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The Oregon Coast Range contains large acreages of nonstocked high site land. With the increasing demand for wood products, more attention is being given to the problems of reforesting these lands.

This study develops financial guidelines to the reforestation of nonstocked high site lands. A number of possible owner constraints are examined as well as a variety of forest yield functions. Guidelines are given for the maximum amount available for reforestation at a number of interest rates.

Economic Guidelines to Reforestation Under Alternative Types of Forest Ownership

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ECONOMIC GUIDELINES TO REFORESTATION UNDER ALTERNATIVE TYPES OF FOREST OWNERSHIP

I. INTRODUCTION

The Coast Range of Oregon and Washington contains some of the world's most productive timberland. Beuter and Handy (5) estimated that over half of the commercial forest land in the Coast Range is classed as Douglas-fir site index 140 or better. Defining land of site index 140 or better as "high site land," we estimated that 25 percent of the high site land in the Coast Range is less than 40 percent stocked by Forest Service survey standards. Another 65 percent of the high site land was estimated to be 40 to 70 percent stocked, but with inhibiting vegetation or other problems which decrease productivity. In another study, Grotkowski et al. (13) estimated that 20 percent of the highly productive land in the Oregon-Washington Coast Range and foothills of the Washington Cascades is currently occupied by non-productive species.

More work is needed to put these figures into perspective. Whether low stocking or inhibiting vegetation constitutes a problem depends upon the objectives and constraints a given landowner has.

One key question: How much can a given landowner afford to spend to rehabilitate and regenerate high site lands that are now poorly stocked with economically productive species?

Objective and Scope

The purpose of this study was to develop guidelines for determining the maximum amount which could be spent by landowners for rehabilitation and reforestation[1] of nonstocked high site lands in coastal Oregon. Timber production in the form of stumpage was assemed to be the primary objective and Douglas-fir the primary species.

What constitutes "the maximum amount an owner can spend to rehabilitate an acre of land"? Assuming a landowner wishes future yields to at least recover his costs, the maximum amount available for rehabilitation is the discounted difference between all revenues from the sale of timber as stumpage and all management costs, including property taxes, incurred after seedling establishment. The maximum amount available for rehabilitation will be called the discounted net return in this report. This definition of discounted net return includes the implicit assumption that the ground is currently

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[1] Rehabilitation and/or reforestation as used in this study refer to the establishment of Douglas-fir seedlings on previously nonstocked land or land currently stocked with undesirable species; including site preparation, planting, replanting, and vegetation and animal control measures.

unstocked and will remain so unless reforestation takes place. Though some stocking may occur naturally and constitute a future return I have ignored that here.

A separate guideline has been formulated for each alternative combination of management intensity and owner constraints. Stumpage prices, management costs and tax rates (where applicable) are the same for each guideline. Each alternative is evaluated at a number of interest rates allowing a particular landowner to choose the rate which best applies to his situation.

Review of the Literature

Little work has been done concerning the maximum amount to spend on reforestation in the Douglas-fir region. The Department of Natural Resources (DNR) of the state of Washington in their June 1973 Sustainable Harvest Analysis (9) uses linear programming to determine guidelines to reclamation planning. Present value of the existing timber (hardwoods)[2/] is compared to the present value if reclamation is done in ten years. Both are then judged in terms of their effect on the DNR's sustainable harvest model. Present values are given in table form for a number of stocking levels and hardwood quality levels.

[2/] Hardwoods are not considered to be the primary species as the return is lower than for softwoods. In my study, hardwoods have no value and are considered to be brush.

Yoho, Chappelle and Schweitzer (37) defined conditions where it would be more profitable to convert red alder to Douglas-fir than manage for red alder. Red alder should be converted immediately under most circumstances. Retention of the red alder was recommended only when sites were poor, conversion costs high, and stumpage prices low.

Nadeau (20) studied the direct and indirect returns from a stand of site class I sugar pine. Both present net worth and internal rate of return were used to judge the economic feasibility of reforestation. Using a hypothetical model Nadeau found the internal rate of return from reforestation varied between four and six percent for the firm and was approximately eight percent for the state. He concluded that "in spite of low economic feasibility at the individual or firm's level reforestation is still highly desirable because of indirect benefits associated with multiple use such as recreation and soil and water conservation" (20).

Other studies have dealt with the scheduling or ranking of various reforestation projects or methods. Teeguarden and von Sperber (30) looked at three alternative ways of scheduling Douglas-fir reforestation projects on the BLM's Roseburg District. Capital budgeting, linear programming and rules-of-thumb were compared for efficiency in allocating a fixed reforestation budget among a number of reforestation projects. Linear programming proved to be the most efficient method.

In another article (28) Teeguarden ranked different reforestation methods by benefit-cost ratios. He used expert opinion to arrive at a probability of success for each method and looked at the difference between what the particular reforestation method would accomplish and what would occur naturally. However, Teeguarden was looking for the regeneration method to use in a particular situation and not for the maximum amount which could be spent on regeneration.

Teeguarden (29) also looked at the use of economic criteria when making reforestation investment decisions. He concluded that due to the long term nature of forestry present value analysis is subject to large amounts of error and uncertainty. Faith in future prices and costs is what really determines whether or not to reforest, and present value analysis is used to confirm that faith or lack of it. Teeguarden concluded that the best use of economic criteria comes when deciding the most efficient use of a fixed budget, and that economic criteria were not helpful in deciding whether or not to reforest.

II. ASSUMPTIONS, CONSTRAINTS, DATA AND METHODS

The factors I considered when determining discounted net returns are divided into three main categories: 1) types of owners, 2) timber yield data, and 3) other considerations.

Types of Owners

Owners were distinguished on the basis of their 1) criteria for setting rotation length, 2) time horizon and 3) harvest flow constraints.

Rotation Length

Two general methods of determining rotation length were used: culmination of mean annual increment and financial maturity. These two methods were chosen to reflect differences in the objectives and constraints facing different types of owners. Using the criteria of culmination of mean annual increment reflects an objective of maximizing wood production. Using a criteria of financial maturity reflects an objective of maximizing discounted net return. Since each combination of management intensity and owner constraints is evaluated at a number of interest rates, the point of financial maturity (rotation length) may change as the interest rate changes.

Many public agencies currently use a rotation length of 100 years, so discounted net returns were also calculated using this rotation length. This was done to compare discounted net returns using a public agency rotation length with discounted net returns using other criteria for determining rotation length.

Time Horizon

The planning period of a given landowner affects the amount available for rehabilitation. Two planning horizons were considered in this study: one rotation and an infinite series of rotations. To represent these two horizons, the concepts of present net worth (PNW)[3/] and capitalized value (CV) were used. Present net worth is used to compute the present value of costs and returns over one rotation and capitalized value is used to compute the present value of a perpetual stream of costs and returns.

Present net worth was calculated as follows:

[Present net worth] = [Present value of revenues] - [Present values of costs]

Where:

$$[\text{Present value of revenues}] = \sum_{t=1}^{n} \left([\text{Revenue in year } t] \times \left[\frac{1}{(1+i)^t} \right] \right)$$

[3/] Present net worth (PNW is used rather than the internal rate of return because PNW is more useful when comparing investment alternatives which are mutually exclusive.

$$[\text{Present value of costs}] = \sum_{t=1}^{n} ([\text{Cost in year } t] \times [\frac{1}{(1+i)^t}])$$

n = year of final harvest

t = year in which revenue or cost appeared

i = decimal form of alternate rate of return

Capitalized value was calculated as follows:

[Capitalized value] = [Present value of revenues] - [Present value of costs]

where:

$$[\text{Present value of revenues}] = \sum_{t=1}^{n} (\frac{[\text{Revenue in year } t] \times (1+i)^{n-t}}{(i+1)^n - 1})$$

$$[\text{Present value of costs} = \sum_{t=1}^{n} \frac{[\text{Cost of year } t] \times (1+i)^{n-t}}{(1+i)^n - 1}$$

n = year of final harvest

t = year in which revenue or cost appeared

i = decimal form of alternate rate of return

This assumes that costs and returns are distributed the same way in all future rotations.

Harvest Flow Constraints

Some landowners operate under constraints requiring an even periodic flow[4/] of timber. This situation changes the way in which a landowner can look at the question of whether or not to regenerate.

If the land to be regenerated is in the allowable cut base[5/] failure to reforest it results in a decrease in the allowable cut by an amount equal to the expected average annual growth on the land in question. For example, assume an acre of land in the allowable cut base yields 72000 board feet with a 90 year rotation. Failure to regenerate one acre will result in a yearly loss of 72000/90 = 800 board feet in allowable cut. Therefore, in order to reforest this land and prevent a decrease in the allowable cut a landowner, who had a even flow constraint, would be willing to pay the present value of the series of revenues generated from 800 board feet per year.

Conversely, if the land is not in the allowable cut base, its reforestation and addition to the base would serve to increase the allowable cut by the average yearly growth. Using the example given above, a landowner would be willing to spend an equal amount to increase the allowable cut by 800 board feet per year as he would to prevent an 800 board foot per year decrease. However, in order to increase the allowable cut there must be a reserve of

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4/ For purposes of this paper the period is one year. This corresponds to the period used by most public agencies in this region in allowable cut calculations.

5/ Allowable cut base is defined here as that portion of the forest land base used in determinations of the level of even flow.

merchantable timber available to cut.

Therefore, under these even flow conditions the discounted net return was calculated as follows:

$$[\text{discounted net return}] = \frac{[\text{Yearly revenues - Yearly taxes}^{6/}]}{i} - [\text{Discounted costs}]^{7/}$$

where:

$$[\text{Yearly revenues}] = \frac{[\text{Total expected growth in one rotation}]}{r} \times [\text{Price for timber grown to } r]$$

$$[\text{Yearly taxes} = \frac{[\text{Taxes on total growth in one rotation}]}{r}$$

$$[\text{Discounted costs}] = [\text{Discounted costs incurred in current and future rotations}]$$

r = rotation length in years

i = decimal form of alternate rate of return

6/ The tax used here is the Western Oregon Ad Valorem Tax. Where applicable taxes are paid on the average yearly revenue while assuming timber is at rotation age. A further discussion of the application and effect of taxes is given in a later section.

7/ This calculates discounted net return under even flow for an infinite number of rotations. To calculate discounted net return under even flow for one rotation multiply

$$\frac{[\text{Yearly revenues - Yearly taxes}]}{i} \text{ by } \frac{(1+i)^r}{(1+i)^r - 1} \text{ where } r = \text{rotation}$$

length, then add to [Discounted costs] the present value of all costs occurring in future rotations.

For example, assume a pre-commercial thinning plus frequent light commercial thinning management regime on Site I land with a 50 year rotation, price responsive to diameter, and a five percent interest rate. Total expected growth to age 50 is the sum of all commercial thinnings prior to age 50 plus the final harvest at age 50; in this case 13509 cubic feet. Given a price of $48 per cunit at age 50, total revenue is $6484.32 and yearly revenue equals $129.69.

Taxes are now calculated. Given a total revenue of $6484.32, total taxes are ($6484.32)(0.7)(0.025) = $113.48, and yearly taxes equal $2.27. Subtracting yearly taxes from yearly revenue leaves $127.42 and dividing by the decimal form of the interest rate gives $2548.

Discounted costs are the present value of management costs incurred in current and future rotations. At a five percent interest rate the present value of pre-commercial thinning cost is $27 and regneration cost is $6, giving total discounted costs of $33. Subtracting this from $2548 leaves a discounted net return of $2515. Under conditions where price is not responsive to diameter and taxes are not incurred this calculation is greatly simplified.

Use of this type of calculation requires the presence of an even periodic flow constraint, but presence of an even flow constraint does not require use of this calculation.

Using this type of discounted net return calculation is called the allowable cut effect (ACE). As defined by Schweitzer, Sassaman, and Schallau the ACE (25) is "the immediate increase in today's allowable cut which is attributable to expected future increases in yields." As can be seen from the previous examples it is also the amount which is attributable to prevention of a decrease in today's allowable cut. For a short history of ACE and another example of its use see Appendix D.

Timber Yield Data

Because the purpose of the study was to develop guidelines for reforestation for nonstocked lands for varying types of owners, a number of yield functions of different management intensities were used. Yield functions representing varying degrees of management intensity provide a comparison of the effect that type of forest management has on discounted net returns.

To compute present value, the amount and timing of harvests was needed for all the yield functions used. To gain this information two questions were asked:

1) Should "The Yield of Douglas-fir in the Pacific Northwest" by McArdle (hereafter referred to as Bulletin 201) (19) be used as a base or should some other set of yield data be used? Bulletin 201 is the most used and most complete set of Douglas-fir yield tables currently in existence

in the Pacific Northwest. However, the data refers strictly to natural (normal) stands without any intensive management (thinning, fertilization, etc.).

2) What is the effect on yields of various levels of management intensity?

The following are examples of various attempts to answer these questions.

One approach is the development of new yield tables which can take into account various levels of management intensity. G. E. Hoyer (16) has developed a simulation technique for interpreting Douglas-fir management practices. New yield functions were developed from sample plots maintained by the Washington State Department of Natural Resources.

Another approach is the use of foreign yield tables. George Barnes (2) has taken British yield tables for Douglas-fir and translated them into American units. The British tables are based on 50-year thinning studies. G. E. Hoyer (15) has also converted British thinning yield tables to American units. David Bruce (6) converted nine foreign production functions for Douglas-fir to American units. These yield functions indicate higher potential production and shorter rotations from intensive thinning.

The more traditional approach involves percentage increases in the growth figures given in Bulletin 201 (19) to represent varying degrees of management intensity. Discussions with silviculturists (4) led me to believe that with intensive management a 40 percent increase in yields over Bulletin 201 is a reasonable expectation. The types of management necessary are the use of genetically improved stock, pre-commercial and commercial thinning and in some cases fertilization. However, the 40 percent increase is in total yields over the rotation, including intermediate as well as harvest cuts. The amounts removed and the timing of harvests are presently unknown and this data is necessary for the computation of present value.

The Bureau of Land Management (BLM) in its Allowable Cut Plan for Western Oregon (35) used percentage increases in Bulletin 201 growth figures. The BLM uses Bulletin 201, Table 3, "Yield tables for Douglas-fir on a fully stocked acre, trees 7 inches in diameter and larger," as the base for an unmanaged forest. The yields from various practices, except thinning, are represented by percentage increases in the yields from the unmanaged stands represented by Bulletin 201. For example, genetically superior stock is assumed to increase total yields 11 percent above those for an unmanaged forest. Thinning is assumed to affect the growth rate of the stand from one thinning to the next. Stands are assumed to be 75 to 125 percent of normal (Bulletin 201) stocking prior to thinning and light thinnings are taken at 10 year intervals. The growth of the stands between thinnings is based on the gross basal area growth figures in Staebler's gross yield tables (26). The figures in Staebler's tables are adjusted to include stand mortality and therefore represent the maximum amount of growth for an unmanaged stand.

The BLM has not estimated the yields for combinations of management practices. For example, yields from the use of pre-commercial thinning are evaluated only in terms of the unmanaged stand, never in combination with another practice, such as commercial thinning. The failure to look at combinations of management. practices is primarily due to the lack of data concerning the effects on yields of combinations of practices.

Reukema and Bruce (7, 22) are currently developing yield functions for Douglas-fir based on sample plots maintained by the U.S. Forest Service. These functions will represent the effects of light commercial thinning alone and in combination with pre-commercial thinning.

After consultations with Bruce (7), I used yield functions representing a frequent light commercial thinning and pre-commercial thinning plus frequent light commercial thinning, both of which are adapted from Bulletin 201 and Staebler's gross yield tables (26). These particular yield functions were chosen because they give the results from combining different management practices. The adaptations conform closely to the preliminary results of

Reukema and Bruce. Additionally, yield functions representing a final harvest only and an early heavy commercial thinning were adapted from Bulletin 201.

All the yield functions used in this study are based on cubic feet in recognition of the trend towards use of this measure (14). For purposes of conversion one cubic foot equals six board feet Scribner Dec. C and one cunit equals 100 cubic feet (17). After consultations with the U. S. Forest Service and silviculturists (1, 4) I adopted a minimum merchantable diameter of seven inches dbh.

Final Harvest Only

The yield function representing a final harvest only is taken directly from Bulletin 201 ". . . trees 7" dbh in diameter and larger" for Sites I, II, and III, indices 200, 170, and 140 respectively (Table 6). This represents the least intensive management allowed in this study. Land is planted and no further management is undertaken until the final harvest. The basic assumption made in all the yield functions used in this study, except pre-commercial thinning which will be discussed later, is that when you enter the stand for the first time after establishment, the stand is normal according to Bulletin 201. For a final harvest only management regime, the stand is assumed to have the volume given in Bulletin 201 when the final harvest is taken.

Frequent Light Commercial Thinning

To arrive at a yield function representing a frequent light thinning regime (Table 8) I took the volume figures given in Bulletin 201 for "Douglas-fir on a fully stocked acre, total stand", and after the first scheduled thinning, added to the ten-year growth figures given in Bulletin 201 one-half of Staebler's mortality estimates (27). According to the thinning schedule, as adopted from Reukema and Bruce, the stand is first thinned when the average size of the entire stand is seven inches dbh or larger. For Sites I and II this is at age 30, and for Site III it is age 40. The first thinning takes 30 percent of the standing volume, the second takes 25 percent, the third takes 20 percent, the fourth takes 15 percent, and subsequent thinnings take 10 percent.

For example, assume the total stand volume at age 30 is 4750 cubic feet and the ten-year growth, given in Bulletin 201, to age 40 is 2750 cubic feet. Staebler's mortality estimate for the decade 30-40 is 600 cubic feet. Adding one-half of this, 300 cubic feet, to 2750 results in total growth of 3050 cubic feet. Because a thinning at age 30 takes 30 percent of the standing volume, or 1425 cubic feet, the volume at age 40 prior to thinning is 4750-1425 + 3050 = 6375 cubic feet.

Because the "total stand" includes the total volume of all trees 1.5 inches dbh and larger and I adopted a minimum merchantable diameter of seven inches dbh these modified total stand yield functions were adjusted to only include trees seven inches dbh in the following manner:

[Inventory volume in 7" dbh and larger in year t] =

$$\frac{\text{[Bulletin 201 7'' and larger volume in year t]}}{\text{[Bulletin 201 total stand volume in year t]}} \quad X$$

[Modified total stand volume in year t]

[Amount cut 7" dbh and larger in year t] =

$$\frac{\text{[Bulletin 201 7'' and larger volume in year t]}}{\text{[Bulletin 201 total stand volume in year t]}} \quad X$$

[Modified total stand amount cut in year t]

where:

Modified total stand volume (amount cut) = yield function figures derived from Bulletin 201 "total stand" figures combined with one-half of Staebler's mortality estimates.

Referring to the above example, 6375 cubic feet coresponds to the "modified total stand volume in year t," and 1425 cubic feet corresponds to the "modified total stand amount cut in year t." These figures were then modified to only include trees seven inches dbh and larger. The ratio of volume in trees seven inches and larger to total stand from Bulletin 201 at age 30 is 4370/4750;

therefore, the amount cut of trees seven inches and larger is 1425 X 4370/4750 = 1311 cubic feet, leaving a residual volume at age 30 of 4370 (volume seven inches and larger) - 1311 = 3059 cubic feet.

The inventory prior to thinning at age 40 is calculated in a similar manner. The "modified total stand volume" is 6375 cubic feet as shown above. The ratio of volume in trees seven inches and larger to total stand at age 40 is 7390/7500; therefore the "inventory volume in 7" dbh and larger" is 7390/7500 X 6375 - 6281 cubic feet.

To derive this yield function a number of assumptions were made:

1) Growth rates are based on total stand rates and adjusted to only include trees seven inches dbh and larger.

2) Commercial thinnings are not heavy enough to change the amount of stand volume growth or rate of diameter growth. Thinnings capture mortality, (specifically one-half of Staebler's mortality estimates adjusted to seven inch dbh and larger stand), and redistribute the normal volume growth to fewer trees.

3) Commercial thinnings do not affect the average stand diameter. Thinnings are taken from each diameter class in proportion to the stand volume contributed by that particular diameter class.

4) The final harvest only takes material 7" dbh and larger. Other trees, if cut, are not considered merchantable.

5) The thinnings take place at ten year intervals.

This light thinning regime is used because it has often been suggested for thinning Douglas-fir.

Early Heavy Commercial Thinning

Another commercial thinning yield function was developed to simulate an early heavy commercial thinning (Table 7). The first thinning takes place at the same time as for the light commercial thinning regime, 30 years for Site I and II, and 40 years for Site III. The stand is first thinned to 50 percent of normal value.[8/] Subsequent thinnings are taken when the stand is equal to or greater than 75 percent of normal; the stand is again thinned to 50 percent of normal. In order to use this yield function two additional assumptions were necessary:

1) After thinning the stand approaches normal volume at the rate given in Table 28 of Bulletin 201, "Estimated increase in normality in a 10-year period"(19). This table estimates the benefit to the residual stand from a decrease in competition.

[8/] Normal volume as used here is that volume given in Bulletin 201 for a stand seven inch dbh and larger for the site and age in question.

2) One-half of Staebler's mortality estimates are added to represent the capturing of one-half of the expected mortality by thinnings.

Volumes and growth were calculated in the following manner:

$$[\text{Volume in year } t + 10] = [\text{Amount of normal volume for year } t + 10] + \frac{[\text{Modified Staebler's mortality estimates for the decade } t \text{ to } t + 10]}{2}$$

$$[\text{Growth from year } t \text{ to } t + 10] = [\text{Volume in year } t + 10] - [\text{Voume in year } t]$$

where:

$$[\text{Amount of normal volume for year } t + 10] = \frac{[\text{Volume in year } t]}{[\text{Normal volume in year } t]} + [\text{10 year normality increase (Table 28 Bulletin 201) for years } t \text{ to } t + 10] \times [\text{Normal volume in year } t + 10]$$

$$[\text{Modified Staebler's mortality extimates for the decade } t \text{ to } t + 10] = \frac{[\text{Bulletin 201 normal volume for trees 7'' dbh and larger in year } t{+}10]}{[\text{Bulletin 201 normal volume for total stand in year } t{+}10]} \times [\text{Staebler's mortality estimated for the decade } t \text{ to } t + 10]$$

For example, assume the stand volume seven inches and larger at age 30 is 4370 cubic feet. After thinning the remaining volume is 2185 cubic feet, or 50 percent of normal. Turning to Table 28, Bulletin 201 (10 year normality increase) a stand at 50 percent of normal is 56 percent of normal in ten years. Normal volume at age 40 is 7390 cubic feet; and 56 percent of this is 4138 cubic feet. Staebler's mortality estimate for the decade 30-40 is 600 cubic feet. This is modified to only include trees seven inches dbh and larger by multiplying by the percentage of trees seven inches and larger in the total stand at age 40 (Bulletin 201). In this case the percentage is 7390/7500 = 98.5 percent, so (600) (0.985) = 591 cubic feet. This figure is divided by two (to get one-half of the mortality estimate) and added to 4138. Therefore, the volume at age 40 is 4434 cubic feet.

The basic assumption of this early heavy commercial thinning yield function is that the stand grows towards Bulletin 201 normal at a given rate plus a growth accelerator. Whenever a thinning occurs the volume in ten years is 56 percent of normal (Table 28, Bulletin 201) plus one-half of Staebler's mortality estimates. This assumes that the thinning has opened up the stand and reduced the nutrient and space competition for the remaining trees. But there is a limit beyond which extra growth will not be stimulated this much as each remaining tree already has all the space and nutrients it can use. This fact is not taken into account in this yield function. Due to these problems of growth estimation, culmination of mean annual increment was not used as a criteria for setting rotation length for this yield function.

Pre-Commercial Thinning Plus Frequent Light Commercial Thinning

A yield function including pre-commercial thinning is given in Table 9. Pre-commercial thinning is assumed to move the yields from the frequent light thinning regime ahead ten years (7). Therefore, the yield function including pre-commercial thinning is exactly the same as the frequent light thinning regime except all volumes and amounts cut are moved ahead ten years. This assumption roughly corresponds to preliminary results of thinning studies conducted by Reukema and Bruce (22). If the first commercial thinning takes place at age 30 with a volume of 4370 cubic feet, pre-commercial thinning will produce this volume at age 20 with a corresponding increase in diameter growth to also move the first commercial thinning up to age 20. For purposes of this study pre-commercial thinning is assumed to take place at age 10.

Other Considerations

In addition to the types of owners and yield functions, discounted net returns depend on the owner's view of 1) risk, 2) future prices and costs, 3) the prevailing rate of interest, and 4) his tax situation.

Risk

Due to the long term nature of forestry, the risk of loss of investment is important in decision making. Therefore, the landowner's attitude toward risk should be included in any discussion of the amount he should invest in reforestation. Basically there are three ways to account for risk in the model used here: altering returns, altering yields, or altering the interest rate.

Vaux in discussing the growing of sugar pine (36) uses a 25 percent increase in costs for risk allowance. The BLM reduces gross yields and therefore revenues by a given percentage to account for breakage, etc. This method could also be used to account for risk. However, both these approaches assume a risk averse decision-maker and the same degree of aversity on the part of all decision-makers. Yet all landowners do not necessarily have the same attitudes toward risk. Differences in risk preference can be accounted for by varying the interest rate. However, this introduces the problem of inflation of the risk allowances due to compounding.

Risk was not dealt with directly in this study. However, by evaluating each combination of owner type and yield function at various interest rates landowners can interpolate between my discounted net revenue figures to arrive at a rate applicable to them which includes their own paricular margin of risk. Though this method is also subject to the effects of compounding, owners can see these effects and adjust their rate accordingly.

Future Prices and Costs

For the purposes of this study a basic stumpage price of $90 per thousand board feet (MBF) Scribner Dec. C was used (1). This price was adopted because it reflects the average Douglas-fir stumpage prices received by National Forests in Western Oregon prior to the large price increases of the first quarter of 1973. Consultations with the U. S. Forest Service (1, 3) led me to believe that the first quarter price increases were temporary, as can now be seen, and that a price in the range of $80 to $100 per MBF was a better estimate of the current worth of Douglas-fir stumpage. Because this analysis uses cunits as the unit of volume measure all prices and costs were based on cunits. This resulted in a basic stumpage price of $54 per cunit. In addition to using a constant stumpage price, discounted net return was calculated using stumpage prices that varied with diameter.

A recent study by Darr (8) has shown that at average stand diameters less than 20 inches, stumpage price varied with diameter, and that there was little stumpage price variation in stands over 20 inches average dbh (diameter at breast height). For this study I have priced all stands 20 inches dbh or greater at $54 per cunit with price decreasing as diameter decreases below 20 inches dbh.

Table 1 gives stumpage price as a function of average stand diameter. These were converted to price per decade for use in evaluating the yield functions. To arrive at this price schedule a number of assumptions were made:

1) All timber in stands averaging 20 inches dbh and over is priced at $54 per cunit.

2) Stumpage prices decrease three dollars for each one inch decrease in average stand diameter below 20 inches dbh. This particular price structure is used because it roughly corresponds to the results found by Darr (8).

3) Diameter growth under all management regimes except the pre-commercial thinning regime follows Bulletin 201 for trees 7" dbh and larger. Pre-commercial thinning moves diameter growth up ten years.

4) All diameters were rounded to the nearest inch for pricing purposes.

According to Darr, lower stumpage prices for stands averaging less than 20 inches dbh were due primarily to the problems of utilization by mills unprepared to handle small diameter timber. He expects the price differential to decrease as industry adapts to smaller diameter timber. I believe that there will continue to be a discrepancy between the stumpage prices of small and large

Table 1. Stumpage price varying with average stand diameter. Timber 20 inches dbh and over is priced at $54 per cunit.

Average stand Diameter	Stumpage price
- inches -	-dollars-
7	15
8	18
9	21
10	24
11	27
12	30
13	33
14	36
15	39
16	42
17	45
18	48
19	51
20+	54

diameter timber. This is due to the necessity of handling more individual trees to obtain a given volume as diameter decreases.

In addition to stumpage prices, a cost level was needed. After consultation with the U.S. Forest Service (1) I adopted costs of $40 per acre for pre-commercial thinning and $65 per acre for future regeneration costs (Table 2). The regeneration costs of $65 per acre also agrees with figures gathered earlier by Beuter and Handy (5). Protection and administration costs were not included because I assumed they would be the same whether or not reforestation was accomplished and were therefore treated as fixed costs.

One inherent problem in the choice of a real price level is some landowners may not agree with my prices and costs. Basically there are two ways in which a particular landowner may disagree: 1) he believes there is a real difference between my price levels and his and 2) he believes there is a real price trend. In the first case the landowner multiplies the revenues received at a particular time by the ratio of his price level to my price level. For example, if discounted net returns using my price level of $54 per cunit are $5000 and a landowner believes the price level should be $50 per cunit he arrives at a new discounted net return in the following manner:

$$\frac{\$50}{\$54} \times \$5000 = \$4630$$

Table 2. Present values of all costs used to determine discounted net return. 2A. Future regeneration costs are $65 per acres, and 2B. Pre-commercial thinning costs are $40 per acre at age 10. Table 2A. Present value of regeneration costs.

Interest rate in percent	Rotation length in years										
	20	25	30	35	40	45	50	60	70	80	100
	-dollars-										
5	39	27	20	14	11	8	6	4	2	1	0
7	23	15	10	7	5	3	2	1	1	0	0
10	11	7	4	2	1	1	1	0	0	0	0
12	8	4	2	1	1	0	0	0	0	0	0
15	4	2	1	0	0	0	0	0	0	0	0

Table 2B. Present value of pre-commercial thinning costs.

Interest rate in percent	One rotation outlook	Infinite series of rotations outlook Rotation length in years						
		20	25	30	40	50	60	100
	-dollars-	-dollars-						
5	25	39	35	32	29	27	26	25
7	20	27	25	23	22	21	21	20
10	15	18	17	16	16	16	15	15
12	13	14	14	13	13	13	13	13
15	10	11	10	10	10	10	10	10

In the second case a landowner may believe there is a real price trend, such as a two percent per year increase in real prices. Inflation was not included in my model due to the problems inherent in choosing an applicable rate of inflation and deciding whether or not the same rate applies to both prices and costs. Therefore, current costs and prices were used throughout. However, as a rule-of-thumb the general rate of inflation can be subtracted from the alternate rate of return to arrive at the real earning rate on the investment. In the case where a landowner believes there is a two percent inflation rate and his alternate rate of return is five percent, the actual earning rate is approximately three percent.

Interest Rate

Each alternative achieved through combinations of owner types and production functions was analyzed at five interest rates; five, seven, ten, twleve, and fifteen percent. These rates were chosen because I felt they encompassed the alternate rates of return facing most forest landowners. If a landowner does not find his exact rate shown, interpolation of discounted net returns between rates or extrapolation to slightly higher ones is easily done.

Taxes

Timber taxes affect regeneration decisions because they are a variable cost which can be avoided by not reforesting. To make these guidelines applicable to private owners and to show the effect of taxes on present value, I have included taxes. For this study the Western Oregon Ad Valorem Property Tax was used as the basis for computing tax liabilities. This tax was chosen because the majority of forest landowners in the Oregon Coast Range operate under it.

The ad valorem tax consists of a yearly tax on land which is based on the land's productivity and whether or not it is being used in its highest and best use. In addition a tax is levied on any merchantable[9/] timber on the land. This rate is levied on the true cash value (TCV).[10/] When timber is cut the tax rate is applied to 70 percent of the immediate harvest value (IHV).[11/] Non-merchantable timber is excluded unless cut and sold; then the tax rate is applied to 100 percent of the IHV. Timber taxes generally begin when the Oregon Department of Revenue finds approximately 500 board feet per acre Scribner Dec. C on a person's property (11).

[9/] Merchantable timber is defined for tax purposes as any timber 12 inches dbh and larger. This 12 inch starting point is used because all Oregon Department of Revenue volume calculations are based on Scribner Dec. C which only includes trees 12 inches dbh and larger.

[10/] True cash value is defined as 30 percent of the immediate harvest value.

[11/] Immediate harvest value is defined as the current market value of timber.

For the purposes of this study a timber tax rate of $25 per $1000 TCV was used. This rate was adopted because it represents the average taxable rate for the Oregon Coast Range (11). The tax on land was excluded because it is paid whether or not reforestation takes place and can be treated as a fixed cost.

The volumes used in this study were based on trees seven inches dbh and larger while only trees 12 inches dbh and larger are taxable. Timber 12 inches dbh and larger was broken out in the following manner:

$$[\text{Volume } 12'' \text{ dbh and larger in year } t] = \frac{[\text{Bulletin 201 } 12'' \text{ and larger volume in year } t]}{[\text{Bulletin 201 } 7'' \text{ and larger volume in year } t]} \times [\text{Volume } 7'' \text{ and larger in year } t]$$

$$[\text{Amount cut } 12'' \text{ dbh and larger in year } t] = \frac{[\text{Bulletin 201 } 12'' \text{ and larger volume in year } t]}{[\text{Bulletin 201 } 7'' \text{ and larger volume in year } t]} \times [\text{Amount cut in year } t]$$

where:

[Volume 7" and larger in year t] = volume given in yield function.

Because the management regimes used in this study are hypothetical, the effects of intensive management on diameter growth are not known and the actual determination of taxable volumes at a point in time was not possible. Taxes, therefore, were approximated in the following manner:

[Tax at beginning of decade] = [Standing volume] X [True cash value] X [Tax rate]

[Tax between decades] = [Average taxable volume in decade] X [True cash value] X [Tax rate] X [9]

[Tax on harvest] = ([Amount cut 12" dbh and larger] X [0.7] X [Immediate harvest value] + [Amount cut 7" dbh to 12" dbh] X [Immediate harvest value]) X [Tax rate]

where:

[Average taxable volume in decade =

$$\frac{[\text{Average volume 12'' dbh and larger in decade}]}{[\text{Average volume 7'' dbh and larger in decade}]} \times$$

[Average yield function volume in decade]

[Average volume of 7" and 12"] = ([Volume at beginning of decade] + [Volume at end of decade]) X $\frac{1}{2}$

[Tax rate] = $25 per $1000 of valuation

[9] = the number of years between decades

For example, assume a standing volume after thinning of

3059 cubic feet and a thinning volume of 1311 cubic feet at age 30. Taxable volume of the standing timber is the amount 12 inches dbh and larger. The ratio of volume in trees 12 inches and larger to seven inches and larger at age 30 is 1850/4370, so the taxable volume is 1850/4370 X 3059 = 1295 cubic feet. Given a true cash value of (0.3) X $54 per cunit and a tax rate of $25 per $1000 of valuation, the tax on standing timber is $5.24

The tax on the timber harvested is then calculated. The volume harvested in trees 12 inches and larger is 1850/4370 X 1311 = 555 cubic feet. The tax rate is applied to 70 percent of the immediate harvest value (IHV) of timber 12 inches and larger when cut; so given an IHV of $54 per cunit, the tax is $5.24. Timber under 12 inches dbh when harvested has the tax rate applied to 100 percent of the IHV. This volume is 1311-555 = 756 cubic feet and the tax is $10.21. So the total tax at age 30 is $20.69.

The tax between decades is approximated by taking the tax at the midpoint and multiplying by 9. Continuing the above example, the standing volume at age 40 is 6281 cubic feet, so the volume at age 35 is $\frac{(5281 + 3059)}{2}$ = 4670 cubic feet. Turning to Bulletin 201 the volume at age 35 in trees seven inches and larger is $\frac{(4370 + 7390)}{2}$ = 5880 cubic feet, and the volume in trees 12 inches inches and larger is $\frac{(1850 + 5650)}{2}$ = 3780 cubic feet. So the average taxable volume is 4670 X $\frac{3780}{5880}$ = 2979 cubic feet. Given an IHV of

(0.3) X \$54 per cunit and a tax rate of \$25 per \$1000 of valuation, the average tax is \$12.06 and the total tax between decades is \$12.06 X 9 = \$108.57.

A number of assumptions were necessary in order to determine taxable volume:

1) The stand is similar to a Bulletin 201 stand in the distribution of diameters and the percentage of stand volume associated with each diameter class.

2) The taxes paid on standing volume at the midpoint of a decade are equal to the average taxes paid during the decade.

3) Pre-commercial thinning moves diameter growth ahead ten years, so the point where taxes begin is also moved ahead ten years. This is the same assumption as was made for growth in the pre-commercial regime.

The year in which taxes begin, 500 board feet per acre Scribner Dec. C or more, as calculated for all management regimes except pre-commercial thinning are: 20 years for Site I, 25 years for Site II, and 30 years for Site III. For the pre-commercial regime taxes begin ten years earlier: 10 years for Site I, 15 years for Site II, and 20 years for Site III.

III. RESULTS

The guidelines for maximum expenditures justified to reclaim brushlands are presented in Tables 7-28. They are divided into two basic groups: one excluding taxes (Appendix B) and one including taxes (Appendix C). Each table shows one production function with rotation length set either by culmination of mean annual increment, financial maturity or the given length of 100 years. The upper part of each table gives discounted net returns under the assumption price does not depend on diameter, while the lower part gives discounted net returns under the assumption price does depend on diameter.

To find the maximum amount he can spend for regeneration, a landowner must choose his:

1) tax situation (either subject to taxes or not)
2) Level of management intensity (final harvest only, early heavy thinning, frequent light thinning, or pre-commercial thinning)
3) method of determining rotation length (culmination of mean annual increment, financial maturity, or the given length of 100 years)
4) price assumption (price dependent on diameter or price not dependent on diameter)

5) planning horizon (one rotation or an infinite series of rotations)

6) land productivity (Site I, II, or III0

The owner is then able to compare discounted net returns at a number of interest rates and choose the rate which applies to his situation. Given that his objective is to produce stumpage, the resulting figure is the maximum amount the landowner can spend for rehabilitation and reforestation and still earn the indicated rate of return on his investment.

For example, suppose a landowner finds himself in the following circumstances:

1) subject to taxes
2) plans on taking a final harvest only
3) rotation length is set by financial maturity
4) he feels price doesn't depend on diameter
5) plans an infinite series of rotations (CAP)
6) land is Site II
7) alternate rate of return is five percent

The maximum amount he can afford to spend is $546 per acre with a 35 year rotation. For these circumstances the discounted net return, if the landowner is operating under the circumstances discussed in the section on harvest flow constraints (the allowable cut effect)[12/] is also given.

Landowners should be cautioned about the use of these tables; the discounted net returns given are accurate only within the context of the assumptions made in this model.

Discussion of Results

General Trend of Discounted Net Returns

Discounted net returns decrease rapidly as the alternate rate of return increases and generally increase as management intensity or site class increases. Figure 1 shows the relationship between discounted net returns and the alternate rate of return for Site I, II, and III with a frequent light thinning management regime and an 80 year rotation. Figure 2 compares Site II for each of the management regimes at a 100 year rotation. The highest discounted net returns occur at the lowest interest rate and under the most intensive management. This is primarily a result of early returns from thinning. The pre-commercial thinning regime has a cost of $40 per acre at age 10, yet still yields the highest discounted net returns at all interest rates and rotation lengths. Pre-commercial thinning pays off because volumes and growth rates and the time of the first

[12/] The allowable cut effect has been calculated only for an infinite series of rotations. However, as explained in Chapter II, this figure can easily be adjusted to a one rotation outlook.

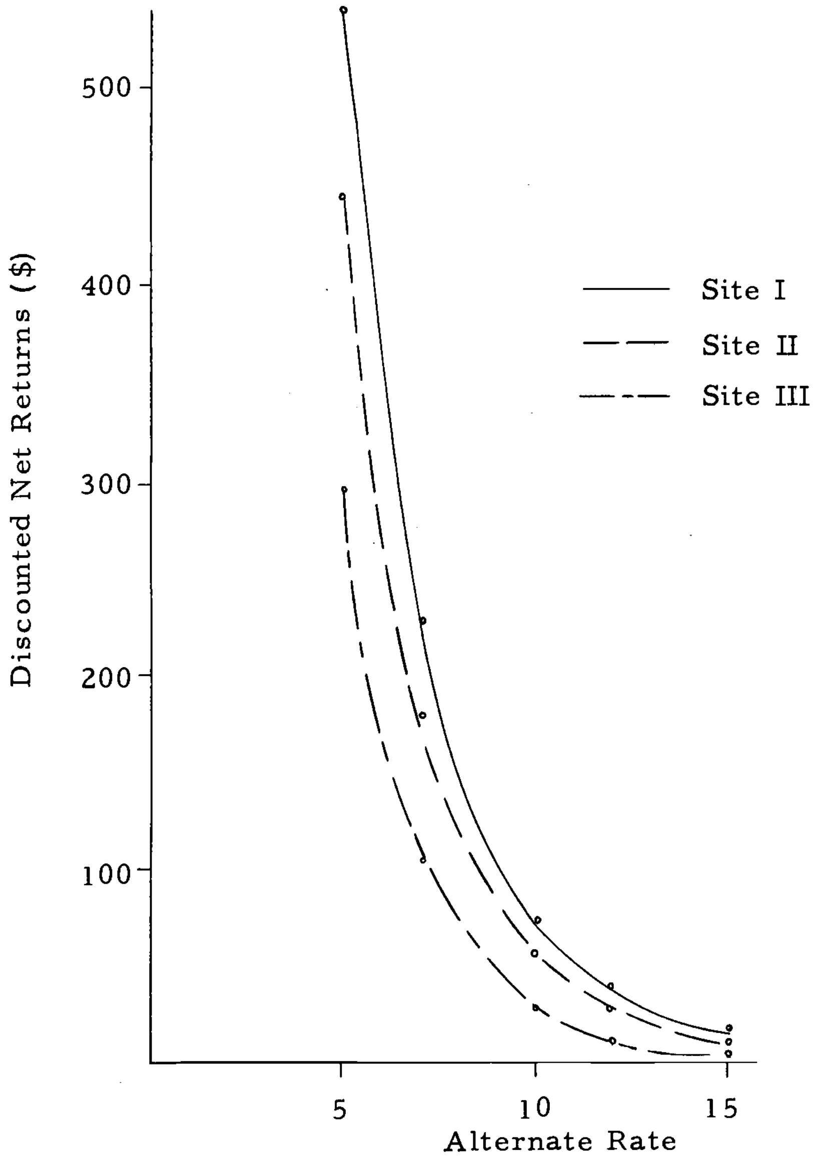

Figure 1. A comparison of discounted net returns for three sites at various interest rates. An 80 year rotation under a a Frequent Light Thinning regime is used as an example.

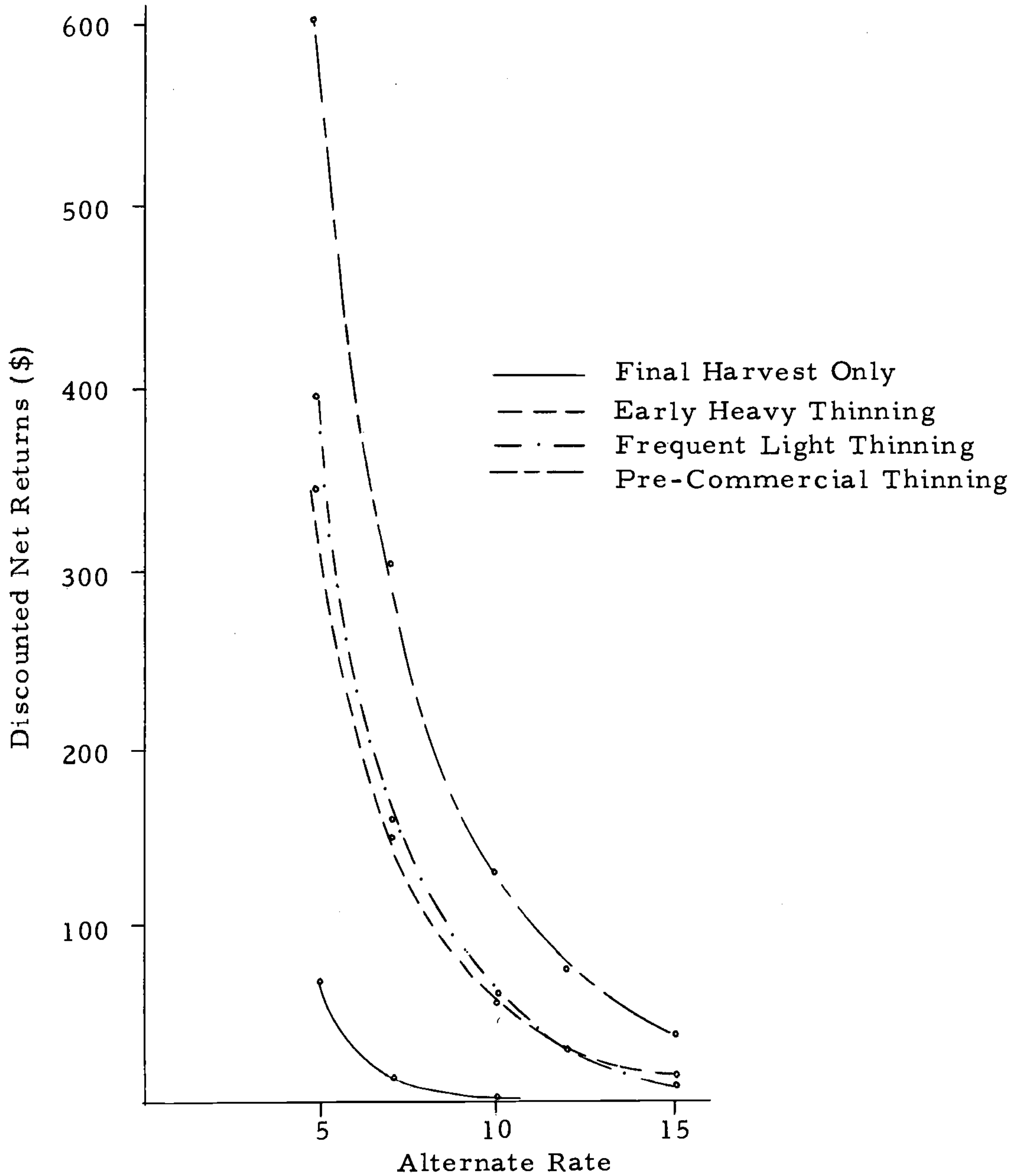

Figure 2. A comparison of discounted net returns from all the yield functions used in this study. The rotation length is 100 years on Site Class II.

thinning are moved up ten years as a consequence of the pre-commercial thinning.

Financial Maturity

The point of financial maturity decreases as the alternate rate of return increases (Figure 3). As the interest rate rises, timber holding costs become higher and the rate of timber value growth drops below the alternate rate sooner. Under both price assumptions rotations range from 20-60 years. Though rotations shorter than 50 years may not be practical for other reasons, for example a desire for larger timber for commercial or recreational use, these results show that under financial criteria, most rotations should be less than 50 years under either price assumption.

100 Year Rotation Length

As the rotation length increases, past the point of financial maturity, discounted net returns decrease (Figure 4). A rotation length of 100 years was evaluated in this analysis because this rotation length is currently used on many public lands in the Pacific Northwest. Use of this rotation length decreases discounted net return unless it is combined with an even flow constraint. Under the latter conditions the allowable cut effect (to be discussed) increases discounted net returns.

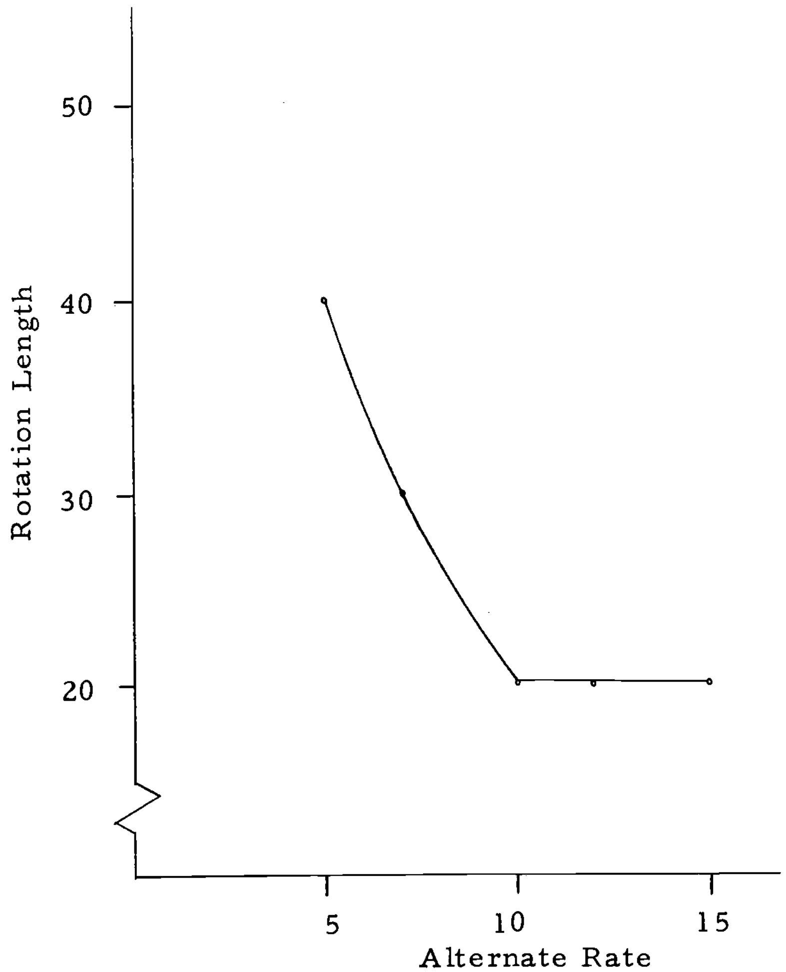

Figure 3. The relationship between rotation length and interest rate under a financial maturity model. Site II under a pre-commercial thinning regime and a one rotation outlook is used as an example. A 20 year rotation is the shortest allowed in this model.

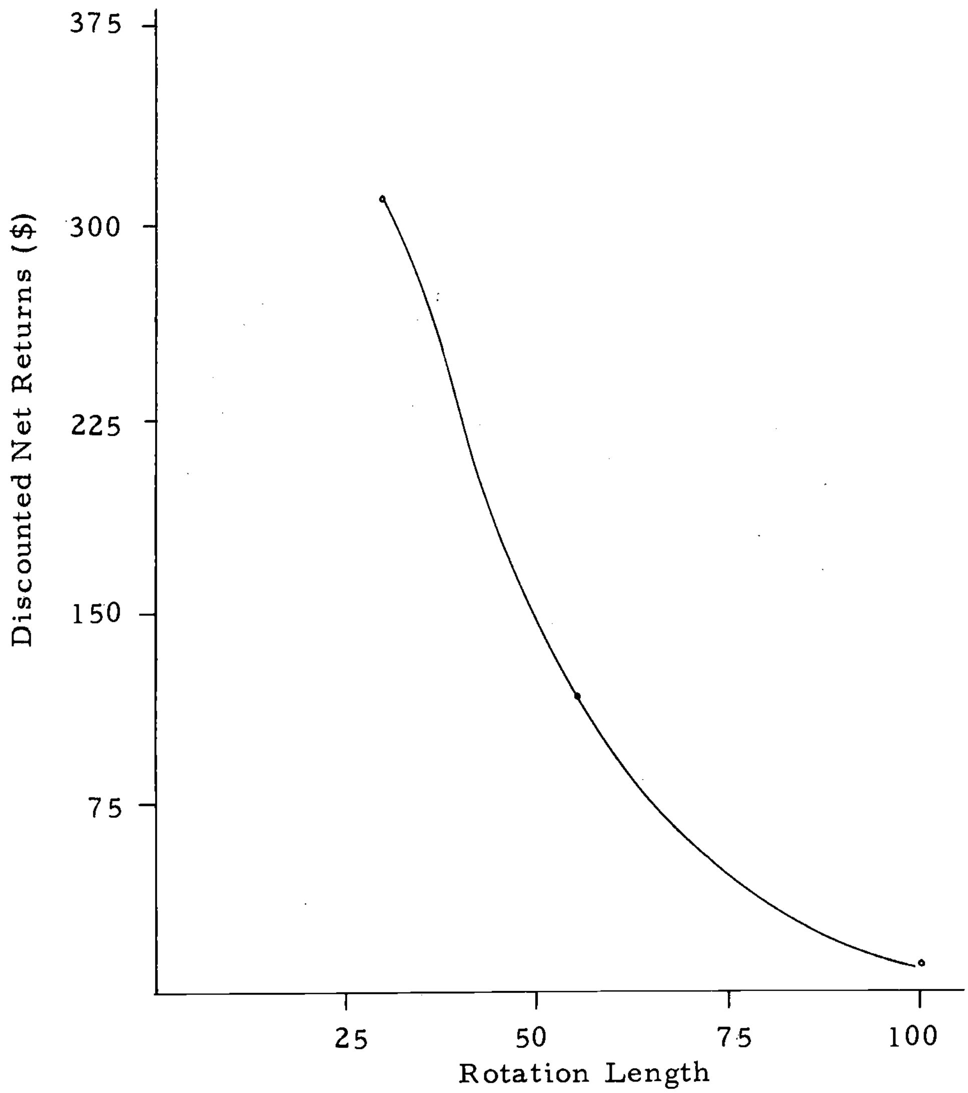

Figure 4. The relationship between discounted net return and rotation length. Site I under a Final Harvest Only regime is used as an example.

Planning Horizon

As the alternate rate of return increases, the difference between a one rotation and an infinite series of rotations outlook goes to zero (Table 3). At higher interest rates the effect of costs and returns from future rotations either balance out or, as in the case of this study, both future costs and future returns have zero present value. Therefore, for higher interest rates the results are insensitive to the choice among the planning horizons considered here. High alternate rates effectively shorten the planning horizon, in terms of the decision to reforest, to one rotation.

Stumpage Prices

When price is responsive to diameter, discounted net returns fall (Table 3). Because it is smaller, timber early in the rotation is worth less than the larger timber later in the rotation. Hence, thinnings are worth less under the variable pricing scheme used here.

The point of financial maturity increases under the variable pricing scheme (Figure 5) because value growth is relatively greater later in the rotation when a premium is paid for larger timber. Though use of a pricing scheme which varied by diameter increased rotation lengths calculated by financial maturity, few rotations were greater than 50 years.

Table 3. A comparison of discounted net returns under fixed and variable pricing. An 80 year rotation on Site II under the frequent light thinning regime excluding taxes is used as an example.

Interest rate in percent and planning horizon		Type of pricing: Fixed	Variable
		-dollars-	
5	PNW[1]	444	259
	CAP[2]	453	264
7	PNW	180	94
	CAP	181	94
10	PNW	57	26
	CAP	57	26
12	PNW	29	13
	CAP	29	13
15	PNW	12	5
	CAP	12	5

1/ PNW xymbolizes a one rotation outlook.

2/ CAP symbolizes an infinite series of rotation outlook.

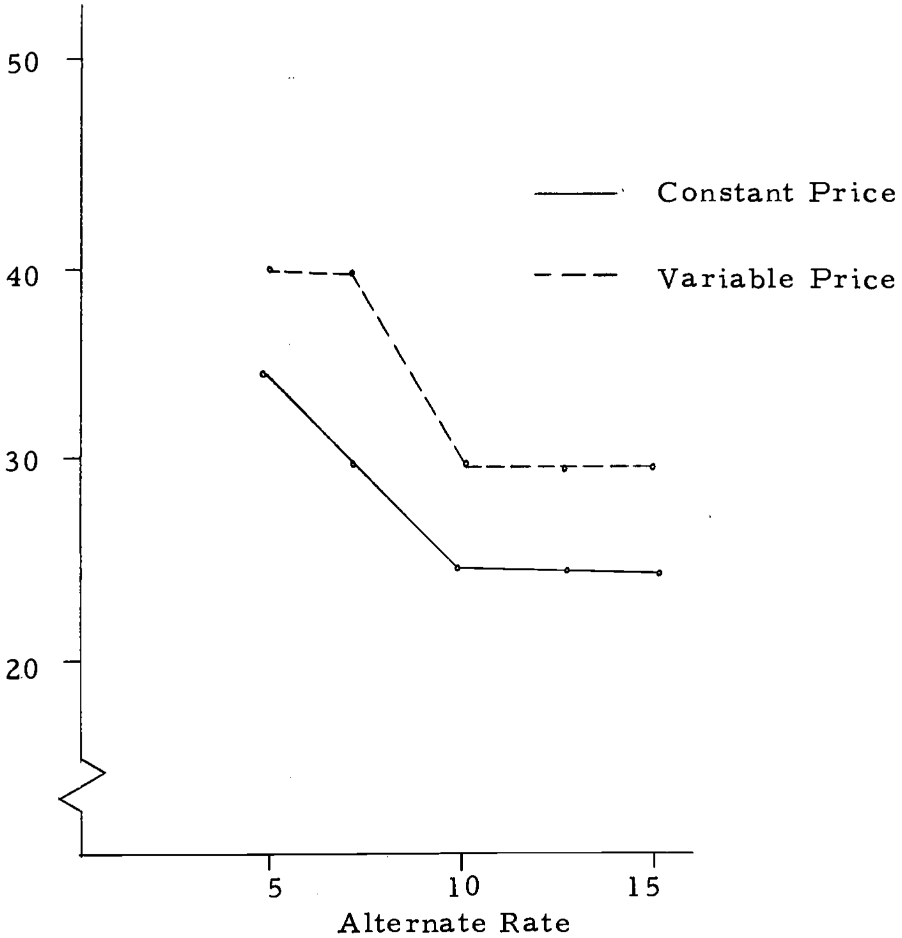

Figure 5. A comparison of the point of financial maturity under a Constant Pricing Scheme and a Variable Pricing Scheme. Site I under a Final Harvest Only regime is used as an example.

Variable Pricing Scheme

This pricing scheme responds to diameter growth by assuming a three dollar per inch increase in stumpage price between seven and twenty inches, with all timber twenty inches and larger priced at $54 per cunit. In this model commercial thinning is assumed not to change diameter growth from that given in Bulletin 201 (19). Pre-commercial thinning is assumed to affect diameter growth by moving it up ten years. If pre-commercial thinning has a greater effect on diameter growth, as shown in studies by Reukema and Bruce (22), but the volume yields are about the same as those used here, the discounted net returns found under a variable price assumption approach those found under a constant price assumption.

Allowable Cut Effect

The allowable cut effect (ACE), as defined in the section on harvest flow constraints, is applicable when the landowner operates under a restrictive set of circumstances. ACE is dependent upon the average annual value growth through the rotation. The highest average annual physical growth occurs, by definition, at culmination of mean annual increment. When price is not responsive to diameter, value growth and physical growth are maximized at the same point, and ACE is maximized at culmination of mean annual increment.

Therefore, with a constant price assumption, setting rotation length by culmination of mean annual increment for lands to be rehabilitated and reforested yields the highest discounted net returns when the allowable cut effect is used.

If price is responsive to diameter, value growth and physical growth are not necessarily maximized at the same point and ACE is not necessarily maximized at culmination of mean annual increment.

Discounted net returns are always higher when circumstances allow use of the allowable cut effect (Table 4). However, the allowable cut effect is applicable only under a restrictive set of conditions; specifically the calculation and harvest of an allowable cut, and in the case of adding land to the allowable cut base, the presence of a reserve of merchantable timber. For a further discussion of the current controversy surrounding the allowable cut effect see Appendix D.

Taxes

Because taxes are a cost to private landowners, they reduce the amount that can be spent for reforestation on private lands (Table 5). Taxes lowered discounted net returns the most at low interest rates and long rotations; while their effect diminished as the interest rate increased or rotation length decreased. Site I land was affected the most because taxes took effect earlier than on other sites. At low

Table 4. A comparison of discounted net returns without and with the allowable cut effect. Examples were chosen at random from the results given in Appendices B and C.

Discounted net returns: Without allowable cut effect	Discounted net returns: With allowable cut effect
-dollars-	
378	2250
2	645
244	1040
10	152
347	1114
671	1740
18	148
3	509
11	637
416	1587
-5	371

Table 5. A comparison of discounted net returns excluding and including taxes. A 60 year rotation on Site I under the final harvest only regime with constant pricing and a one rotation outlook are used as an example.

Interest rate in percent	Tax: Excluding	Tax: Including
	- dollars -	
5	361	254
7	116	68
10	22	6
12	8	0
15	2	-1

interest rates and long rotations this caused Site I land to have the lowest discounted net return of all three sites.

In a few instances taxes caused a change in the financially determined rotation length. This was always to a shorter rotation. However, because their absolute effect is relatively small, taxes only affect the marginal reforestation decisions.

Relating Discounted Net Returns to Current Rehabilitation Costs of Brush - Occupied Land

In a study conducted by Beuter and Handy (5) various methods and costs of rehabilitation and reforestation of brushed-occupied high site land were gathered. At that time, the least cost method of brush control and seedling establishment was approximately $100 per acre. Adopting this $100 per acre as the minimum discounted net return necessary for reforestation of brushed over land, the results of this study were analyzed in relation to each interest rate used in this study. Referring to Tables 10-31 lines separate discounted net returns of $100 or more (feasible) from those less than $100 (unfeasible). The allowable cut effect was not taken into account because it yields discounted net returns of $100 or more at most combinations.

Using the just discussed $100 as the dividing line between feasible and unfeasible, reforestation in general is not feasible at interest rates of ten percent or more. Additionally, feasibility is affected by management intensity and rotation length. At the highest management intensity studied, pre-commercial thinning plus frequent light commercial thinning, and rotation length set at culmination of mean annual increment, reforestation was feasible on Sites I and II at a 15 percent interest rate. At the lowest management intensity studied, final harvest only, reforestation was feasible only at the lowest interest rate used, five percent.

As the rotation length increased the interest rate at which reforestation was feasible decreased. Referring to the example given above, when the rotation length increased to 100 years reforestation was feasible only at interest rates of 12 percent or less for Sites I and II under the pre-commercial thinning plus frequent light commercial thinning regime. For the final harvest regime and a 100 year rotation reforestation was not feasible at any of the interest rates used.

IV. CONCLUDING COMMENTS

The purpose of this study was the development of guidelines for determining the maximum amount which could be spent by landowners for rehabilitation and reforestation of nonstocked high site lands in coastal Oregon. Discounted net returns were calculated for numerous combinations of constraints, prices, yield functions and interest rates and presented so an individual landowner can identify his particular situation and locate the discounted net return associated with it. Though the discounted net returns shown are useful only within the context of the assumptions I have made, they do show the effect of varying management intensities, interest rates, tax status, and planning horizons, as well as use of the allowable cut effect on the amount which can be spent for rehabilitation and reforestation.

The effects of changes in the alternate rate and pricing scheme on discounted net returns have been demonstrated (Tables 10-31). Additionally, as management intensity increased discounted net returns increased, somewhat offsetting the effects of increases in the alternate rate. This means that as the alternate rate increases landowners should carefully consider the degree of management intensity to be used.

Additionally, the influence of the allowable cut effect (ACE) on discounted net returns was demonstrated. Given the conditions necessary for use of the ACE, and its actual use, discounted net returns are greatly increased due to the realization of income early in the rotation.

Further research is needed into the development of yield functions which accurately express varying degrees of management intensity. Additionally, work is needed in the area of accurately determining owner constraints as to reforestation, particularly in the area of taxes.

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APPENDICES

Table 6. Production functions for Sites I, II, and III representing a management objective of final harvest only. Only trees seven inches and larger are included.

Site I			Site II			Site III		
	Cubic feet			Cubic feet			Cubic feet	
Age yrs	Volume	Growth	Age yrs	Volume	Growth	Age yrs	Volume	Growth
20	1170		20	590		20	150	
		3200			2680			1850
30	4370		30	3270		30	2000	
		3020			2850			2360
40	7390		40	6120		40	4360	
		2760			2600			2190
50	10150		50	8720		50	6550	
		2350			2120			1950
60	12500		60	10840		60	8500	
		2000			1820			1540
70	14500		70	12660		70	10040	
		1850			1560			1300
80	16350		80	14220		80	11340	
		1530			1320			1050
90	17880		90	15540		90	12390	
		1260			1070			880
100	19140		100	16610		100	13270	
		1060						

Table 7. Production function for Sites I, II, and III representing a management objective of early heavy thinning. Only trees seven inches and larger are included.

Site I					Site II					Site III				
	Cubic feet					Cubic feet					Cubic feet			
Age yrs	Volume	Amount cut	Residual volume	Growth	Age yrs	Volume	Amount cut	Residual volume	Growth	Age yrs	Volume	Amount cut	Residual volume	Growth
20	1170		1170	3200	20	590		590	2680	20	150		150	1850
30	4370	2185	2185	2249	30	3270	1635	1635	2026	30	2000		2000	2360
40	4434		4434	2564	40	3661		3661	2333	40	4360	2180	2180	1748
50	6998		6998	2597	50	5994		5994	2298	50	3928		3928	1900
60	9595	3345	6250	2410	60	8292	2872	5420	2100	60	5828		5828	1718
70	8660		8660	2568	70	7520		7520	2041	70	7546	2526	5020	1640
80	11228		11228	2444	80	9561		9561	1932	80	6660		6660	1570
90	13672		13672	2059	90	11493		11493	1913	90	8230		8230	1482
100	15731		15731	2029	100	13406		13406	1609	100	9712		9712	1358

Table 8. Production functions for Sites I, II, and III representing a management objective of frequent light thinning. Only trees seven inches and larger are included.

Site I					Site II					Site III				
	Cubic feet					Cubic feet					Cubic feet			
Age yrs	Volume	Amount cut	Residual volume	Growth	Age yrs	Volume	Amount cut	Residual volume	Growth	Age yrs	Volume	Amount cut	Residual volume	Growth
20	1170		1170	3200	20	590		590	2680	20	150		150	1850
30	4370	1311	3059	3222	30	3270	981	2289	2916	30	2000		2000	2360
40	6281	1547	4734	3097	40	5205	1301	3904	2801	40	4360	1308	3052	2295
50	7831	1566	6265	2820	50	6705	1341	5364	2460	50	5347	1337	4010	2122
60	9085	1363	7722	2540	60	7824	1171	6653	2239	60	6132	1226	4906	1812
70	10262	1026	9236	2450	70	8892	889	8003	2020	70	6718	1008	5710	1565
80	11686	1169	10517	2150	80	10023	1002	9021	1780	80	7275	727	6548	1346
90	12667	1267	11400	1870	90	10801	1080	9721	1520	90	7894	789	7105	1170
100	13270		13270	1650	100	11241		11241	1390	100	8235		8235	1020

Table 9. Production functions for Sites I, II, and III representing a management objective of pre-commercial thinning and frequent light thinnings. Only trees seven inches and larger are included.

Site I					Site II					Site III				
	Cubic feet					Cubic feet					Cubic feet			
Age yrs	Volume	Amount cut	Residual volume	Growth	Age yrs	Volume	Amount cut	Residual volume	Growth	Age yrs	Volume	Amount cut	Residual volume	Growth
10	1170		1170	3200	10	590		590	2680	10	150		150	1850
20	4370	1311	3059	3222	20	3270	981	2289	2916	20	2000		2000	2360
30	6281	1547	4734	3097	30	5250	1301	3904	2801	30	4360	1308	3052	2295
40	7831	1566	6265	2820	40	6705	1341	5364	2460	40	5347	1337	4010	2122
50	9085	1363	7722	2540	50	7824	1171	6653	2239	50	6132	1226	4906	1812
60	10262	1026	9236	2450	60	8892	889	8003	2020	60	6718	1008	5710	1565
70	11686	1169	10517	2150	70	10023	1002	9021	1780	70	7275	727	6548	1346
80	12667	1267	11400	1870	80	10801	1080	9721	1520	80	7894	789	7105	1170
90	13270	1327	11943	1650	90	11241	1124	10117	1390	90	8235	824	7411	1020
100	13593		13593	1460	100	11507		11507	1200	100	8431		8431	880

APPENDIX B

THE MAXIMUM EXPENDITURES JUSTIFIED TO RECLAIM BRUSHLANDS, EXCLUDING TAXES

Table 10. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a final harvest only. Excluding taxes. Rotation length is set by culmination of mean annual increment.

PNW[1/], CAP[2/], and ACE[3/] by site under two price assumptions	Interest rate and rotation length* 5%		7%		10%		12%		15%	
	60	70	60	70	60	70	60	70	60	70
					-dollars-					
Constant price										
Site I										
PNW	361		116		22		8		2	
CAP	378		118		22		8		2	
ACE	2250		1607		1125		937		750	
Site II										
PNW		225		60		9		2		0
CAP		230		60		9		2		0
ACE		1953		1395		977		814		651
Site III										
PNW		178		48		7		2		0
CAP		182		48		7		2		0
ACE		1549		1106		775		645		516

Table 10. Continued.

PNW[1/], CAP[2/], and ACE[3/] by site under two price assumptions	Interest rate and rotation length*									
	5%		7%		10%		12%		15%	
	60	70	60	70	60	70	60	70	60	70
	-dollars-									
Variable price										
Site I										
PNW	321		104		20		7		1	
CAP	335		104		20		7		1	
ACE	1996		1428		1000		833		667	
Site II										
PNW		175		47		7		2		0
CAP		179		46		7		2		0
ACE		1517		1084		760		633		506
Site III										
PNW		109		29		4		1		0
CAP		111		28		4		1		0
ACE		945		675		473		394		316

*Rotation length is in years.

1/ PNW symbolizes a one rotation outlook.

2/ CAP symbolizes an infinite series of rotation outlook.

3/ ACE symbolizes operation under an even flow harvest constraint.

Table 11. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a final harvest only. Excluding taxes. Rotation length is set by financial maturity.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length												
	5%				7%			10%		12%		15%	
	30	35	40	50	30	35	40	25	30	25	30	25	30
	-dollars-												
Constant price													
Site I													
PNW		576			310			138		88		45	
CAP	710				357			152		93		47	
ACE	1553				1114			591		495		397	
Site II													
PNW			469			237			101	61		32	
CAP		561			267				106	65		33	
ACE		1438			831				584	343		276	
Site III													
PNW			334			161			62		36	18	
CAP			390			177			66		37	18	
ACE			1166			694			356		298	153	

Table 11. Continued.

PNW, CAP and ACE by site under two price assumptions	Interest rate and rotation length												
	5%				7%			10%		12%		15%	
	30	35	40	50	30	35	40	25	30	25	30	25	30
	-dollars-												
Variable price													
Site I													
PNW			346				163		60		35		16
CAP				372			170		60		34		15
ACE				1576			866		346		289		232
Site II													
PNW				228			98		39		23	11	
CAP				244			100		38		22		10
ACE				1040			520		225		189		152
Site III													
PNW				137			61		21		12		5
CAP			144				61		18		10		5
ACE			547				322		116		98		79

Table 12. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a final harvest only. Excluding taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5% / 100	7% / 100	10% / 100	12% / 100	15% / 100
			-dollars-		
Constant price					
Site I					
PNW	79	12	1	0	0
CAP	79	12	1	0	0
ACE	2067	1477	1034	861	689
Site II					
PNW	68	10	1	0	0
CAP	68	10	1	0	0
ACE	1794	1281	897	747	598
Site III					
PNW	54	8	1	0	0
CAP	54	8	1	0	0
ACE	1433	1024	717	597	478
Variable price					
Site I					
PNW	79	12	1	0	0
CAP	79	12	1	0	0
ACE	2067	1477	1034	861	689
Site II					
PNW	68	10	1	0	0
CAP	68	10	1	0	0
ACE	1794	1281	897	747	598
Site III					
PNW	45	7	0	0	0
CAP	46	7	0	0	0
ACE	1194	853	597	498	398

Table 13. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for an early heavy thin. Excluding taxes. Rotation length is set by financial maturity.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length															
	5%				7%					10%			12%		15%	
	40	45	50	60	30	35	40	50	60	25	30	40	25	30	25	30
								-dollars-								
Constant Price																
Site I																
PNW	617						315			138			88		45	
CAP	715				357					152			93		47	
ACE	1776				1114					591			495		397	
Site II																
PNW		494					248				101		61		32	
CAP	565				267						107		65		33	
ACE	1419				831						585		343		276	
Site III																
PNW			352			161					62			36	18	
CAP	390					177					66			37	18	
ACE	1166					694					356			298	153	

Table 13. Continued

PNW, CAP and ACE by site under two price assumptions	Interest rate and rotation length															
	5%				7%					10%			12%		15%	
	40	45	50	60	30	35	40	50	60	25	30	40	25	30	25	30
	-dollars-															
Variable price																
Site I																
PNW				368			167					62		35		16
CAP			388				174					63		34		15
ACE			1427				775					545		289		232
Site II																
PNW				239				106			39			23	11	
CAP			253					107				39		22		10
ACE			1269					909				317		189		152
Site III																
PNW				159					61		22			12		5
CAP				164				63				20		10		5
ACE				797				417				228		98		79

Table 14. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for an early heavy thin. Excluding taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5%	7%	10%	12%	15%
	100	100	100	100	100
			-dollars-		
Constant price					
Site I					
PNW	434	196	74	42	18
CAP	438	196	74	42	18
ACE	2296	1640	1148	957	765
Site II					
PNW	342	151	56	31	14
CAP	345	151	56	31	14
ACE	1935	1382	967	806	645
Site III					
PNW	252	97	28	13	4
CAP	254	97	28	13	4
ACE	1557	1112	779	649	519
Variable price					
Site I					
PNW	272	106	36	19	8
CAP	274	107	36	19	8
ACE	2296	1640	1148	957	765
Site II					
PNW	190	71	24	13	5
CAP	191	71	24	13	5
ACE	1935	1382	967	806	645
Site III					
PNW	126	43	11	5	2
CAP	127	43	11	5	2
ACE	1298	927	649	541	433

Table 15. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a frequent light thin. Excluding taxes. Rotation length is set by culmination of mean annual increment.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5%	7%	10%	12%	15%
	80	80	80	80	80
			-dollars-		
Constant price					
Site I					
PNW	541	223	72	37	15
CAP	551	224	72	37	15
ACE	2497	1784	1249	1041	832
Site II					
PNW	444	180	57	29	12
CAP	453	181	57	29	12
ACE	2120	1515	1060	883	707
Site III					
PNW	296	105	26	11	4
CAP	301	106	27	11	4
ACE	1641	1172	820	684	547
Variable price					
Site I					
PNW	379	140	40	20	7
CAP	386	141	40	20	7
ACE	2497	1784	1249	1041	832
Site II					
PNW	259	94	26	13	5
CAP	263	94	26	13	5
ACE	1884	1346	942	785	628
Site III					
PNW	150	50	12	5	1
CAP	153	50	12	5	1
ACE	1093	781	547	456	365

Table 16. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for frequent light thin. Excluding taxes. Rotation length is set by financial maturity.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length													
	5%			7%				10%			12%		15%	
	40	50	60	30	35	40	50	25	30	40	25	30	25	30
	-dollars-													
Constant price														
Site I														
PNW		651				320		138			88		45	
CAP	741			347				145			89		45	
ACE	2039			1114				591			495		397	
Site II														
PNW		538				257			101		61		32	
CAP	597					271			103		61		31	
ACE	1659					1188			585		343		276	
Site III														
PNW		352			161				62			36	18	
CAP	379				170				62			35	16	
ACE	1166				694				356			298	153	

Table 16. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length 5%			7%				10%			12%		15%	
	40	50	60	30	35	40	50	25	30	40	25	30	25	30
						-dollars-								
Variable price														
Site I														
PNW			432			180			60			35		16
CAP			452			188				64		34		15
ACE			2157			890				625		289		232
Site II														
PNW			278				116		39			23	11	
CAP			290				118			39		22		10
ACE			1370				768			370		189		152
Site III														
PNW			165				62		21			12		5
CAP			171				63			20		10		5
ACE			874				454			228		148		119

Table 17. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a frequent light thin. Excluding taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5%	7%	10%	12%	15%
	100	100	100	100	100
			-dollars-		
Constant price					
Site I					
PNW	490	208	70	37	15
CAP	493	208	70	37	15
ACE	2432	1737	1216	1013	811
Site II					
PNW	399	167	56	29	11
CAP	403	167	56	29	11
ACE	2053	1466	1026	855	684
Site III					
PNW	264	96	25	11	4
CAP	266	96	25	11	4
ACE	1580	1129	790	658	527
Variable price					
Site I					
PNW	328	125	38	19	7
CAP	330	125	38	19	7
ACE	2432	1737	1216	1013	811
Site II					
PNW	225	83	25	12	5
CAP	227	83	25	12	5
ACE	2053	1466	1026	855	684
Site III					
PNW	135	45	11	5	1
CAP	136	45	11	5	1
ACE	1317	941	658	549	439

Table 18. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for pre-commercial thin. Excluding taxes. Rotation length is set by culmination of mean annual increment.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length									
	5%		7%		10%		12%		15%	
	50	60	50	60	50	60	50	60	50	60
	-dollars-									
Constant price										
Site I										
PNW	983		496		199		114		52	
CAP	1071		511		198		115		54	
ACE	2884		2061		1442		1203		963	
Site II										
PNW	809		401		156		88		38	
CAP	878		413		155		88		40	
ACE	2440		1743		1219		1017		814	
Site III										
PNW		493		209		59		25		5
CAP		499		209		59		25		5
ACE		1873		1338		936		781		625

Table 18. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length									
	5%		7%		10%		12%		15%	
	50	60	50	60	50	60	50	60	50	60
	-dollars-									
Variable price										
Site I										
PNW	679		317		112		58		23	
CAP	738		326		111		59		23	
ACE	2561		1830		1280		1068		855	
Site II										
PNW	428		197		66		33		11	
CAP	463		201		65		33		11	
ACE	1615		1154		807		674		539	
Site III										
PNW		235		83		18		3		-4
CAP		245		88		17		3		-4
ACE		1135		810		567		472		378

Table 19. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for pre-commercial thin. Excluding taxes. Rotation length is set by financial maturity.

PNW, CAP, and ACE by site under two price assumptions	Interest rates and rotation length												
	5%					7%				10%		12%	15%
	20	25	30	40	50	20	25	30	40	20	30	20	20
	-dollars-												
Constant price													
Site I													
PNW				1036				609		336		232	134
CAP	1349					772				383		251	139
ACE	2282					1636				1151		961	772
Site II													
PNW				852				486		244		170	98
CAP			1053			565				281		184	102
ACE			2175			1211				854		714	574
Site III													
PNW				549			296			146		99	56
CAP		668					346			160		103	56
ACE		1312					941			511		428	345

Table 19. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length												
	5%					7%				10%		12%	15%
	20	25	30	40	50	20	25	30	40	20	30	20	20
						-dollars-							
Variable price													
Site I													
PNW					679			334			151	96	54
CAP				742				374			156	99	53
ACE				2044				1160			815	415	335
Site II													
PNW					428				209		87	58	32
CAP				468					218	91		58	30
ACE				1308					936	314		264	214
Site III													
PNW					245				102	39		24	12
CAP					262			105			36	20	7
ACE					1020			403			285	128	105

Table 20. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a pre-commercial thin. Excluding taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length 5% / 100	7% / 100	10% / 100	12% / 100	15% / 100
	-dollars-				
Constant price					
Site I					
PNW	748	382	167	101	50
CAP	754	384	167	101	50
ACE	2585	1844	1290	1075	860
Site II					
PNW	605	303	129	76	36
CAP	610	304	129	76	36
ACE	2178	1553	1086	905	724
Site III					
PNW	389	164	50	21	4
CAP	393	165	50	21	4
ACE	1665	1187	830	691	553
Variable price					
Site I					
PNW	484	220	84	47	20
CAP	488	220	84	47	20
ACE	2585	1844	1290	1075	860
Site II					
PNW	321	137	49	25	9
CAP	324	137	49	25	9
ACE	2178	1553	1086	905	924
Site III					
PNW	185	65	13	1	-4
CAP	186	65	13	1	-4
ACE	1477	1063	736	613	491

APPENDIX C

THE MAXIMUM EXPENDITURES JUSTIFIED TO RECLAIM BRUSHLANDS, INCLUDING TAXES

Table 21. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a final harvest only. Including taxes. Rotation length is set by culmination of mean annual increment.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length									
	5%		7%		10%		12%		15%	
	60	70	60	70	60	70	60	70	60	70
	-dollars-									
Constant price										
Site I										
PNW	254		68		6		0		-1	
CAP	265		70		6		0		-1	
ACE	2206		1578		1105		921		737	
Site II										
PNW		145		29		0		-2		-2
CAP		148		29		0		-2		-2
ACE		1916		1369		959		799		639
Site III										
PNW		137		32		4		0		0
CAP		140		32		4		0		0
ACE		1518		1084		760		633		507

Table 21. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length									
	5%		7%		10%		12%		15%	
	60	70	60	70	60	70	60	70	60	70
					-dollars-					
Variable price										
Site I										
PNW	253		75		11		3		-1	
CAP	266		75		11		3		-1	
ACE	1960		1402		982		819		655	
Site II										
PNW		129		30		3		0		-1
CAP		132		31		3		0		-1
ACE		1489		1065		746		622		497
Site III										
PNW		89		22		2		0		0
CAP		90		21		2		0		0
ACE		927		662		464		387		310

Table 22. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a final harvest only. Including taxes. Rotation length is set by financial maturity.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length												
	5%				7%			10%		12%		15%	
	30	35	40	50	30	35	40	25	30	25	30	25	30
	-dollars-												
Constant price													
Site I													
PNW		552			296			135		86		44	
CAP	682				341			149		91		46	
ACE	1528				1089			578		483		386	
Site II													
PNW		447				230			98	59		31	
CAP		546			259				104	63		32	
ACE		1403			811				571	335		269	
Site III													
PNW			322			157			60		35	18	
CAP			376			173			64		36	18	
ACE			1139			677			347		291	148	

Table 22. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length												
	5%				7%			10%		12%		15%	
	30	35	40	50	30	35	40	25	30	25	30	25	30
	-dollars-												
Variable price													
Site I													
PNW			322				150		57		33		15
CAP			365				156		57		32		14
ACE			1185				849		338		283		287
Site II													
PNW				203			92		38		22	11	
CAP				217			94		37		21		10
ACE				1002			508		220		184		148
Site III													
PNW				124			59		20		12		5
CAP				130			59		17		10		5
ACE				592			314		113		96		77

Table 23. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a final harvest only. Including taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5% / 100	7% / 100	10% / 100	12% / 100	15% / 100
			-dollars-		
Constant price					
Site I					
PNW	-81	-48	-18	-8	-3
CAP	-82	-48	-18	-8	-3
AGE	2031	1451	1015	846	677
Site II					
PNW	-38	-26	-8	-4	-1
CAP	-39	-26	-8	-4	-1
AGE	1762	1259	881	734	587
Site III					
PNW	-6	-11	-3	-2	0
CAP	-6	-11	-3	-2	0
ACE	1408	1005	704	586	469
Variable price					
Site I					
PNW	-41	-29	-9	-5	-1
CAP	-42	-29	-9	-5	-1
ACE	2031	1451	1015	846	677
Site II					
PNW	-2	-10	-4	-2	-1
CAP	-3	-10	-4	-2	-1
ACE	1762	1259	881	734	587
Site III					
PNW	11	-3	-2	-1	0
CAP	12	-3	-2	-1	0
ACE	1173	838	586	489	391

Table 24. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for an early heavy thin. Including taxes. Rotation length is set by financial maturity.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length														
	5%				7%					10%		12%		15%	
	40	45	50	60	30	35	40	50	60	25	30	25	30	25	30
	-dollars-														
Constant price															
Site I															
PNW	579						294			135		86		44	
CAP	671				341					149		91		46	
ACE	1740				1089					578		483		386	
Site II															
PNW		473					237				98	59		31	
CAP	542				259						104	63		32	
ACE	1387				811						571	335		269	
Site III															
PNW			334			157					60		35	18	
CAP	376					173					64		36	18	
ACE	1139					677					347		291	148	

Table 24. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length														
	5%				7%					10%		12%		15%	
	40	45	50	60	30	35	40	50	60	25	30	25	30	25	30
								-dollars-							
Variable prices															
Site I															
PNW			326				157				57		33		15
CAP	351						163				57		32		14
ACE	1062						761				338		283		287
Site II															
PNW			220					99			38		22	11	
CAP			236					100			37		21		10
ACE			893					640			220		184		148
Site III															
PNW				147					56		20		12		5
CAP				152				60			17		10		5
ACE				783				409			113		96		77

Table 25. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for an early heavy thin. Including taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5%	7%	10%	12%	15%
	100	100	100	100	100
			-dollars-		
Constant price					
Site I					
PNW	319	151	60	35	15
CAP	323	151	60	35	15
ACE	2255	1611	1127	940	752
Site II					
PNW	266	124	49	27	13
CAP	269	124	49	27	13
ACE	1899	1357	950	791	633
Site III					
PNW	207	82	24	11	3
CAP	209	82	24	11	3
ACE	1528	1091	764	637	509
Variable price					
Site I					
PNW	187	76	28	15	7
CAP	188	77	28	15	7
ACE	2255	1611	1127	940	752
Site II					
PNW	141	55	20	11	4
CAP	142	55	20	11	4
ACE	1899	1357	950	791	633
Site III					
PNW	104	36	9	4	2
CAP	105	36	9	4	2
ACE	1275	911	637	531	425

Table 26. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a frequent light thin. Including taxes. Rotation length is set by culmination of mean annual increment.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5%	7%	10%	12%	15%
	80	80	80	80	80
			-dollars-		
Constant price					
Site I					
PNW	429	176	57	27	12
CAP	437	177	57	27	12
ACE	2451	1752	1226	1022	817
Site II					
PNW	372	152	49	25	11
CAP	380	153	49	25	11
ACE	2080	1486	1040	867	694
Site III					
PNW	258	91	22	9	4
CAP	262	92	23	9	4
ACE	1608	1149	804	670	536
Variable price					
Site I					
PNW	299	110	31	16	6
CAP	304	111	31	16	6
ACE	2451	1752	1226	1022	817
Site II					
PNW	223	79	22	11	4
CAP	226	79	22	11	4
ACE	1851	1323	926	772	617
Site III					
PNW	130	43	10	4	1
CAP	133	43	10	4	1
ACE	1074	768	537	448	358

Table 27. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for frequent light thin. Including taxes. Rotation length is set by financial maturity.

PNW, CAP and ACE by site under two price assumptions	Interest rate and rotation length													
	5%			7%				10%			12%		15%	
	40	50	60	30	35	40	50	25	30	40	25	30	25	30
	-dollars-													
Constant price														
Site I														
PNW	601			296				135			86		44	
CAP	688			331				142			87		44	
ACE	1098			1089				578			483		386	
Site II														
PNW		500				345			98		59		31	
CAP	569					258			100		59		30	
ACE	1623					1162			571		335		269	
Site III														
PNW		333			157				60			35	18	
CAP	365				166				64			36	16	
ACE	1139				677				347			291	148	

Table 27. Continued.

PNW, CAP and ACE by site under two price assumptions	Interest rate and rotation length													
	5%			7%				10%			12%		15%	
	40	50	60	30	35	40	50	25	30	40	25	30	25	30
	-dollars-													
Variable price														
Site I														
PNW			377			168			57			33		15
CAP		403				176				59		32		14
ACE		1632				874				614		283		227
Site II														
PNW			251				107		38			22	11	
CAP			262				109			37		21		10
ACE			1346				755			364		184		148
Site III														
PNW			153				58		20			12		5
CAP			158				59			19		10		5
ACE			858				446			223		96		77

Table 28. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a frequent light thin. Including taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5% / 100	7% / 100	10% / 100	12% / 100	15% / 100
			-dollars-		
Constant price					
Site I					
PNW	336	159	55	27	12
CAP	368	159	55	27	12
ACE	2388	1706	1194	995	796
Site II					
PNW	318	138	48	25	11
CAP	321	138	48	25	11
ACE	2015	1439	1008	840	672
Site III					
PNW	220	81	21	9	4
CAP	222	81	21	9	4
ACE	1550	1107	775	646	517
Variable price					
Site I					
PNW	237	92	29	15	6
CAP	238	92	29	15	6
ACE	2388	1706	1194	995	796
Site II					
PNW	179	66	21	11	4
CAP	181	66	21	11	4
ACE	2015	1439	1008	840	672
Site III					
PNW	110	37	9	4	1
CAP	111	37	9	4	1
ACE	1294	924	647	539	431

Table 29. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for pre-commercial thin. Including taxes. Rotation length is set by culmination of mean annual increment.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length									
	5%		7%		10%		12%		15%	
	50	60	50	60	50	60	50	60	50	60
	-dollars-									
Constant price										
Site I										
PNW	840		417		163		92		40	
CAP	942		428		164		92		42	
ACE	2831		2022		1415		1180		945	
Site II										
PNW	724		356		138		77		33	
CAP	785		366		137		77		35	
ACE	2390		1708		1194		997		798	
Site III										
PNW		438		184		50		20		3
CAP		441		184		50		20		3
ACE		1837		1311		918		765		612

Table 29. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length									
	5%		7%		10%		12%		15%	
	50	60	50	60	50	60	50	60	50	60
	-dollars-									
Variable price										
Site I										
PNW	590		270		92		46		17	
CAP	640		277		91		47		17	
ACE	2515		1797		1257		1049		839	
Site II										
PNW	385		175		59		28		9	
CAP	416		178		56		28		9	
ACE	1587		1134		793		662		530	
Site III										
PNW		209		71		14		1		-5
CAP		218		76		13		1		-5
ACE		1114		795		557		464		371

Table 30. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for pre-commercial thin. Including taxes. Rotation length is set by financial maturity.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length												
	5%					7%				10%		12%	15%
	20	25	30	40	50	20	25	30	40	20	30	20	20
	-dollars-												
Constant price													
Site I													
PNW			954					562		319		220	128
CAP	1289					736				364		237	131
ACE	2259					1619				1139		952	764
Site II													
PNW				790				462		236		164	95
CAP			1003			547				272		178	98
ACE			2154			1200				846		707	568
Site III													
PNW				518			288			142		96	54
CAP		651					335			155		100	54
ACE		1299					932			507		424	342

Table 30. Continued.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length												
	5%					7%				10%		12%	15%
	20	25	30	40	50	20	25	30	40	20	30	20	20
	-dollars-												
Variable price													
Site I													
PNW					590			316			139	91	51
CAP			680					354			143	93	50
ACE			1589					1139			801	405	327
Site II													
PNW					385				193		82	56	31
CAP				434					201	88		56	29
ACE				1284					919	306		257	209
Site III													
PNW					224				95	38		23	11
CAP					240			100			34	19	6
ACE					1002			393			278	124	102

Table 31. The maximum expenditures justified to reclaim brushlands, compared at five interest rates under two price assumptions for a pre-commercial thin. Including taxes. Rotation length is set at 100 years.

PNW, CAP, and ACE by site under two price assumptions	Interest rate and rotation length				
	5% / 100	7% / 100	10% / 100	12% / 100	15% / 100
			-dollars-		
Constant price					
Site I					
PNW	542	285	128	78	38
CAP	546	387	128	78	38
ACE	2539	1811	1267	1055	845
Site II					
PNW	469	244	108	64	31
CAP	473	245	108	64	31
ACE	2138	1525	1067	888	711
Site III					
PNW	312	134	41	16	2
CAP	315	134	41	16	2
ACE	1634	1165	814	678	543
Variable price					
Site I					
PNW	331	155	61	34	14
CAP	334	155	61	34	14
ACE	2539	1811	1267	1055	845
Site II					
PNW	233	103	38	19	7
CAP	235	103	38	19	7
ACE	2138	1525	1067	888	711
Site III					
PNW	142	49	9	-1	-5
CAP	143	49	9	-1	-5
ACE	1451	1034	723	602	482

APPENDIX D

AN EXAMPLE AND SHORT HISTORY OF THE ALLOWABLE CUT EFFECT

APPENDIX D

An Example and Short History of The Allowable Cut Effect

The allowable cut effect (ACE) pertains to specific circumstances of forest land management and can have an important impact on the economic analysis if those particular conditions exist for owners. The following is an example borrowed from Schweitzer et al. (25) of the effect of ACE on the return to an investment.

Consider a planting to Douglas-fir of 1000 acres. If we assume a final harvest of 72,000 board feet per acre at age 90, $30 per MBF stumpage and the only costs are planting costs totaling $30,000, the investment yields about a five percent internal rate of return.

If the allowable cut is determined by a Hanzlik-like formula:[1/]

$$\text{Annual allowable cut} = \frac{\text{volume of mature timber}}{\text{length of rotation}} + \text{mean annual increment}$$

the ACE for this example implies that the mean annual increment would be increased by:

[1/] Formulas of this type have two determinants of the amount to cut: 1) a factor relating to the conversion of stands of mature and over-mature timber to younger faster growing stands, and 2) a factor relating to the current growth in the management unit. The amount to be cut is the sum of these two factors.

$$\frac{72000 \text{ board feet per acre}}{90 \text{ years}} \times 1000 \text{ acres} = 800,000 \text{ board feet per year}$$

This means that the planting has increased average yearly growth by 800,000 board feet and that this amount can be cut yearly, in addition to the already calculated allowable cut. For this example the result is an 80 percent internal rate of return on the marginal investment.

The reason for the large increase in the rate of return due to ACE is that it immediately increases the allowable cut. Instead of waiting until the end of a rotation for the return on the investment, (90 years in the previous example), credit is taken for it immediately.

The allowable cut effect (ACE) was first used by Flora (12) in a study of the returns from treatment of dwarf mistletoe infected ponderosa pine. All treatments were analyzed as to their effects on growth and how much this would increase the current allowable cut. This procedure served to substantially raise the returns associated with the treatments.

La Bonta (18) discussed the relation between increased growth and revenue. He mentioned the time lag between establishment and harvest and the associated problems of carrying costs. Noting that most large timberland owners (public and private) are committed to sustained yield and allowable cut and assuming a reasonably good balance of age classes, he said one can bypass the conventional discount and capitalization approach with their inhibiting compound interest. Under these assumptions you can start cutting increased growth (due to fertilization, genetics, planting of non-stocked acreages not in the allowable cut base, etc.) immediately. This increases markedly the return on the investment.

The Douglas-fir Supply Study (33) in seeking ways to increase the supply of timber from National Forests mentions:

> It is the surplus growing stock on most working circles that permits immediate increases in timber harvest and stumpage returns following most intensive management practices. Thus, rates of return are much higher than if it were necessary to wait for those practices themselves to bear fruit in additional growth and yield (34).

Sassman et al. (22) give the economic returns from thinning stagnated ponderosa pine stands. The results are given with and without the allowable cut effect.

The Bureau of Land Management in their Allowable Cut Plan for Western Oregon for 1970 (35) used the allowable cut effect when calculating both the returns from intensive management practices and the allowable cut for the next decade.

Schweitzer et al. (25) brought discussions of use of the allowable cut effect up to date, illustrated its use (see previous example), and examined some of the economic implications.

Neff (21) reviews the policy changes the U.S. Forest Service is currently undergoing in regard to calculation of allowable cuts.

He suggests that the Forest Service may begin using the allowable cut effect in future calculations.

Teeguarden (31) attacks the use of the allowable cut effect by Schweitzer _et al._ (25) in a number of ways. The ACE effectively allows the cutting of existing merchantable stands and credits the return from this action to the future growth increase caused by some management practice. What actually happens is a relaxation of the even flow constraint to allow a speed-up of liquidation of merchantable reserves. Thus "ACE measures not just the rate-of-return on a marginal dollar of expenditure on planting, but in addition the rate-of-return associated with a marginal change in the constraint which limits the allowable cut"(32). Teeguarden then states that it is wrong to allocate all the increased cash flow due to ACE to a particular management program because the reserve timber which is cut may have value in an alternate use, housing for example. He then states that in the decision-making contexts in which ACE can be used it is more likely to lead to bad decisions, rather than good ones.

Teeguarden concludes by saying the use of ACE can be improved by computing an optimal (in terms of present net worth) timber harvest program with and without a new management practice. The difference would then be attributable to ACE.

In response to Teeguarden, Schweitzer _et al._ (24) claim that Teeguarden is actually attacking the policy constraints within which

National Forests operate, while they were trying to provide guidelines for use within their policy constraints.

This is the current status of discussion about the allowable cut effect. Its use or misuse will continue to be argued for some time. However, because it is a method of investment analysis advocated by many foresters, I have included it in my discussion of the maximum amount to spend on rehabilitation and reforestation.