USE OF ALTERNATIVE COSTS IN DETERMINING THE ECONOMIC ROTATION AGE OF DOUGLAS-FIR

by

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INTRODUCTION

The ultimate aim of a forest owner, like any other investor, is to achieve the maximum return on his investment. In accomplishing this aim there are two major kinds of decisions to be made in respect to a forest enterprise: (1) determining whether to invest in a forest enterprise; and (2) determining the most profitable age to harvest his timber after he has made the investment. This study is concerned with the second kind of decision. The analysis is oriented to privately owned timber. Farmers alone own nearly two million acres of forest land in the Douglas-fir region of Oregon.

Many woodland owners in the Douglas-fir region are being confronted with the decision as to time of harvest, and the advice they receive generally is confusing. There is pressure from sawmills and loggers to cut readily available private timber, even stands as young as 40 to 50 years of age. The recent development of markets for the products of small timber and the design of logging equipment and sawmills to handle logs down to six inches in diameter is making the harvesting of small timber economically feasible. As late as 1940, small second-growth timber was considered valueless by most people. Stumpage prices of these young stands currently are several times higher than prewar prices of old-growth Douglas-fir.

An opposite influence on private timber owners is the advice of many professional foresters to hold their timber to a greater age. This advice usually is based on either of two concepts. One concept is the attainment of maximum average volume growth. The other is attainment of the maximum average interest rate on the investment in woodland. The investment in this case is the cash inputs, including land and annual cash expenses.

Most of these young stands do not have to be harvested at an early age, at least for silvicultural reasons. Many of the stands in the Douglas-fir region of Oregon are in the 50 to 80 year age group. This corresponds roughly with the period of predominant agricultural settlement of the area. Timber at this age usually is still growing vigorously, and will continue to add both volume and value for some time.

Douglas-fir normally occurs in even aged stands, because it is not shade tolerant. It must eventually be clear-cut to establish reproduction. Some thinnings may be made to harvest what would be the normal mortality, but a complete harvest still is necessary at some point. At what age should this harvest be made? From an economic standpoint the question may be stated: What is the most profitable age at which to harvest a stand of Douglas-fir?

The Problem

The problem for this study is to determine and to apply the appropriate economic principles for deciding when to harvest Douglas-fir on land that is to be retained in a forest enterprise.

The decision to harvest is actually a choice between alternatives. Economically, the investor will choose the most profitable alternative use of his capital. Standing timber may be looked upon as capital stock, or an agent of production. Generally, economists consider the cost of an agent of production to be the maximum amount, or value, of any other product it can produce (10, pp.96,97). The cost of any alternative then is the return which can be realized in another alternative. While still retaining ownership of the land, the value of the timber represents the liquid portion of the investment. The alternatives open to a timber owner for the use of this investment are: (1) retain the capital in standing timber, or (2) transfer the investment to interest-bearing assets or other productive uses, either on the same land or on another enterprise. The last is an alternative to the first. The alternative cost of retaining the capital in standing timber is the income opportunity from an equivalent amount of capital in other uses. The owner must forego the income from other alternatives whenever he makes his choice. A rational choice among alternatives is the one which yields the highest return on the investment.

Investment and Alternative Costs

The total investment in a timber enterprise is the market value of the timber and the value of the bare land. The alternative cost concept illustrates that market value is the relevant measure of investment for a woodland manager, whether this market value is more or less than the actual money invested. The question arises: What is the relevant portion of the total investment to use in determining an alternative cost for making a decision to harvest?

Since the timber investment must be converted into money to find a different use, market value of the timber represents the size of the investment which could be directed to another use and still retain the land for growing timber. Land also may be converted into money, but to do so would terminate the woodland enterprise. Therefore, only the investment in standing timber is considered relevant in computing alternative costs for deciding when to harvest. If liquidation of the woodland enterprise is a consideration jointly with question of time of harvest, then land should be included with timber in figuring the value of investment.

The decision to harvest is basically different than the decision to invest or disinvest in a forest enterprise, but the distinction often may be overlooked. Different factors and different methods are involved in reaching each one. The decision to invest or disinvest in the enterprise normally will be determined by the over-all profitability prospects of the enterprise. This is arrived at by comparing estimated costs and estimated returns over the entire period of a rotation or perpetual series of rotations. The decision to harvest is determined by the rate of return on the capital value of the stand, rather than on costs.

Methods Used in the Past to Determine Time of Harvest

Various accounting techniques have been used in an attempt to determine the most profitable harvesting age for Douglas-fir. Duerr and Bond (2, pp.12-16) and Guttenberg (3, p.714) have used the alternative cost method recently in all-aged stands in the South, but foresters generally have used the accounting method. Vaux (8, pp.13-48) has used the alternative cost method in planning disease control programs in California.

Accounting techniques are helpful to the investor in choosing from among various long range investment alternatives. Other things being equal, the investor will choose the enterprise yielding the highest average rate of return on his original investment.

The method most widely used by foresters is essentially that of accumulated costs. A schedule of costs is compounded and accumulated during the rotation at a tentatively selected interest rate and compared with the value of the stand at a selected rotation age. Trial and error is used to determine the best combination of interest rate and rotation age. Estimation of rotation age at the time of initial investment is an important guide to the investor. It is one step in the process of estimating over-all profitability of the enterprise. However, the estimated rotation age at the time of the initial investment need not be a final decision on time of harvest.

The principles involved in the alternative cost method will be discussed in the following chapter. After demonstration of the operation of the method by its application to data for a given situation, some practical considerations in its application by private owners will be discussed.

ANALYSIS OF METHODS OF DETERMINING ROTATION AGE

A basic assumption in the alternative cost method of analysis is that capital will be invested where it will earn the highest net return commensurate with the risks involved. This is equivalent to the assumption that entrepreneurs and investors strive to maximize money profits.

Net return is the difference between all revenues and all costs, including costs of capital as well as of land and labor. Net return is maximized at the point where any increase in cost brought about by a small increase in the use of any agent of production is just paid for by increased revenue. Stated another way, net return is maximized when the additional cost of the last unit of production is equal to the additional revenue from this unit of product. The additional cost is known as the marginal cost of the last unit of output. The additional revenue is the marginal revenue.

By definition, marginal costs are those costs that are increased in order to increase production. Marginal costs, then, relate to variable costs. In a forest enterprise these are the costs that would not have been incurred if the timber had not been carried for another year.

Marginal and Alternative Costs

Costs that change as the rotation age is changed are variable. In Douglas-fir these normally are any taxes based on timber volume and value, and the alternative cost of the timber investment.

Property taxes, protection, administration, land charges, or any fixed per acre cost, will have to be met each year whether there is mature timber or a reproduction stand on the land. These costs are not variable. For example, these per acre costs would be the same over a 150-year period whether it covered two 75-year rotations or three 50-year rotations. Only when a forest enterprise is to be completely liquidated after harvest, so that these costs will stop, are they variable costs. This is not to say that the fixed per acre costs are not "real" costs. In a permanent forest enterprise there is no alternative to meeting them annually.

An alternative cost is the highest return that can be expected from other alternative uses of an agent of production. This is not an out-of-pocket cost, but a foregone income opportunity. This cost often is called an "opportunity cost." Merchantable timber can be liquidated, and the capital obtained therefrom invested in production pursuits outside the forest enterprise. Income that could be obtained from an alternative investment of the capital represented by standing timber is a cost of retaining this capital in timber.

Although the alternative rate of return on woodland capital may be constant over time, the alternative income on this capital will vary with the volume and value of merchantable timber. Thus, the alternative income, the cost of retaining the capital in standing timber, enters the accounting as a marginal cost. How this cost is handled in determining the most profitable rotation age of Douglas-fir is discussed in the following sections of this chapter.

Marginal Revenue in Producing Timber

In a forest enterprise, the annual increase in value of the stand is the marginal revenue. Economists call this the marginal value product, but here it may more descriptively be called the marginal value growth (4, pp.12,13). It arises from two sources: (1) the value of the volume added, and (2) an increase in unit value of the entire stand. Unit value increases because of the improvement in log quality and a decrease in logging costs per unit of volume.

Annual volume growth of Douglas-fir, as shown in the following chapter, reaches its maximum at a relatively early age and then gradually declines (5, p.43). That is, the total volume then increases at a diminishing rate. On the basis of this one source of marginal value growth, the value added each year would decrease after the point of maximum annual growth. An offsetting factor to this diminishing return is the increase in unit value of the entire volume of the stand as trees become larger. The relevant marginal revenue, or marginal value growth, is a combination of these two sources of annual increase in value.

Deduction of certain marginal costs from marginal value growth simplifies the procedure in determining the optimum rotation age. The two categories of marginal costs discussed previously are (1) changes in annual out-of-pocket costs, and (2) alternative income opportunities of woodland capital. As a matter of convenience, marginal costs in the first category are deducted from the marginal revenue to obtain the net marginal value growth. The net marginal value growth is equivalent to net annual income from a stock of capital retained in standing timber, excluding the fixed annual charges. This net annual income then can be compared directly with the income possibilities of the same size investment in alternative uses to arrive at the proper rotation age.

Equating Marginal Cost and Marginal Revenue

Net marginal value growth may be compared with the net income from alternative investments in terms of actual dollars. The yields of stocks, bonds, and loans, which are the most universally available forms of investment, are usually measured by the dividends or interest paid. Net marginal value growth will be converted to per cent return for easy comparison with the yield on alternative investments. The conversion is made by dividing net marginal value growth by the value of the timber stand at the beginning of the year.

For a particular individual, this alternative cost rate might be derived from any of several sources. It could be the dividend or interest from an investment in stocks or bonds, or the rate he would have to pay if he were to borrow. A farmer may have an alternative productive investment, such as a dairy enterprise, that would yield much more than the market rate of interest. Subjective values, such as an individual discount rate or time preference, also enter into the determination of the individual's alternative cost rate.

Whatever the individual's alternative cost rate may be, net marginal value growth expressed in per cent will aid in determining when the timber stand has reached the point where it is just producing at that rate, which is the optimum. This point, where the two rates of return are equal, is the optimum because beyond that point the net marginal value growth will be less than the return from the alternative investment. Short of that point it will exceed the alternative return. As long as net marginal value growth exceeds the alternative return, it pays the investor to retain his capital in standing timber. When net marginal value growth becomes less than the alternative return, it pays to transfer timber capital to the alternative investment.

A simplified example for a farmer who is paying 5 per cent interest on a mortgage will illustrate the operation of the principle.

Age	Current value of stand	Net marginal value growth	% return on investment
60	$600	$35	5.8
61	635	35	5.5
62	670	35	5.2
63	705	35	5.0
64	740	35	4.7

In this case it would pay the farmer to harvest at the end of the 63rd year and apply his capital on the mortgage. Until that time his timber investment was giving him a higher rate of return than he was paying as interest. During the 62nd year he would get a net return of $35 on a $670 investment, while paying $33.50 on $670 of his mortgage. After the 63rd year, the mortgage would be costing more than the return from the same amount of money invested in timber. At the end of that year, he would have $240 invested and would get a return of only $35 during the next year. Meanwhile, the interest on $740 of his mortgage would cost him $37, a net loss of $2. It must be understood that this is a highly simplified hypothetical case, and that such precise data for each year are seldom available. The accuracy of the results given by the use of this method depends upon the accuracy of price and physical volume and growth estimates for a particular stand of timber. Prerequisite to accuracy from any method of determining rotation age are accurate estimates of future yields and values for timber.

Under the alternative cost method, the decision to harvest has to be made during each rotation. Thus, the consideration of more than one rotation does not alter the application, except for the possibility of heavy establishment costs. The investor may wish to spread this cost over a longer rotation, or he might want to postpone this cost. Other than this, the decision as time to harvest must be made for each rotation in the light of then current costs and revenues.

Comparison of Accounting and Alternative Cost Methods

In accounting, every cash cost or interest charge over the entire rotation is considered in determining the overall or average profitability of the enterprise. All costs are historical. Even future costs are based on the extension of actual past or present costs.

In the alternative cost method, all costs are ignored except those incurred in achieving a greater output, or delaying the harvest. These costs need not be out-of-pocket costs, nor need they be fixed charges over time. The major cost is passing up other opportunities that will yield an income.

The two concepts of cost are different, and necessarily lead to a different concept of investment. In accounting, investment is considered to be the compounded costs, either past or predicted. Land is included in the computations to derive investment. The accounting is performed for the entire period from initial investment until time of harvest. In the alternative cost method, investment is considered to be the current market value of the standing timber. The only way to determine how much capital is available for an alternative investment at a given time is to determine the market value of the stand. Thus, for the alternative cost method, market value becomes the relevant value of investment. Land should be considered a part of the investment for deciding when to harvest when consideration is given to liquidation of the forest enterprise.

Both methods are intended only as procedures to help forest owners and advisors in reaching decisions. The data available to apply in each method are subject to error, so the answers they give are approximations. They indicate a period to harvest, rather than an exact year.

The two methods conceivably could give the same answer on time of harvest, but only by coincidence. The accrued costs would have to just equal the value of the timber at a point where the interest rate used to compound costs was the same as the alternative rate of return. The shape of the cost curve under compound interest and the value growth curve of Douglas-fir are greatly different; and the alternative rate of return fluctuates while the compounding rate is assumed to be constant. Thus, the likelihood of this coincidence is low.

The alternative cost method is a management tool useful in making the decision as to the most profitable time of harvest. The basic feature of the method is a comparison of the current rate of return on the market value of the timber investment with the alternative use values of this investment. It tells the manager nothing about the over-all profitability of the enterprise for the entire rotation. It may allow him either to maximize profits or minimize losses.

Accounting methods are useful to investors in making a choice among alternative initial investments. Comparison of expected total costs and returns in various alternative uses of capital is helpful in choosing an enterprise for investment. These expected costs and returns may not be realized because of errors in estimation or unforeseen changes in conditions. During the time a stand is merchantable, the enterprise may be earning less or more than an estimated rate at the time the original investment was made.

Integration of the Two Methods

The two methods are designed to deal with different decisions, but it would be well to see how the methods may be used to supplement each other.

The rotation age of a given stand can be estimated by the alternative cost method at the time a decision is to be made on whether to invest. This estimated rotation age will define a period of time in which to figure income prospects from an investment in woodland. This estimate of time to harvest would be an aid in the investment decision, rather than a final decision on harvesting.

The market value of the stand at harvest can be considered as the present value of the accrued costs. This value can be discounted at the appropriate rate to determine the productive value of the land and other inputs in timber production. This would make it unnecessary to set a different interest earning capacity on different sites. Since it is not rational for an investor to buy land that will earn three per cent if there is another investment that will earn five per cent, it would be better to determine the productive value on which to establish land value and warranted establishment costs.

Accounting methods often are necessary in determining the investor's alternative rate of return. He may use accounting methods to estimate future returns from other enterprises.

Thus, the two methods are useful in arriving at two separate kinds of decisions. There is no conflict between the two. The decision on time of harvest is a separate problem from that of determining whether to invest. This thesis is concerned with the decision to harvest. Application of the method to data will be shown in the following chapters.

SOURCES OF DATA AND PROCEDURES IN ESTIMATING COSTS AND VALUES

The main purpose of this chapter is to present information necessary for the determination of the optimum rotation age of Douglas-fir by use of the alternative cost method. The needed information may be divided into three categories: (1) yield data for timber stands over a period of years, (2) price data for timber stands at various ages, and (3) data on the relevant costs of producing timber.

Yield data at ten-year intervals were taken directly from U. S. Department of Agriculture Technical Bulletin 201 (5, p.27). This is the standard source of basic growth and yield data for Douglas-fir. Log prices were taken from Oregon State College Extension Service market reports of actual prices being paid by mills. Logging and hauling costs were based on cost schedules used by the Bureau of Land Management (7, pp.7,8,14). Variable costs, taxes on standing timber, are the author's estimates based on known procedures of various county assessors.

Estimates of Investments and Value Growth

Estimates of investment and value growth are derived from yield and price data. The estimates differ for stands on different site classes. Separate investment and value growth estimates for each type of data will be made for each of three common site classes found on Oregon farms.

Yield Data: The unit of measurement of volume most widely used in the Douglas-fir region is board feet, Scribner rule. This rule estimates the amount of lumber which can be sawed from a log or tree. There are other rules for measuring board foot volume, and other measures of volume than board feet, but common usage favors the Scribner rule. This rule originated in the days when only large trees were considered merchantable, and the normal yield tables give Scribner rule data only for trees down to 12 inches, diameter breast height. Much smaller trees are being utilized for saw timber at the present time. Consequently, the data for the early merchantable years of a stand are conservative.

"Normal" yields as given in the reference tables (5, p.27) are the yields to be expected from fully stocked stands on a given site class. Adjustment of yields for understocked stands may be made according to methods described in the same publication (5, pp.69,70).

Site quality is a measure of the combined effects of physical characteristics of an area which result in a certain degree of favorability for tree growth. These characteristics include rainfall, temperature, elevation, slope, aspect, soil and drainage (5, p.8). The index of site quality for Douglas-fir in common use is the average total height of the dominant and codominant trees at

100 years of age. For example, if the average total height of the dominant and codominant trees in a stand is 120 feet, the site index is 120.

Table 1. Yield of Douglas-fir on fully stocked acre, trees 12 inches in diameter and larger, Scribner rule.[1]

Age Years	Site Class II Index 170 Bd. ft.	Site Class III Index 140 Bd. ft.	Site Class IV Index 110 Bd. ft.
30	2,600	300	
40	11,900	4,500	200
50	27,400	12,400	3,300
60	42,800	23,800	8,100
70	57,200	35,200	14,000
80	70,000	45,700	20,100
90	81,000	55,000	26,000
100	90,400	62,800	31,400
110	98,300	69,400	36,300

[1]Taken from U.S.D.A. Tech. Bul. No. 201, p.27.

The yields shown in Table 1 are the total board foot volume of live timber on one acre. Total volume per acre increases for many years. Annual, or marginal, growth reaches its maximum quite early, and the rate of increase in volume then diminishes. This marginal growth is extremely important from an economic standpoint, as it is one of the determinants of the rate of value growth. The total yield and annual growth patterns by site class are shown in Figure 1 (5, pp.29,45). Much of Oregon's farm timber is on sites II, III and IV, so data for these sites will be used in this study.

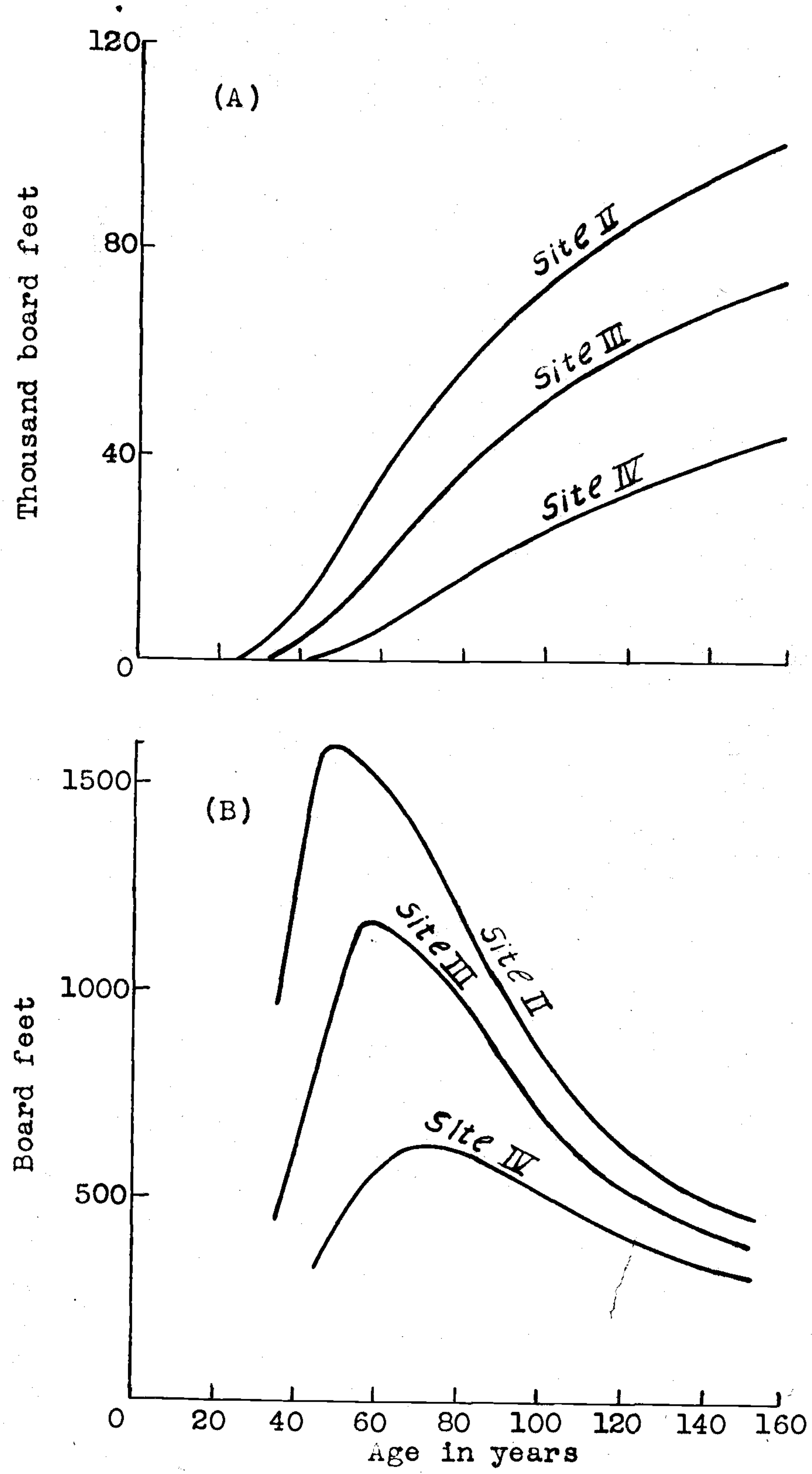

Figure 1. Volume per acre (A) and periodic annual increment per acre (B) in board feet, Scribner log rule, trees 12 inches in diameter and larger.

Price Data: Actual selling prices of standing timber, or stumpage, by age and site class are not easily ascertained. A limited amount of stumpage price data are available. Stumpage prices are derived by deducting estimated logging and hauling costs from recent log prices. Average prices and costs for 1953 were used in these computations.

On the same piece of ground, logging costs will depend on size of log and volume per acre. Volume per tree for each age group in each site class was approximated by dividing total volume by the number of trees per acre. All logging and hauling costs were then assessed according to the volume per tree, modified somewhat by the volume per acre. Detail costs are shown in the Appendix.

Log values depend upon both size and quality as determinants of log grade. Stand tables were used as a guide in determining the proportions of logs in various grades (5, pp.47,48).

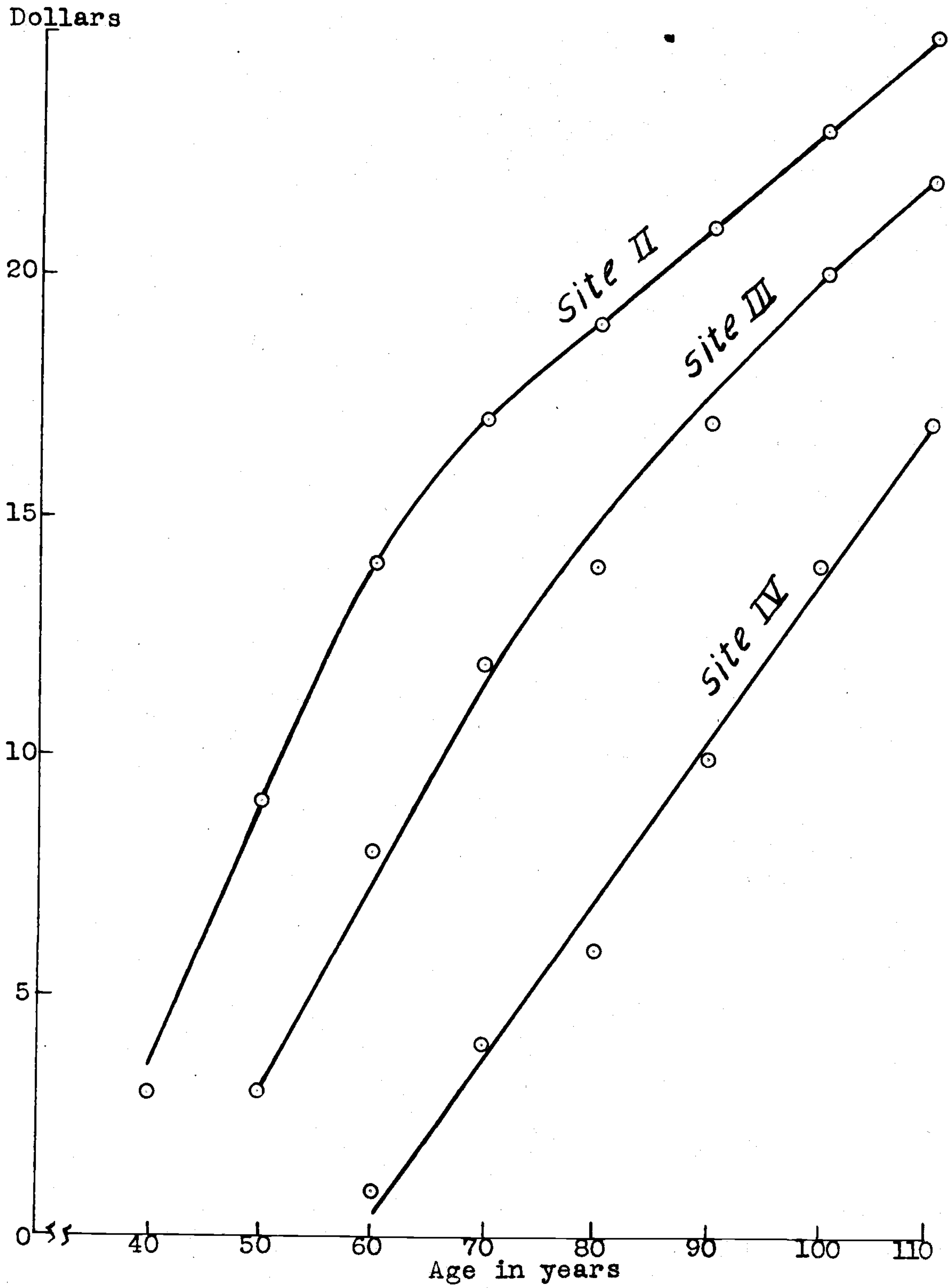

Figure 2. Stumpage prices of Douglas-fir in western Oregon, 1953.

Table 2. Estimated log values, logging and hauling costs, and stumpage prices per thousand board feet for Douglas-fir in western Oregon, 1953.

Age Yr.	Site Class II Log Val.	Site Class II Cost	Site Class II Stump. Price	Site Class III Log Val.	Site Class III Cost	Site Class III Stump. Price	Site Class IV Log Val.	Site Class IV Cost	Site Class IV Stump. Price
40	$31	$28	$ 3						
50	33	24	9	$31	$28	$ 3			
60	35	21	14	33	25	8	$31	$30	$ 1
70	36	19	17	34	22	12	32	28	4
80	37	18	19	35	21	14	33	27	6
90	38	17	21	36	19	17	35	25	10
100	39	16	23	38	18	20	37	23	14
110	40	15	25	40	18	22	39	22	17

All costs were then deducted from the log value at the mill to arrive at a stumpage price (Table 2). Data for each site class were plotted and a free-hand curve was fitted (Figure 2). Prices to the nearest 50 cents were read off the curve.

On the basis of the very limited stumpage price data available, these prices appear to be reasonable. A possible exception might be made for stands under 60 years old on the better sites. Present-day log utilization standards and the development of light logging equipment have made young stands valuable. Costs and log values for these young stands were modified in an attempt to make these price estimates realistic (see Appendix).

Value of Investment: Stumpage price times total yield gives the value of the stand at the beginning of each decade (Table 3). Marginal value growth is measured at a point roughly midway in each decade. Therefore, the value of investment is taken at the mid-point. Value of investment at the mid-point of each decade was determined visually from Figure 3. A simple average between the beginning and end figure for each decade will give nearly identical results after the investment has reached $300. Before that, plotted figures are considerably less than simple averages. The differences are not significant unless a rather high alternative rate of return is used.

Table 3. Estimates of the value of Douglas-fir stands at different ages in western Oregon, 1953.[1]

Age	Site II	Site III	Site IV
40	$ 42		
50	247	$ 37	
60	599	178	$ 4
70	972	405	56
80	1,330	685	141
90	1,701	962	273
100	2,079	1,256	424
110	2,458	1,527	617

[1]Obtained by multiplying yields at different ages in Table 1 by the stumpage prices in Table 2.

<u>Value Growth</u>: The difference in the value of the stand at the beginning and the end of each decade is the decadal value growth. For convenience, the annual, or marginal, value growth was arrived at by taking a simple average of the decadal value growth. This resulted in an approximation of the marginal value growth at the mid-point of each

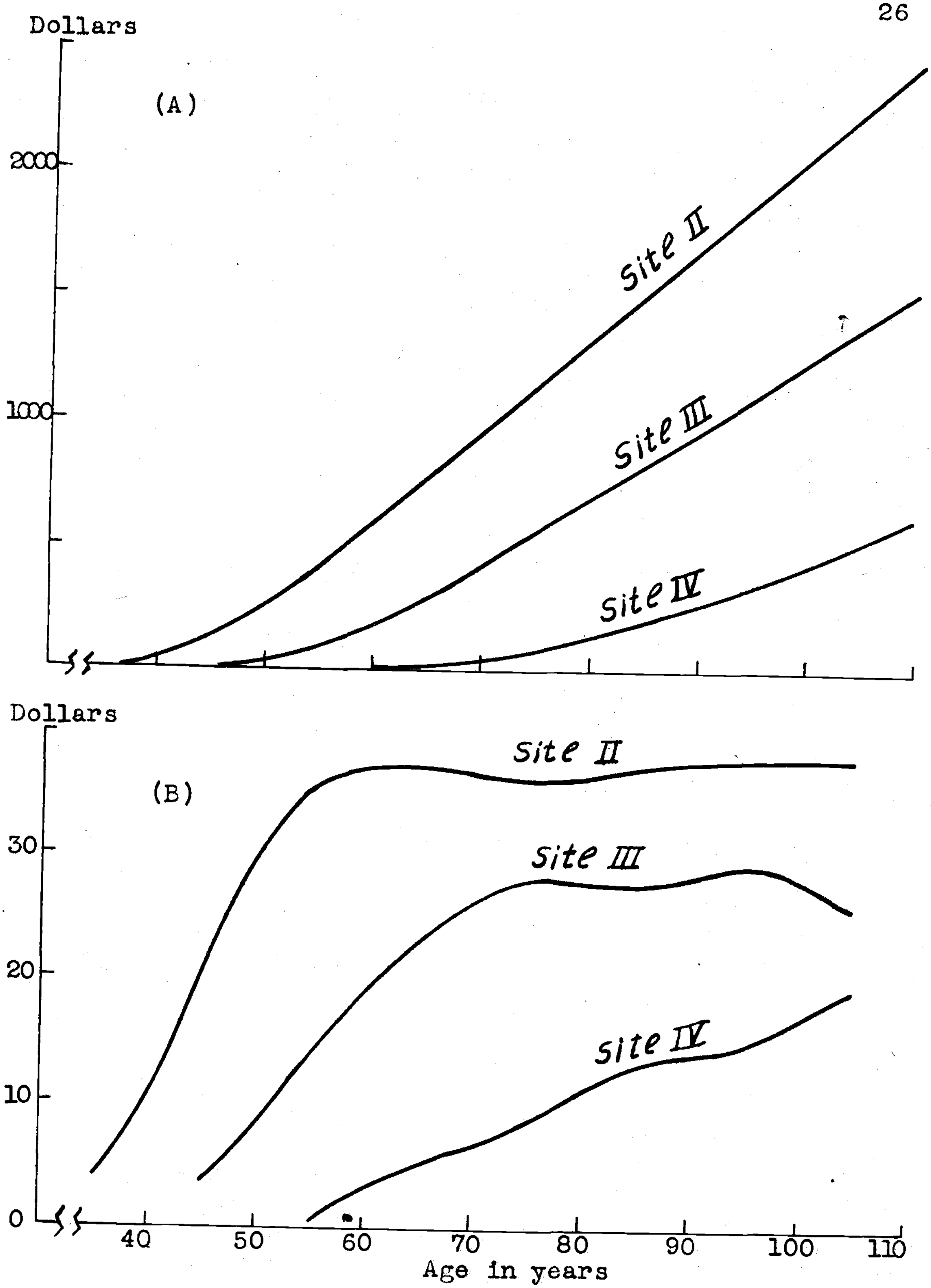

Figure 3. Total value of stand (A) and marginal value growth (B) of Douglas-fir in western Oregon, 1953.

decade. The patterns of marginal value growth are derived from Table 3 and are shown in Figure 3. The uneven curves are caused by the rapid decline in annual growth immediately after the maximum is reached. When the decline in growth rate slows down, the increased unit value causes a temporary increase in marginal value growth until the rate of increase in unit value, too, slows down.

Cost Estimates

Most farm woodlots in western Oregon are subject to the tax on standing timber. This tax is dependent on volume, hence it is the only cash cost that normally varies with volume under present-day conditions. The method of applying this tax varies widely from county to county.

Assessed valuation of standing timber, assessed volume, and millage rates differ greatly. Assessed valuation was assumed to be one dollar per thousand board feet of the yield table volume. A 50 mill rate was used, giving a tax of five cents per thousand.

The derived taxes for each age group are shown in Table 4. Most assessors do not adjust this tax frequently, so it is assumed here that the tax will remain the same for the entire decade for which it is figured.

Table 4. Estimated taxes per acre of Douglas-fir timber at five cents per thousand board feet in western Oregon, 1953.

Age	Site II	Site III	Site IV
30	*	*	--
40	$0.60	$0.20	--
50	1.35	0.60	$0.15
60	2.15	1.20	0.40
70	2.85	1.75	0.70
80	3.50	2.30	1.00
90	4.05	2.75	1.30
100	4.50	3.15	1.55
110	4.90	3.45	1.80

*While there is some merchantable volume on these sites at this age, it is the common practice to begin assessing timber at 40 years.

Alternative costs are most easily expressed as a rate of return. Probably the most universal alternative rate used in farm accounting is an interest charge of five per cent. It is beyond the scope of this study to provide a basis for selecting any particular alternative rate of return. The five per cent rate is selected for use in working out rotation ages for the three sites. It is recognized that the alternative rate for individual owners will vary.

ESTIMATING ROTATION AGES FOR THREE SITES OF DOUGLAS-FIR

Once the necessary data are at hand, the procedure of determining the optimum rotation age is rather mechanical. The first section of this chapter is concerned with this procedure. Since yield, price, and cost data are the major determinants of rotation age, the general effect of changes in these factors will be considered. Finally, application of the method by a private owner will be discussed.

Determination of Rotation Age

After the marginal value growth has been determined, the variable costs are deducted to arrive at net marginal value growth. Determination of the optimum rotation age involves a comparison of the marginal returns of capital retained in timber and the same capital employed in other uses. Comparisons of alternative returns and net marginal value growth are converted to rates or percentages. These rates, or percentages, are equivalent to interest yields of assets.

Conversion of net marginal value growth to a percentage return on timber capital is accomplished by dividing it by the value of the investment at the midpoint of the decade. This gives a net marginal rate of return to the investment in standing timber. Hereafter, this will be referred to as the marginal rate of return.

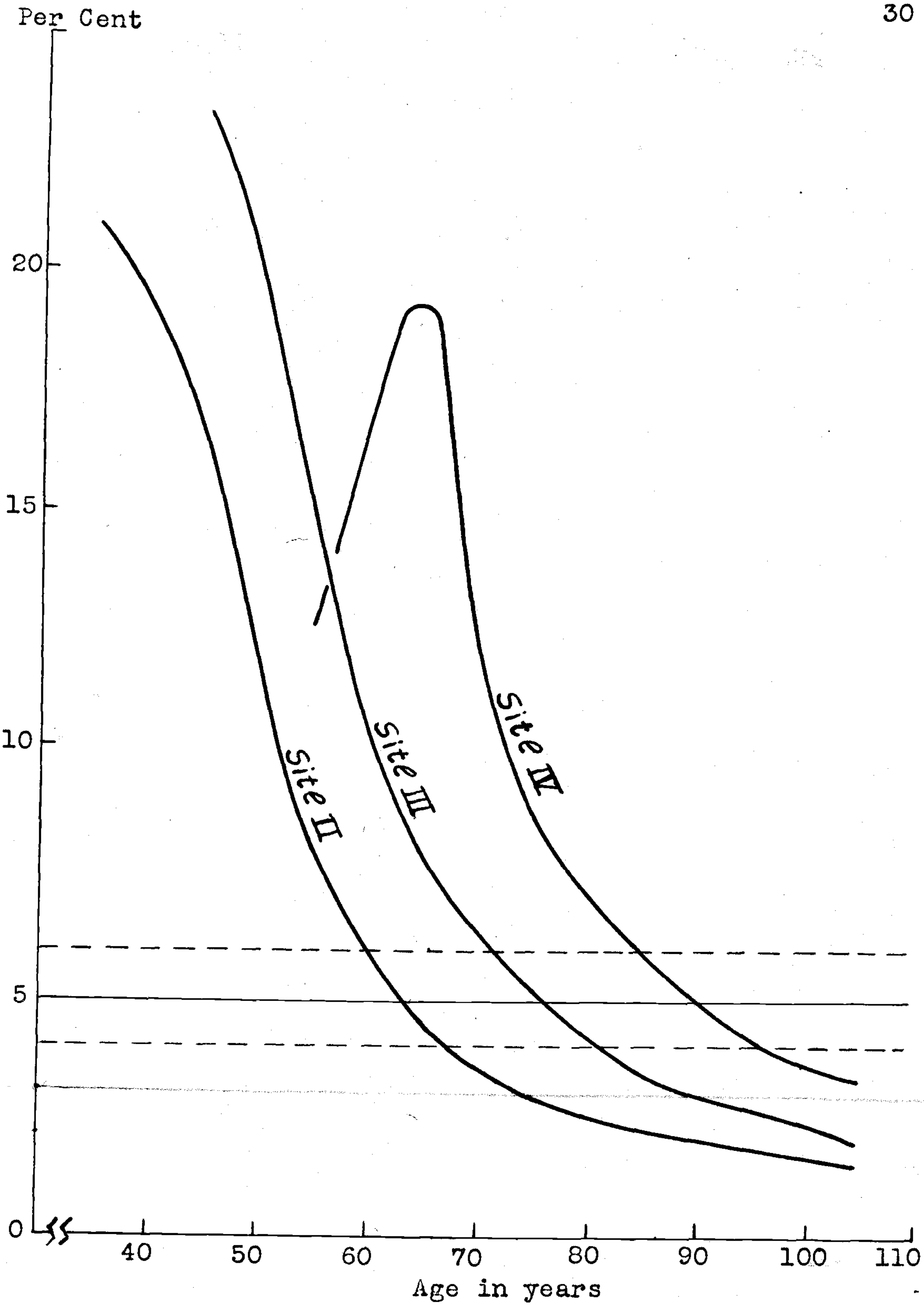

Figure 4. Marginal rate of return for Douglas-fir in western Oregon, 1953.

Tables 5, 6 and 7 give the data used for each site, with the rates of return shown in the right-hand column. A free-hand curve was fitted to these rates (Figure 4).

A horizontal line drawn at the level of the alternative rate of return intersects the curve at the approximate rotation age. Using five per cent as the alternative rate, the ages indicated are 62 years for site II, 74 years for site III, and 89 years for site IV. With our present lack of accurate growth, cost and price data, these ages can be considered only approximations of the optimum rotation ages.

The effect of different growth rates on rotation age is shown by the different rotation ages for the three sites. The better sites produce merchantable timber much earlier, and the annual growth rate reaches its peak at an earlier age. The better sites quickly build up a rather large value. This larger value, as compared with that attained on poorer sites, causes lower marginal rates of return at given ages for the good sites even though their net marginal revenue is relatively high. Thus, it is most profitable for the forest investor to harvest the better sites at an earlier age than the poor sites.

Table 5. Estimation of marginal rate of return for site II Douglas-fir in western Oregon, 1953.

Age	Value of stand[1]	Marginal value growth	Variable costs[2]	Net marginal value growth[3]	Marginal rate of return[4]
30					
	$ 20	$ 4.20	$0.00	$ 4.20	21.0
40					
	120	20.50	0.60	19.90	16.6
50					
	420	35.20	1.35	33.85	8.1
60					
	785	37.30	2.15	35.15	4.5
70					
	1,145	35.80	2.85	32.95	2.9
80					
	1,510	37.10	3.50	33.60	2.2
90					
	1,885	37.80	4.05	33.75	1.8
100					
	2,265	37.90	4.50	33.40	1.5
110					

[1]Value of stand at decadal midpoint.

[2]Taxes on standing timber.

[3]Annual marginal value growth minus variable costs.

[4]Net marginal value growth divided by value of investment.

Table 6. Estimation of marginal rate of return for site III Douglas-fir in western Oregon, 1953.

Age	Value of stand[1]	Marginal value growth	Variable costs[2]	Net marginal value growth[3]	Marginal rate of return[4]
					%
40					
	$ 15	$ 3.70	$0.20	$ 3.50	23.3
50					
	95	14.10	0.60	13.50	14.2
60					
	285	22.70	1.20	21.50	7.5
70					
	540	28.00	1.75	26.25	4.9
80					
	820	27.70	2.30	25.40	3.1
90					
	1,105	29.40	2.75	26.65	2.4
100					
	1,390	27.10	3.15	23.95	1.7
110					

[1]Value of stand at decadal mid-point.

[2]Taxes on standing timber.

[3]Annual marginal value growth minus variable costs.

[4]Net marginal value growth divided by value of investment.

Table 7. Estimation of marginal rate of return for site IV Douglas-fir in western Oregon, 1953.

Age	Value of stand[1]	Marginal value growth	Variable costs[2]	Net marginal value growth[3]	Marginal rate of return[4]
50					
	$ 2	$ 0.40	$0.15	$ 0.25	12.5
60					
	25	5.20	0.40	4.80	19.2
70					
	90	8.50	0.70	7.80	8.7
80					
	205	13.20	1.00	12.20	6.0
90					
	345	15.10	1.30	13.80	4.0
100					
	515	19.30	1.55	17.75	3.4
110					

[1]Value of stand at decadal mid-point.

[2]Taxes on standing timber.

[3]Annual marginal value growth minus variable costs.

[4]Net marginal value growth divided by value of investment.

Effects of Changes in Various Factors

Stocking: Below-normal yields may be realized when the stand is not fully stocked. Stocking, or stand density, usually is measured by the number of trees per acre, normal being the number which will give the most effective growth (5, pp.10,11). The number of trees per acre decreases as the stand gets older and bigger. Thus the understocked stand tends to approach normality. This tendency is rather slow acting except in young stands.

It would seem that this approach to normality, resulting in an above-normal annual growth on a less-than-normal investment, would lengthen the rotation age. Offsetting this larger physical growth, however, is a slower-than-normal rate of increase in unit value. Understocked stands usually are rough and limby, with a lower average log value (5, pp.9,10). Smaller volume per acre also increases logging costs somewhat, but this may be at least partially offset by larger volume per log. Thus, while the investment may be smaller than in a fully stocked stand and the physical growth larger, the marginal value growth has about the same relationship to investment as a fully stocked stand.

There are indications that on all sites the marginal rate of return on understocked stands is higher than on fully stocked stands in the early years. This rate declines more rapidly than on fully stocked stands. Between rates of four and six per cent there is practically no difference in rotation age unless the stand is less than 50 per cent stocked. On stands with less than 50 per cent stocking, the total revenue is so small that the initial investment cannot be carried. In this case, immediate liquidation of the growing stock for a fresh start usually is warranted.

<u>Thinning Operations</u>: The total yield on a managed stand may be increased by periodic thinnings. This increase is accomplished by harvesting what would be normal mortality while the timber is still alive and merchantable. Whether thinnings heavier than this can be made without reducing the volume per acre at final harvest still is doubtful (1, p.535). Very little data are available on the economics of the thinning operation itself, so the discussion here must be theoretical.

Theoretically, thinning would tend to lengthen the rotation. Cutting a part of the stand would reduce the value of the investment by the value of the amount harvested. When the amount of the normal decadal mortality is harvested, the yield at the end of the rotation is unchanged. The growth is put on fewer trees, presumably of better quality, so unit values may be higher than for an unmanaged stand (9, p.9). Because of the reduction in investment at the beginning of the decade, the marginal value growth would be increased correspondingly.

The effects of thinning on rotation age would be very slight at the present time, however. Logging costs for light thinnings are quite high, and in many cases there is little residual stumpage value above these costs (10, pp.137,138). More data are needed in this field before anything but general conclusions can be drawn.

Taxation: Ad valorem taxes on standing timber have been used in previous cost estimates. This resulted in increasing costs as timber volume increased, and this often has been cited as a cause of premature cutting. Such ad valorem taxes may have caused premature cutting because this expense cannot be postponed.

The owner may liquidate his growing stock in order to reduce cash expenses and pay those already incurred. However, it would be to his benefit to borrow to pay these expenses as long as the stand is increasing in value at a higher rate than he would have to pay for credit. In the absence of knowledge as to the rate of return currently being earned by the stand, this type of premature cutting may become quite common.

An ad valorem tax based solely on land would lengthen the rotation very slightly at alternative rates of four per cent or more. The elimination of taxes on standing timber as a variable cost increases the net marginal value growth by the amount of the tax. This amount is so small when compared to the value of investment that its elimination lengthens the rotation by only one to three years.

Yield taxes have the same effect on rotation age as taxes on land alone. The value of investment is reduced by the amount of the tax, which is 12½ per cent of the stumpage value in Oregon. The net value of the stand at any time is the total value less the tax. Since the tax is proportional, the marginal value growth is reduced accordingly. The tax is deducted from gross value of the investment, and in effect eliminates taxes as a variable cost.

Prices: Stumpage price estimates have been based on estimated costs and values which were correlated to volume, tree size and quality. Many loggers or sawmills currently do not consider these characteristics with the same weighting as used here. If there is less price differentiation by these factors, the rotation age would be shortened somewhat, as a substantial part of the marginal value growth has been added by increased unit value. Since empirical data are not available, this problem only can be mentioned.

Price cycles may be a major influence in modifying the indicated rotation age. It is well known that prices fluctuate in long-term patterns. When prices are rising, it may pay to hold timber past the indicated age to take advantage of price raises. Conversely, falling prices may wipe out gains through physical growth and force earlier harvesting. The timing of these cycles is difficult to predict.

Year-to-year fluctuations also are unpredictable, but need not influence the owner's decision to any great degree as long as they do not obscure the secular trend. The indicated rotation age is not so precise that a specific year for harvesting need be followed, but harvest can be postponed to take advantage of better prices.

Seasonal price cycles may be quite important to the timber owner, providing the timber is accessible at all times of the year. Log prices tend to be from $2 to $7 per thousand board feet higher during the winter and early spring months. Stumpage prices for timber that can be logged then will generally be at least $2 above timber that can be logged only during the summer months, because there is less timber available for year-round cutting.

<u>Alternative Rate of Return</u>: Obviously, a change in the alternative rate of return will change the rotation age. As the alternative rate increases, the rotation age will be shortened. As it decreases, the rotation age will be

lengthened. As shown in Figure 4, at an alternative rate of six per cent, the rotation age will be shortened to about 60 years for site II, 70 years for site III, and 85 years for site IV. An alternative rate of four per cent would lengthen the rotation age to about 67 years for site II, 80 years for site III, and 95 years for site IV.

A high discount rate on future incomes from an investment, a high alternative rate, may be one reason timber owners harvest at an earlier age than is considered most profitable. Another reason for premature cutting may be lack of knowledge of the future value growth of the stand.

Application of the Alternative Cost Method by the Private Timber Owner

The alternative cost method is intended as a management tool. It is one of the guides to be used in determining the time of harvest. The results given by this type of analysis must be considered in the light of the owner's over-all plans as a matter of judgment by him. Such items as present and future price outlook, money needs of the owner, and his other management and investment plans may all play a part in how he manages his timber capital.

One of the big difficulties facing the private owner in using the alternative cost method is that of obtaining accurate data. Physical data may be obtained through the services of a trained forester or approximated by the use of simplified procedures by the owner himself. Information on present age and volume, stocking, and site quality is necessary for the operation of the method. Future growth may be estimated after these other data are obtained. The more accurate this physical information is, the more reliable will be the answer obtained from the method.

Future price and market uncertainty complicate all management decisions. This uncertainty is a major reason why the alternative cost method can be used only to give an approximate rotation age. From a management standpoint, uncertainty has still another effect. Discount rates for future incomes may be higher than current rates of earnings on capital because of the uncertainty factor. This would have the effect of increasing the alternative rate of return.

In spite of the difficulties involved, the alternative cost method offers a systematic approach to making the decision to harvest. Reasonable estimates of the necessary data will make possible more accurate estimates of the current earning power of a particular stand than are now available. These estimates of earning power can then be weighed along with the other factors a manager must consider in reaching the best possible decision for his own particular circumstances.

The alternative cost method, as used in this thesis, does not apply until the stand reaches merchantable size, since the value of standing timber is considered to be zero until there are merchantable trees in the stand. In the early years of merchantable timber, the marginal rate of return on timber capital is quite high. However, in cases where land is a relevant portion of the investment for determining an alternative cost, the rate of return would be low. This is because the proportion of land in total investment is high until a sizable amount of timber capital has accumulated. The proportion of total investment represented by land decreases as the value of merchantable timber increases; at the approximate optimum rotation ages for Douglas-fir, the inclusion of land in investment makes little difference in the marginal rate of return.

SUMMARY AND CONCLUSIONS

The problem for this study was to determine and apply the appropriate principles for deciding upon the time to harvest Douglas-fir, or the rotation age. A solution of this problem involves the use of economic principles relating to the alternative costs of growing timber.

Standing timber is a stock of capital with earning power if retained in timber or diverted to another productive use. The timber owner has two alternatives for this capital: (1) retain it in standing timber, or (2) transfer it to other uses. In choosing an alternative, the owner foregoes the income opportunity of the capital in any other use. The cost of any alternative is the maximum return that could be realized in another use. The market value of the timber is the size of the investment that could be used in another alternative if land is to be retained by the owner for timber production.

Returns from other investments commonly are given in terms of an interest rate, so returns to the timber investment are converted to a marginal rate of return. This is performed by dividing the net marginal value growth by the value of standing timber at different stand ages. Net marginal growth is the annual increase in value of the stand, less ad valorem taxes on standing timber. As long as the marginal rate of return on the timber investment exceeds the alternative rate of return, it is profitable to retain the capital in timber. When the marginal rate of return on timber begins to fall below the alternative rate, it pays the investor to transfer his timber capital to an alternative use.

Data necessary for use in the alternative cost method were yields, prices and variable costs. These data were obtained from government agencies, federal, state and local, and by computations and estimates by the author when necessary. Separate estimates of price and cost data for each of three common site classes were made.

Application of the method to these data indicated that at an alternative rate of five per cent, the optimum rotation age for site II Douglas-fir was between 60 and 65 years. For site III, it was about 75 years, and for site IV, between 85 and 90 years. An increase in the alternative rate shortened the rotation age and a decrease in alternative rate lengthened it.

Changes in certain factors affect rotation age. Yield taxes or a tax on land only would tend to lengthen the rotation by one to three years. Thinning operations also would tend to lengthen the rotation somewhat, but available data are not adequate to predict the extent. The degree of stocking would influence the rate of return in very early years, but has little effect at later stages.

When prices are rising, it may pay to hold timber past the indicated age to take advantage of price increases. Conversely, falling prices may wipe out gains through physical growth and force earlier harvesting.

One difficulty a private timber owner has in applying the alternative cost method is in obtaining accurate data, particularly future yields and prices. In spite of this difficulty, it offers a systematic approach to the problem of deciding when to harvest Douglas-fir.

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APPENDIX

APPENDIX

The logging and hauling costs developed by the Oregon and California Revested Lands Administration are primarily for use with heavy equipment in old-growth Douglas-fir in mountainous country. These costs, especially yarding and loading, are higher than will be encountered with light equipment designed for small logs.

Appendix Table 1. Logging and hauling cost per thousand board feet for site II Douglas-fir in western Oregon, 1953.

Age	Vol. per acre	Vol. per tree	Falling and bucking	Yarding and loading	Hauling	Total costs
	M b.f.	b.f.				
30	3	95	$6	$18	$8	$32
40	12	160	6	15	7	28
50	27	230	5	13	6	24
60	43	305	5	11	5	21
70	57	410	4	10	5	19
80	70	525	4	9	5	18
90	81	650	4	8	5	17
100	90	785	3	8	5	16
110	98	925	3	7	5	15

Costs were scaled downward as the average volume per tree and per acre decreased. In the absence of a more precise guide, reductions were made so the costs followed a more or less regular curve when taken to the nearest dollar. The few reliable reports of stumpage sales in the 50 to 70 year age class available to the author were extended on the basis of these adjusted costs and the use of judgment. Transportation costs were figured on the basis of a five-mile haul.

No allowance was made for profit and risk. It is felt that the costs are high enough to cover these items, particularly since no allowance was made for the relatively good terrain generally found on farm woodland.

Appendix Table 2. Logging and hauling cost per thousand board feet for site III Douglas-fir in western Oregon, 1953.

Age	Vol. per acre	Vol. per tree	Falling and bucking	Yarding and loading	Hauling	Total costs
	M b.f.	b.f.				
40	4	110	$7	$17	$7	$31
50	12	155	6	15	7	28
60	24	200	5	14	6	25
70	35	255	5	12	5	22
80	46	310	5	11	5	21
90	55	370	4	10	5	19
100	63	435	4	9	5	18
110	69	500	4	9	5	18

Appendix Table 3. Logging and hauling cost per thousand board feet for site IV Douglas-fir in western Oregon, 1953.

Age	Vol. per acre	Vol. per tree	Falling and bucking	Yarding and loading	Hauling	Total costs
	M b.f.	b.f.				
50	3	115	$7	$18	$8	$33
60	8	140	7	16	7	30
70	14	155	6	15	7	28
80	20	175	6	14	7	27
90	26	200	6	13	6	25
100	31	225	5	12	6	23
110	36	250	5	11	6	22