. The adjustment increases the necessary rate of return and trees are harvested at an earlier age, recognizing that they have to be removed before the next stand can be grown. Since the adjustment is applied to the interest rate, adjusted financial maturity is as easy to apply as simple financial maturity, yet is consistent with the rotation age which maximizes (4), the present value of *all* future net timber income.

3.2 Lands With an Existing Stand

Optimal cutting policies in the bare land case depend on how we *assume* future stands will be managed. Therefore, if an existing stand corresponds to the management regime which would maximize bare land values, harvesting according to adjusted financial maturity is consistent with our economic objective. For any other situation, however, to maximize the present value of all future net income we must recognize two types of income:



WHERE:

- A Represents the net present value of all future income (to be maximized with respect to n),
- B Is net income from the present stand,
- C Represents the value of subsequent income discounted to year n , and
- D Is the net timber income from future stands (with a rotation of r years).

FIGURE 1. Diagram of expected timber income from land with an existing stand.

timber income from the *existing* stand, and timber or other income *following* the present stand (Figure 1). Income after the present stand is the land expectation value for subsequent rotations, market value for land sale, or other expected future income discounted to year n , the year the existing stand is replaced.

The actual value which applies for C in Figure 1 is therefore a constant, depending on the landowner's plans for the land after the present stand is removed. If the land will remain in timber, C is the discounted value of all future net timber income. If the landowner would consider selling the land, C is the expected market value for the land after the stand is cut. C may also represent the discounted net income from alternative land uses such as row crops, pasture, commercial development, etc. To be consistent with our economic objective, C represents expected net income after stand removal, representing the revenue foregone by holding the present stand of timber. The longer we wait before cutting the present stand, the longer we postpone subsequent income.

Consistent with our economic objective, we wish to manage the present stand so that we maximize:

$$\frac{HV_n + C}{e^{in}} \quad (7)$$

Setting the first derivative of (7) with respect to n equal to zero yields:

$$\frac{e^{in} \left(\frac{dHV_n}{dn} \right) - (HV_n + C)(e^{in}) i}{e^{2in}} = 0. \quad (8)$$

Solving for i yields the correct financial maturity guideline for harvesting existing stands:

$$\left(\frac{dHV_n}{dn} \right) / (HV_n + C) = i. \quad (9)$$

Relation (9) tells us to cut the present stand when the annual change in timber harvest value divided by harvest value plus C equals our alternative rate of return. This guideline is consistent with our economic objective of maximizing the present value of all present and future net income.

4. SUMMARY

Although the results presented in this article are not new, they are not always clearly understood by forest resource managers and planners. Simple harvesting guidelines were derived by assuming a single economic objective to be maximized, and applying the reasoning to both bare land and forested conditions. Consistency between commonly applied financial maturity guides and the maximum present value of all future net income was shown with simple calculus. Practicing foresters and forestry students alike can easily understand these results, hopefully making them more useful and meaningful to a broader group of resource managers.

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