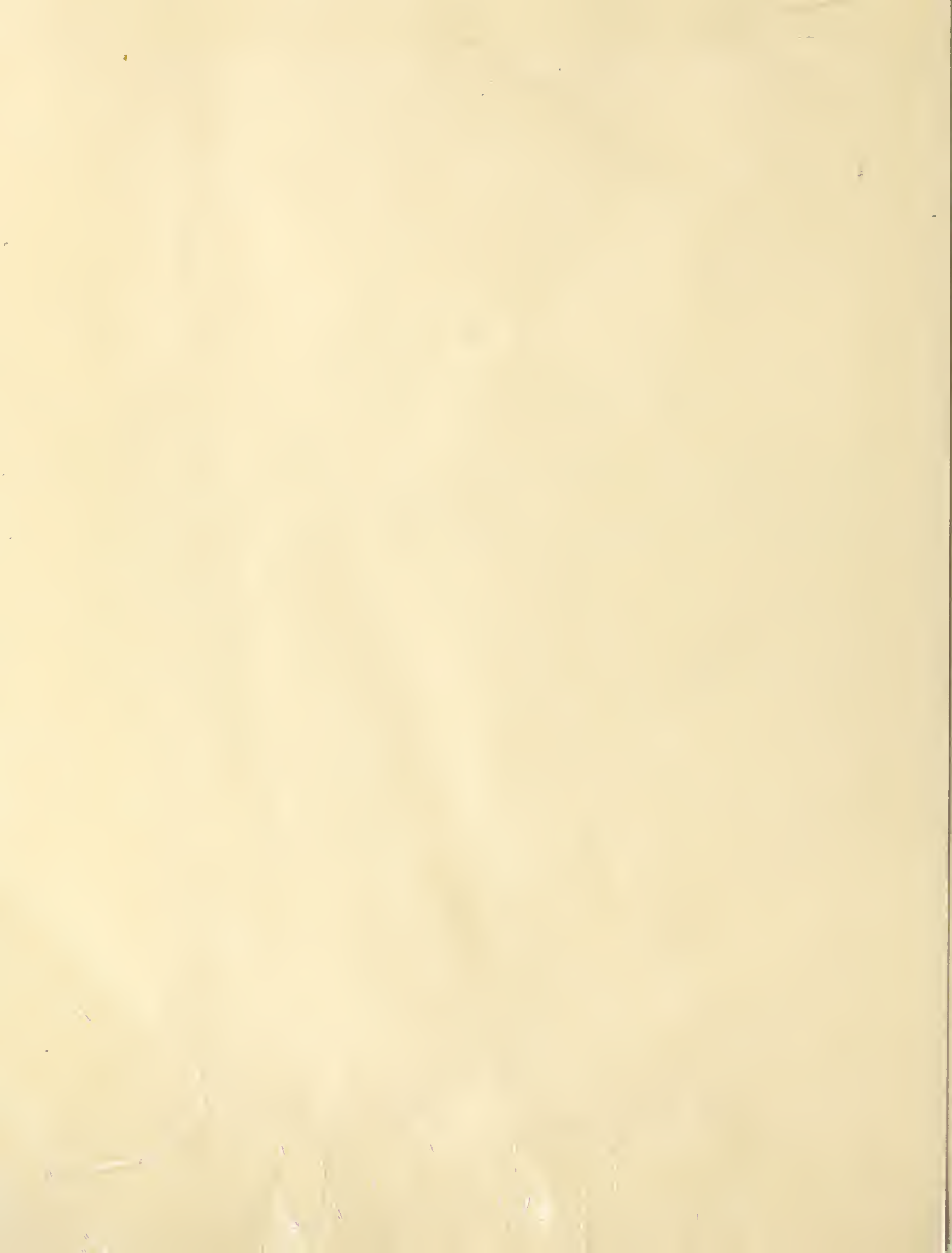


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# THE ECONOMICS OF CONVERTING RED ALDER TO DOUGLAS-FIR

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Table 1.--Types of costs and returns assumed relevant to deciding whether a red alder stand should be retained or replaced by Douglas-fir

Retain red alder	Years of occurrence	Convert red alder stand to Douglas-fir
<u>Incomes</u>  Red alder clearcut (repeated in each rotation)	BEFORE CONVERSION	<u>Incomes</u> Red alder liquidation (once at conversion)
<u>Costs</u> Management (annually)	CONVERSION	<u>Costs</u> Management (annually until conversion)
Red alder clearcut (repeated in each rotation)	CONVERSION	Site preparation (once for liquidated stands less than 30 years of age)
Red alder clearcut (repeated in each rotation)	AFTER CONVERSION	Douglas-fir thinnings and final harvest (repeated in each rotation)  Establishment (repeated in each rotation)  Brush control (repeated in each rotation)  Management (annually)

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## INTRODUCTION

For many years, the old-growth Douglas-fir forests of the Pacific Northwest have supplied a major portion of the Nation's timber. Efforts to renew these forests for a second crop of Douglas-fir have frequently been hampered by the presence of less desirable species, principally red alder, which have invaded cutover areas. Over time, an increasing supply of red alder has led to the development of new uses for the species and a subsequent increase in its value. Now, many forest managers must decide whether to manage for red alder or to replace it with Douglas-fir. This paper deals with the economics of this decision: Should an existing stand of red alder be retained or should it be converted to Douglas-fir? If it is to be converted, when? <sup>1</sup>

A premise of this study is that the forest manager sees red alder as a problem. Compared with Douglas-fir, red alder is a "Johnny-come-lately" that many foresters feel is unworthy of serious consideration. Others consider the species to be a real economic windfall. In any case, we are here interested in developing analytical approaches that will permit managers to make rational decisions regarding the retention or replacement of red alder stands.

Conversion of a young red alder stand to Douglas-fir requires a relatively large capital outlay that may be wholly or partially avoided by a few years' wait for the stand to reach merchantable size. The length of this waiting period depends on the productivity of the site. The financial returns depend on the direct costs of conversion, management costs, the anticipated harvesting regime, future prices, and the firm's opportunity cost of capital. Thus, the two simple alternatives of retaining red alder or converting to Douglas-fir lead to numerous investment management possibilities.

In this study, we concentrated on defining "favorable" and "unfavorable" situations for retaining red alder or for converting to Douglas-fir. We aimed at answering questions such as, "Given this red alder stand on this site, these yields, costs, and prices, would one be better off managing for red alder or converting (in how many years?) the stand and then managing for Douglas-fir?" This analysis is essentially a series of case studies where the number of cases considered is vast; however, that number is still minute when compared with all the possibilities if every conceivable set of assumptions were considered. For this reason, our findings should be applied to the specific problems of a particular ownership with caution.

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<sup>1</sup>The management and utilization of red alder are outlined by Worthington et al. (1962) and the production and marketing of the species by Yoho et al. (1969).

No informal observations, let alone research data, outside of those developed in this study, have ever been systematically collected and summarized for most aspects of this conversion decision. Therefore, so that precision in calculating the absolute profitability of each alternative would not be critical, we developed guidelines that indicate whether or not red alder stands should be converted, given particular sets of assumptions. Ranges of stumpage prices, guiding rates of return, conversion costs, and annual management costs which bracketed nearly all cases found in practice were considered in the analysis.

This study might be criticized as premature because the input data are not firm enough to justify the derivation of management guides. The obvious answer is to pose a question--"How are these decisions being made now?" On reflection, the answer will have to be that such decisions are indeed being made now--made not only on the basis of flimsy or partial data but upon poorly conceived models as well. Decisionmakers in all fields of management must use the best information available to them, after tempering it with their individual insights. The objective of this paper was to provide well-defined guidelines based on explicit values of the relevant variables.

The tentative management guides presented here will be adequate for a given firm if (1) the firm's situation falls within the range of cases analyzed in this study, or (2) it is shown that the conversion decision is not sensitive to the out-of-range variables. If neither of these conditions holds, the reader can insert his own values into the analytical model.<sup>2</sup>

## THE ANALYTICAL MODEL AND ASSUMPTIONS

The first and most basic assumption of the analysis is that the manager wants to maximize present net worth per acre, either by extensively managing (without thinning) red alder or intensively managing (with thinning) Douglas-fir on the same sites. It is further assumed that he is not hampered by limitations or shortages of money, equipment, or labor. Here, it has merely been suggested that costs, in terms of forgone income, accompany such limitations (see the subsection entitled "Scheduling Stand Conversion").

Essentially, the analytical approach was to calculate the present net worths of the perpetual management of red alder for a range of costs and returns and to compare them with the present net worths that could be anticipated from liquidating the existing red alder stands and the subsequent perpetual management of Douglas-fir on the same sites. The costs and incomes relevant to these calculations are listed in table 1, which is printed on the inside of the front cover. (Sample calculations illustrating the entries in this table and utilizing the equations given below are included in Appendix B.) The relative sizes of these costs and incomes, based on middle-of-the-range assumptions, are suggested by figure 1.

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<sup>2</sup>Listings of two computer programs developed to perform the necessary calculations are available upon request from Director, Pacific Northwest Forest & Range Experiment Station, P.O. Box 3141, Portland, Oregon 97208.

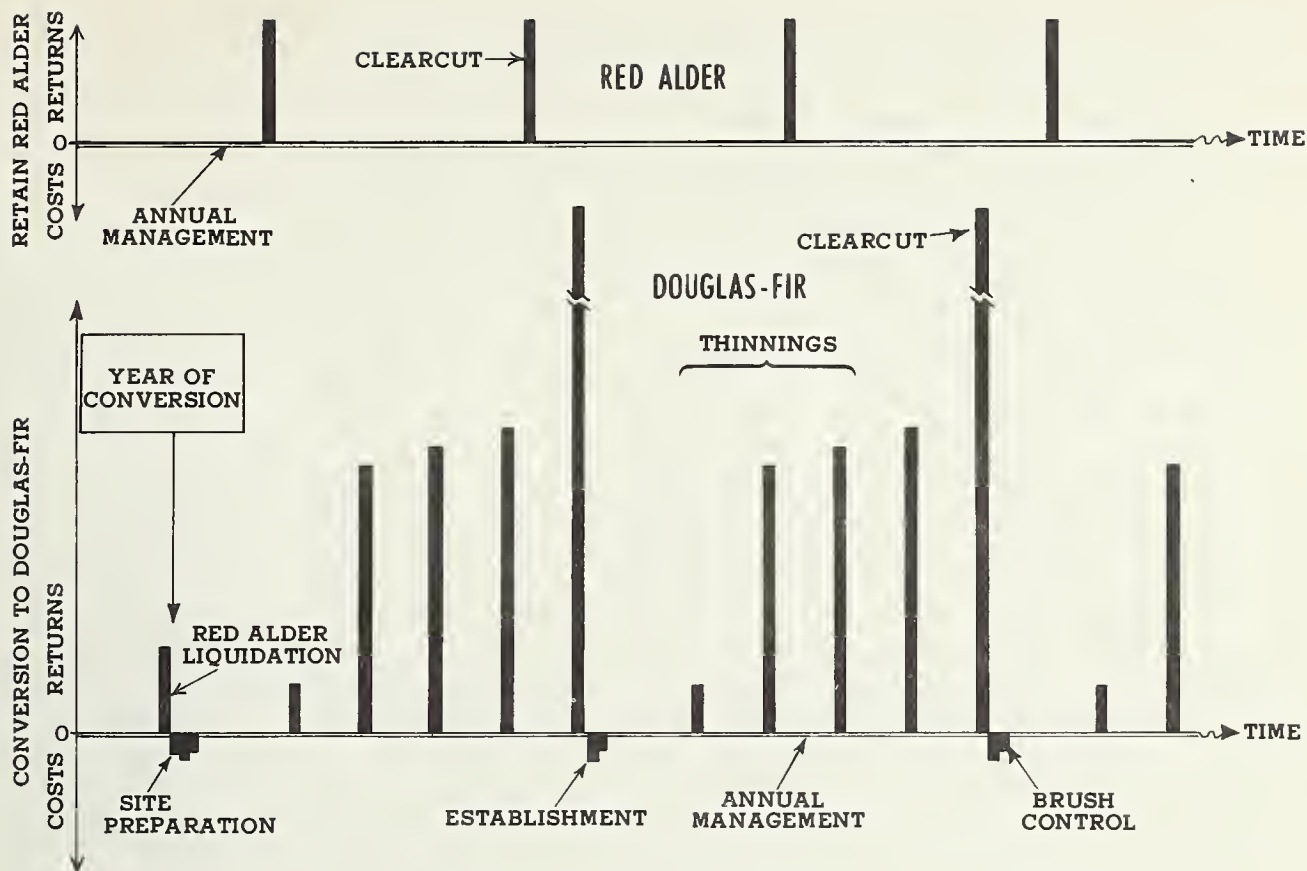


Figure 1.—Representative costs and returns to be expected from retaining red alder and from liquidating red alder and converting the site to Douglas-fir production.

Because the advantages of growing two different species on the same ground had to be compared, it was necessary to relate the productive capacity of the site for red alder to that for Douglas-fir. After the sparse available evidence was examined, the equivalences of site classes for the two species shown in table 2 were assumed.<sup>3</sup> In the same table, the assumptions concerning rotation lengths for each of the species on each site have been summarized.

#### THE PRESENT NET WORTH OF RETAINING RED ALDER

The gross returns to be expected from managing red alder (without thinning) for both pulpwood and sawtimber are shown in table 3. Stands now between 15 and 65 years of age on site indexes 70, 90, and 110 are included. High,

<sup>3</sup> Red alder stands on sites wet enough to hamper Douglas-fir growth are excluded from the study. Also excluded for lack of sufficient data are the economic values derived from alder on certain sites; e.g., the increase of site quality through nitrogen fixing and the control of *Poria weirii* Murr., cause of a root rot of Douglas-fir.

Table 2.--Assumed correlations of red alder and Douglas-fir site indexes  
and corresponding rotation lengths

Red alder		Equivalent site class <sup>3/</sup>	Douglas-fir	
Rotation <sup>1/</sup>	Site index <sup>2/</sup>		Site index <sup>4/</sup>	Rotation <sup>1/</sup>
65 years	70 feet	70/IV	110 feet (IV)	100 years
55 years	90 feet	90/III	140 feet (III)	85 years
45 years	110 feet	110/II	170 feet (II)	70 years

<sup>1/</sup> Assumed rotation lengths are representative of those used in practice.

<sup>2/</sup> Red alder site indexes are on a 50-year basis.

<sup>3/</sup> Equivalences of site indexes are based on a consensus of expert opinions. See the footnotes on pages 3 and 15.

<sup>4/</sup> Relation of Douglas-fir site quality classes to site indexes (at 100 years) based on McArdle et al. (1949).

Table 3.--Expected gross returns per acre from red alder management<sup>1/</sup>

Stand age (years)	Stumpage price levels <sup>2/</sup> for--								
	Red alder/Douglas-fir site class 70/IV			Red alder/Douglas-fir site class 90/III			Red alder/Douglas-fir site class 110/II		
	\$7.50/\$21	\$4.50/\$12	\$1.50/\$4	\$7.50/\$21	\$4.50/\$12	\$1.50/\$4	\$7.50/\$21	\$4.50/\$12	\$1.50/\$4
	-----Dollars per acre-----								
15	39.15	23.49	7.83	75.00	45.00	15.00	110.02	66.01	22.02
25	125.02	75.01	25.00	191.70	115.00	38.34	258.30	154.98	51.66
35	193.35	116.01	38.67	291.67	175.00	58.33	372.21	218.37	72.79
45	245.83	147.51	49.17	366.40	211.63	70.54	520.24	299.23	99.74
55	272.40	157.68	52.56	455.70	261.90	87.30	--	--	--
65	301.98	173.94	57.98	--	--	--	--	--	--

<sup>1/</sup> Based on Appendix A, table 13.

<sup>2/</sup> Stumpage price levels are read, for example, as "\$7.50 per cord for pulpwood and \$21 per M bd. ft. for sawtimber."

medium, and low prices, intended to bracket most situations, were applied to generate the table values. (The underlying physical yield tables are given in Appendix A.)

The value of a perpetual series of red alder rotations, when discounted to the present, is given by:

$$\left[ \begin{array}{l} \text{Present value of} \\ \text{perpetual series} \\ \text{of red alder yields} \end{array} \right] = \left[ \begin{array}{l} \text{Value at} \\ \text{final} \\ \text{harvest} \end{array} \right] \times \left[ \frac{(1+p)^s}{[(1+p)^s - 1](1+p)^{s-j}} \right]$$

where

$p$  = decimal form of guiding rate of return,<sup>4</sup>  
 $s$  = red alder rotation length in years, and  
 $j$  = present age of stand.

The only cost of red alder management that was considered was a constant annual cost which was assumed to include protection, administration, and property taxes. In the subsequent analysis, two levels of this cost were used, \$1 and \$0.50 per acre. The present value of these costs is given by:

$$\left[ \begin{array}{l} \text{Present value of} \\ \text{annual red alder} \\ \text{management costs} \end{array} \right] = \left[ \begin{array}{l} \text{Annual} \\ \text{costs} \end{array} \right] \times \left[ \frac{1}{p} \right]$$

Finally, then, the value of a given alternative can be calculated as follows:

$$\left[ \begin{array}{l} \text{Present net worth} \\ \text{of retaining} \\ \text{red alder} \end{array} \right] = \left[ \begin{array}{l} \text{Present value of} \\ \text{perpetual series of} \\ \text{red alder yields} \end{array} \right] - \left[ \begin{array}{l} \text{Present value of} \\ \text{annual red alder} \\ \text{management costs} \end{array} \right]$$

#### THE PRESENT NET WORTH OF REPLACING RED ALDER WITH DOUGLAS-FIR

As is apparent in table 1, calculating the value of converting red alder to Douglas-fir is somewhat complex. The costs and incomes fall into three categories:

1. The annual costs of managing and the one-time returns from liquidating the present red alder stand BEFORE CONVERSION,
2. Site preparation required at CONVERSION before Douglas-fir can be established, and
3. Those costs and returns resulting from managing Douglas-fir to perpetuity in the AFTER CONVERSION period.

<sup>4</sup> For a discussion of the concept of the guiding rate of return, see Duerr (1960, pp. 143-150) or Pacific Northwest Forest & Range Experiment Station (1963, pp. 13-16).

## Income and Costs BEFORE CONVERSION

The present value of the existing red alder stand that is to be liquidated is given by:

$$\left[ \begin{array}{c} \text{Present value of} \\ \text{existing red alder stand} \end{array} \right] = \left[ \begin{array}{c} \text{Value at time} \\ \text{of liquidation} \end{array} \right] \times \left[ \frac{1}{(1+p)^c} \right]$$

where

$p$  = decimal form of guiding rate of return and  
 $c$  = number of years until conversion (liquidation).

Again, we relied on table 3 for estimates of the value of the stand when it is liquidated. Since age of the youngest red alder stand considered is 15 years and the oldest 65 years, the number of years until conversion ( $c$ ) can vary from 0 to 50 years, by 10-year increments.

Necessarily, we considered the annual costs of protecting, administering, and paying property taxes:

$$\left[ \begin{array}{c} \text{Present value of annual red} \\ \text{alder management costs} \end{array} \right] = \left[ \begin{array}{c} \text{Annual} \\ \text{costs} \end{array} \right] \times \left[ \frac{(1+p)^c - 1}{p(1+p)^c} \right]$$

This permitted writing the current value of the red alder stand now on the ground as:

$$\left[ \begin{array}{c} \text{Present net worth of} \\ \text{existing red alder} \\ \text{stand BEFORE CONVERSION} \end{array} \right] = \left[ \begin{array}{c} \text{Present value of} \\ \text{existing red} \\ \text{alder stand} \end{array} \right] - \left[ \begin{array}{c} \text{Present value of} \\ \text{annual red alder} \\ \text{management costs} \end{array} \right]$$

## Costs at CONVERSION

We assumed that replacing red alder by Douglas-fir would require special site preparation if the original red alder stand were less than 30 years old when liquidated; if older, no special cost was considered (logging in older stands was assumed to insure adequate site disturbance). It was assumed that either scarification or aerial spraying might be used, depending on such factors as the density of understory brush. Cost levels for such operations representative of many conditions are given in table 4.

Since site preparation was assumed to be required only once,  $c$  years from now at the time of conversion, its value is given simply as:

$$\left[ \begin{array}{c} \text{Present net worth of} \\ \text{site preparation costs} \\ \text{at CONVERSION} \end{array} \right] = \left[ \begin{array}{c} \text{Cost at} \\ \text{time of} \\ \text{conversion} \end{array} \right] \times \left[ \frac{1}{(1+p)^c} \right]$$

Table 4.--Representative levels of costs of  
conversion to Douglas-fir

Cost level	Incurred once--at CONVERSION		Incurred in each Douglas-fir rotation--AFTER CONVERSION	
	Site preparation <sup>1/</sup>		Establishment	Brush control
-----Dollars per acre-----				
High	70		80	40
Medium	40		50	25
Low	10		20	10

<sup>1/</sup> A zero cost has been assumed whenever the red alder stand to be liquidated is more than 30 years old.

### Incomes and Costs AFTER CONVERSION

We assumed that Douglas-fir must be artificially established at the beginning of each rotation, either by planting or direct seeding. Alternative cost levels that were employed are shown in table 4. The present value of this periodic cost was calculated as follows:

$$\left[ \begin{array}{l} \text{Present value of} \\ \text{cost of periodically} \\ \text{establishing} \\ \text{Douglas-fir} \end{array} \right] = \left[ \begin{array}{l} \text{Cost at time of} \\ \text{conversion and at} \\ \text{start of all future} \\ \text{stands} \end{array} \right] \times \left[ \frac{(1+p)^t}{[(1+p)^t - 1](1+p)^c} \right]$$

where  $t$  = Douglas-fir rotation length in years.

Maintenance of the newly established and all future Douglas-fir stands was assumed to require control of brush and alder seedlings by aerial spraying 5 years after establishment. The present value of this periodic cost was calculated as follows:

$$\left[ \begin{array}{l} \text{Present value of} \\ \text{cost of periodic} \\ \text{brush control} \end{array} \right] = \left[ \begin{array}{l} \text{Cost 5 years} \\ \text{after establishment} \end{array} \right] \times \left[ \frac{(1+p)^t}{[(1+p)^t - 1](1+p)^{c+5}} \right]$$

Again, representative cost levels are given in table 4.

The final assumed costs of managing Douglas-fir were the (constant) costs of protection, administration, and taxes. Combined, these were estimated at two levels of \$0.60 and \$1.60 per year. Their present values were calculated in the following fashion:

$$\left[ \begin{array}{l} \text{Present value of} \\ \text{annual Douglas-fir} \\ \text{management costs} \end{array} \right] = \left[ \begin{array}{l} \text{Annual} \\ \text{costs} \end{array} \right] \times \left[ \frac{1}{p(1+p)^c} \right]$$

The values that we anticipate from thinning and clearcutting in Douglas-fir are shown in table 5 for a variety of stumpage price levels. This information is all that is required to calculate the present values of the returns from perpetual series of Douglas-fir rotations which will begin when the existing stand of red alder is liquidated.

$$\left[ \begin{array}{l} \text{Present value of} \\ \text{perpetual series of} \\ \text{Douglas-fir yields} \end{array} \right] = \left[ \frac{(1+p)^t}{[(1+p)^t - 1](1+p)^e} \right] \begin{array}{c} \text{final} \\ \text{harvest} \\ \Sigma \\ \text{first} \\ \text{thinning} \end{array} \left[ \begin{array}{l} \text{Value of} \\ \text{thinning} \\ \text{or final} \\ \text{harvest} \end{array} \right] \times \left[ \frac{1}{(1+p)^g} \right]$$

where

$t$  = Douglas-fir rotation length in years and

$g$  = number of years from establishment until thinning or final harvest occurs.

The incomes and costs related to Douglas-fir management can all be brought together by the following expression:

$$\left[ \begin{array}{l} \text{Present net worth} \\ \text{of perpetual} \\ \text{Douglas-fir} \\ \text{management} \\ \text{AFTER CONVERSION} \end{array} \right] = \left[ \begin{array}{l} \text{Present value of} \\ \text{perpetual series} \\ \text{of Douglas-fir yields} \end{array} \right] - \left[ \begin{array}{l} \text{Present value of cost} \\ \text{of periodically} \\ \text{establishing Douglas-fir} \end{array} \right] \\ - \left[ \begin{array}{l} \text{Present value of} \\ \text{cost of periodic} \\ \text{brush control} \end{array} \right] - \left[ \begin{array}{l} \text{Present value of} \\ \text{annual Douglas-fir} \\ \text{management costs} \end{array} \right]$$

Finally, the following equation summarizes the discounted incomes and costs encountered when replacing red alder with Douglas-fir:

$$\left[ \begin{array}{l} \text{Present net worth} \\ \text{of converting red} \\ \text{alder to Douglas-fir} \end{array} \right] = \left[ \begin{array}{l} \text{Present net worth of} \\ \text{existing red alder} \\ \text{stand BEFORE CONVERSION} \end{array} \right] - \left[ \begin{array}{l} \text{Present net worth of} \\ \text{site preparation costs} \\ \text{at CONVERSION} \end{array} \right] \\ + \left[ \begin{array}{l} \text{Present net worth of} \\ \text{perpetual Douglas-fir} \\ \text{management AFTER CONVERSION} \end{array} \right]$$

Again, with reference to table 1, it can be seen that all relevant costs and incomes have been incorporated into the analytical model. Moreover, the present net worths of both retaining red alder and of replacing it with Douglas-fir can be calculated and compared, given a number of explicit assumptions. For those who cannot accept these assumptions, a later section of this paper reports the results of a sensitivity analysis which identifies the variables most critical to the retain or replace decision. The costs of delaying conversion past the recommended time also have been explored briefly.



Table 5.--Expected gross returns per acre from Douglas-fir management with thinnings<sup>1/</sup>

Stand age (years)	Stumpage price levels <sup>2/</sup> for--								
	Red alder/Douglas-fir site class 70/IV			Red alder/Douglas-fir site class 90/III			Red alder/Douglas-fir site class 110/II		
	\$55/\$70	\$45/\$60	\$18/\$22.50	\$55/\$70	\$45/\$60	\$18/\$22.50	\$55/\$70	\$45/\$60	\$18/\$22.50
-----Dollars per acre-----									
25	0	0	0	126.50	103.50	41.40	533.50	436.50	174.60
40	181.50	148.50	59.40	687.50	562.50	225.00	940.50	769.50	307.80
55	297.00	243.00	97.20	737.00	603.00	241.20	1,127.50	922.50	369.00
70	605.00	495.00	198.00	781.00	639.00	255.60	3,626.00	3,108.00	1,165.50
85	429.00	351.00	140.40	2,324.00	1,992.00	747.00	--	--	--
100	1,673.00	1,434.00	537.75	--	--	--	--	--	--

<sup>1/</sup> Based on Appendix A, table 14.

<sup>2/</sup> Stumpage prices are read, for example, as "\$55 per M bd. ft. for thinnings and \$70 per M bd. ft. for final harvests." In each column, the first price was used to generate the value of all thinnings, the second price to generate the final harvest value of the residual stand at the end of the rotation, which is the last value in each column.

## RESULTS OF THE ANALYSIS

In the preceding section, the analytical model and assumptions of the study were outlined. In this section, the results of the analysis are reported and interpreted. Specifically, the data of tables 3 and 5 (expected gross returns), table 4 (conversion costs), and table 6 (stumpage prices and annual management costs) are the assumed values which led to the solutions presented in the composite table 7. A discussion of the impacts on the conversion decision of changes in these fundamental assumptions has been deferred to the next section.

All of the entries in the composite table are defined as the optimal number of years to wait before replacement of an existing red alder stand with one of Douglas-fir. A zero means the red alder stand should be replaced immediately. An "R" means that red alder should be managed in perpetuity. (Boldface entries indicate "borderline" cases which are discussed in the next section under "A General Sensitivity Analysis.") The upper left-hand portion of the table summarizes all decisions involving the assumption of high stumpage prices and low management costs. It tells us, for example, that given low conversion costs, a 6-percent rate of return, and a 15-year-old red alder stand on site 90 land, the manager should immediately clearcut the alder and replace it with Douglas-fir. In contrast, if the same red alder stand were appraised under medium stumpage prices (left center), the most desirable action would be to wait 10 years before liquidation and conversion to Douglas-fir. The other tables should be read and interpreted in a similar fashion. In this way, they can serve as guides to management if the model, data, and assumptions are appropriate. If they are not appropriate, a customized analysis will be required.

Table 6.--*Stumpage prices and annual management costs assumed  
in the basic analysis*

Item	Assumed price and management cost levels		
	High	Medium	Low
-----Dollars-----			
STUMPAGE PRICES			
Red alder:			
Pulpwood (per cord)	7.50	4.50	1.50
Sawtimber (per M bd. ft.)	21.00	12.00	4.00
Douglas-fir:			
Thinnings (per M bd. ft.)	55.00	45.00	18.00
Clearcut (per M bd. ft.)	70.00	60.00	22.50
MANAGEMENT COSTS			
Red alder (per acre per year)	1.00	--	.50
Douglas-fir (per acre per year)	1.60	--	.60

It is important to keep in mind that the entries indicate which alternatives have the larger present net worths. Following these recommendations would not necessarily insure a profit. In fact, the blocked recommendations, which are found under low or medium prices, are for loss-minimizing courses of action. Under these adverse conditions of low stumpage values and high costs, choosing the best management alternative of those considered still led to discounted costs exceeding discounted incomes, or put another way, the guiding rates of return could not be realized in such situations.

If the assumption of active management is dropped, two other alternatives remain. One might elect simply to pay the necessary annual management costs indefinitely, perhaps using the land only for public relations or recreational purposes, without anticipating any dollar returns. If the firm's goal were profit maximization, however, such a management regime could not be justified, for the present worth of these management costs is always greater than the loss-minimizing costs of the optimal active management program. The second and better alternative, given such a firm objective, would be to give up ownership of the land and invest the recovered capital elsewhere.

#### GENERAL CONCLUSIONS

Given our model and assumed values, it is evident that most red alder stands should be converted to Douglas-fir, and most of them immediately. The more profitable red alder management opportunities are generally concentrated on the poorer sites, in older existing alder stands, and under high conversion costs and low stumpage values.

## IMPORTANCE OF THE INDIVIDUAL VARIABLES

The pattern of R's in table 7 illustrates the influence of individual variables on the retain or replace decision. Although there are interactions among the yield, cost, and price assumptions, general trends are readily apparent. Accordingly, the variables can be ranked in terms of their relative influence as follows:

### Guiding Rate of Return

Red alder management is favored only under the most extreme cost and price assumptions when a 3-percent discount rate is used. As the rate increases, retaining red alder is sometimes preferred simply because returns from Douglas-fir are discounted over a greater number of years. This is especially noticeable on medium sites under the most pessimistic assumptions (lower right), where costs of conversion cannot be postponed long enough to offset the heavily discounted returns anticipated from Douglas-fir. The critical role of the guiding rate of return suggests that its determination deserves expert attention: a rule-of-thumb approach is clearly inappropriate.

### Site Class

A quick glance at the table shows that red alder management is most often suggested on the poorest sites. This results from the site class equivalents and physical yield schedules that have been assumed: as the site improves, the productivity of Douglas-fir increases more quickly than the productivity of red alder. The advantages of conversion, therefore, are greatest on the best sites.

### Stumpage Prices

To evaluate the importance of changing stumpage prices, it is necessary to compare certain pairs of table entries: the uppermost entries assume a high level of prices, the middle entries assume medium prices, and the lowest entries assume relatively low prices. High and medium prices lead to nearly identical retain or replace recommendations. However, the lowest stumpage price levels result in a marked increase in the number of recommendations to retain red alder, especially on the poorer sites at high discount rates.

This is primarily due to the changing price differentials between species assumed at the different price levels. Notice (in table 6) that Douglas-fir (clearcut) sawtimber is favored over red alder sawtimber by \$48 per thousand board feet at the medium price level but only by \$18.50 per thousand board feet at the lowest level.

A less important reason why Douglas-fir is favored by higher prices lies in the assumption that prices of the two species move together. As an increase in red alder prices increases the present value of future rotations, it also (to a lesser extent) increases the value of immediately liquidating the present red alder stand. In contrast, an increase in Douglas-fir prices favors only conversion. On balance, then, any increase in the price levels of both species at the rates built into our assumptions will increase the relative desirability of conversion.

Table 7.--Optimal number of years to wait

HIGH STUMPAGE PRICES AND LOW ANNUAL MANAGEMENT COSTS

Red alder/ Douglas-fir site classes	Present age of red alder stands (years)	Guiding rate of return								
		3 percent			6 percent			9 percent		
		High con- version costs	Medium con- version costs	Low con- version costs	High con- version costs	Medium con- version costs	Low con- version costs	High con- version costs	Medium con- version costs	Low con- version costs
-----Number of years-----										
70/IV	15	20	0	0	20	20	10	20	20	10
	25	10	0	0	10	10	0	10	10	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	0	0	0	0	0	0
	65	0	0	0	R	R	<b>0</b>	R	R	<b>R</b>
90/III	15	0	0	0	20	10	0	20	10	10
	25	0	0	0	10	0	0	10	0	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	0	0	0	R	<b>R</b>	<b>0</b>
	110/II	15	0	0	0	0	0	0	10	0
25	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	<b>R</b>	<b>0</b>	0	

MEDIUM STUMPAGE PRICES AND LOW ANNUAL MANAGEMENT COSTS

70/IV	15	20	0	0	20	20	10	<b>30</b>	20	10
	25	10	10	0	10	10	0	20	10	0
	35	0	0	0	0	0	0	10	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	R	0	0	R	0	0
	65	0	0	0	R	R	<b>0</b>	R	R	R
90/III	15	0	0	0	20	10	10	20	20	10
	25	0	0	0	10	0	0	10	10	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	<b>0</b>	0	0	R	R	<b>0</b>
	110/II	15	0	0	0	0	0	0	20	10
25	0	0	0	0	0	0	10	0	0	
35	0	0	0	0	0	0	0	0	0	
45	0	0	0	0	0	0	<b>R</b>	<b>0</b>	0	

LOW STUMPAGE PRICES AND LOW ANNUAL MANAGEMENT COSTS

70/IV	15	<b>R</b>	20	0	<b>R</b>	<b>R</b>	<b>20</b>	<b>R</b>	<b>R</b>	<b>20</b>
	25	<b>R</b>	10	0	<b>R</b>	<b>R</b>	<b>10</b>	<b>R</b>	<b>R</b>	<b>10</b>
	35	<b>R</b>	0	0	<b>R</b>	<b>R</b>	0	<b>R</b>	<b>R</b>	0
	45	<b>R</b>	0	0	<b>R</b>	<b>R</b>	0	<b>R</b>	<b>R</b>	0
	55	<b>R</b>	0	0	<b>R</b>	<b>R</b>	0	<b>R</b>	<b>R</b>	0
	65	<b>R</b>	0	0	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>	<b>R</b>
90/III	15	20	0	0	<b>R</b>	20	10	<b>R</b>	<b>R</b>	20
	25	10	10	0	<b>R</b>	10	0	<b>R</b>	<b>R</b>	10
	35	0	0	0	<b>R</b>	0	0	<b>R</b>	<b>R</b>	0
	45	0	0	0	<b>R</b>	<b>0</b>	0	<b>R</b>	<b>R</b>	0
	55	0	0	0	<b>R</b>	<b>R</b>	0	<b>R</b>	<b>R</b>	<b>R</b>
	110/II	15	0	0	0	20	20	0	<b>R</b>	<b>R</b>
25	0	0	0	10	10	0	<b>R</b>	<b>R</b>	0	
35	0	0	0	0	0	0	<b>R</b>	<b>R</b>	0	
45	0	0	0	<b>R</b>	0	0	<b>R</b>	<b>R</b>	<b>0</b>	

NOTE: An "R" means that red alder should be managed in perpetuity. Entries in bold type indicate "borderline" cases (see discussion in section "A General Sensitivity Analysis"). Entries within blocks are recommendations for loss-minimizing courses of action.

<sup>1/</sup> Stumpage prices and management costs are taken from table 6; alternative costs of conversion are defined in table 4.

before converting red alder to Douglas-fir 1/1

HIGH STUMPAGE PRICES AND HIGH ANNUAL MANAGEMENT COSTS

Red alder/ Douglas-fir site classes	Present age of red alder stands (years)	Guiding rate of return								
		3 percent			6 percent			9 percent		
		High con- version costs	Medium con- version costs	Low con- version costs	High con- version costs	Medium con- version costs	Low con- version costs	High con- version costs	Medium con- version costs	Low con- version costs
-----Number of years-----										
70/IV	15	20	10	0	20	20	10	20	20	10
	25	10	10	0	10	10	0	10	10	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	0	0	0	0	0	0
	65	0	0	0	R	R	<b>0</b>	R	R	<b>R</b>
90/III	15	0	0	0	20	10	0	20	10	10
	25	0	0	0	10	0	0	10	0	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	<b>0</b>	0	0	R	<b>R</b>	<b>0</b>
110/II	15	0	0	0	0	0	0	10	10	0
	25	0	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	<b>R</b>	<b>0</b>	0

MEDIUM STUMPAGE PRICES AND HIGH ANNUAL MANAGEMENT COSTS

70/IV	15	20	20	0	30	20	10	30	20	10
	25	10	10	0	20	10	0	20	10	0
	35	0	0	0	10	0	0	10	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	R	0	<b>0</b>	R	0	0
	65	0	0	0	R	R	<b>R</b>	R	R	R
90/III	15	0	0	0	20	20	0	20	20	10
	25	0	0	0	10	10	0	10	10	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0
	55	0	0	0	<b>R</b>	0	0	R	R	<b>0</b>
110/II	15	0	0	0	0	0	0	20	10	0
	25	0	0	0	0	0	0	10	0	0
	35	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	R	<b>0</b>	0

LOW STUMPAGE PRICES AND HIGH ANNUAL MANAGEMENT COSTS

70/IV	15	R	20	0	R	R	20	R	<b>R</b>	20
	25	R	10	0	R	R	10	R	R	10
	35	R	0	0	R	R	0	R	R	0
	45	R	0	0	R	R	0	R	R	0
	55	R	0	0	R	R	R	R	R	R
	65	R	<b>0</b>	0	R	R	R	R	R	R
90/III	15	20	0	0	R	20	10	R	R	20
	25	10	10	0	R	10	0	R	R	10
	35	0	0	0	R	0	0	R	R	0
	45	0	0	0	R	R	0	R	R	0
	55	0	0	0	R	R	0	R	R	R
110/II	15	0	0	0	R	20	0	R	R	10
	25	0	0	0	<b>R</b>	10	0	R	R	0
	35	0	0	0	<b>R</b>	0	0	R	R	0
	45	0	0	0	R	0	0	R	R	<b>0</b>

See "Note" and footnote 1 on p. 12.

## Present Age of Red Alder Stand

Even when prices are high and costs low, retaining red alder is sometimes indicated when the present red alder stand is in the oldest age class provided for this species. Under our assumptions, stands must be cut by 65 years of age on poor sites, 55 years on medium sites, and 45 years on good sites. If, at the time the retain or replace decision is made, the existing stand must be cut, conversion will often be undesirable because it is not possible to discount the major costs of conversion.

At the other extreme, it is frequently desirable to hold very young stands until they reach 25 or 35 years before replacing them. Such a delay is an expression of the relationship between the rate of increase in red alder yields with stand age and the rates of decrease in present values of both conversion costs and Douglas-fir returns as the discounting period lengthens. In the latter case, our assumption that site preparation costs disappear at age 30 is also important. It is noteworthy that on the best sites, where stands mature soonest, delays in conversion are seldom suggested.

## Costs of Conversion

For each site, high costs of conversion more often lead to delays in replacing red alder than do lower costs. This is particularly apparent when the lowest stumpage prices are assumed.

## Annual Management Costs

Annual management costs have little effect on the retain or replace decision. Contrasting the left-hand entries with those on the right reveals only a slight increase in the number of R's as management costs increase.

Although this basic table of results is strictly applicable only when our assumptions hold, the general influences noted and discussed above have far wider implications. For example, given any set of conditions, holding all the yields, prices, and costs constant while increasing the discount rate will favor retaining red alder. Similarly, possible minor changes in annual property taxes would not have as much effect on the desirability of conversion as would incorrectly estimated site classes.

## **EVALUATING THE STUDY ASSUMPTIONS**

In this section, the basic calculations have been supplemented with a series of sensitivity analyses that suggest which study assumptions are critical and which can be violated without affecting the major conclusions of the study. Such information should help a forest manager judge the applicability of the study to his particular case.

## A GENERAL SENSITIVITY ANALYSIS

A refinement in the analysis enables one to determine which retain or replace recommendations will be reversed if our assumed costs, prices, and yields are changed appreciably. Such an approach sheds considerable light on the stability of the findings and thereby helps put them in their proper perspective. In table 7, boldface type indicates when a 10-percent or smaller change in a calculated present worth will alter the decision to manage red alder or to convert to Douglas-fir.

Consider, for example, the R in the bottom row of the medium-price and low-cost section of table 7. If our assumptions concerning red alder have been too optimistic by 10 percent, or those concerning Douglas-fir too pessimistic by 10 percent, the stand should be converted rather than held in red alder (the detailed calculations for this problem are presented in Appendix B). Similarly, the adjacent boldfaced zero implies that changes favoring red alder by 10 percent would reverse that decision.

The scarcity of these borderline decisions suggests that the general conclusion presented earlier is still valid: under most feasible programs of active management, most red alder stands should be converted to Douglas-fir.

### RELATIVE CHANGES IN STUMPAGE PRICES

In the previous section, it was assumed that future red alder and Douglas-fir prices would move up or down together. In table 8, the results of a few instances where such a relationship does not hold are explored.

There are very few shifts toward red alder management if price schedule A (the high prices of table 7) is replaced by schedule B, which is much less favorable to Douglas-fir. However, a slight further reduction in Douglas-fir prices to those of schedule C (the low prices of table 7) sharply favors retaining red alder. The conversion decision is apparently insensitive to red alder price changes under the investigated conditions: the 80-percent drop in red alder prices between schedules B and C, which would be expected to favor conversion, is overshadowed by the more modest decrease in Douglas-fir prices.

### THE EQUIVALENCE OF RED ALDER AND DOUGLAS-FIR SITES

Another question that might be raised concerns the assignment of Douglas-fir site classification to lands presently supporting only red alder. Our general assumption is that any particular site can be rated as poor, fair, or good for both species.<sup>5</sup>

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<sup>5</sup> In contrast to our assumptions of site class equivalents of 70/IV, 90/III, and 110/II, Smith (1967, p. 274) reports that Schon found the equivalents in British Columbia to be 57/IV, 73/III, and 90/II. The analyses in this paper, then, are somewhat more favorable towards red alder. Also, see footnote on page 3.

Table 8.--Optimal number of years to wait before converting red alder to Douglas-fir, under three guiding rates of return and several stumpage price assumptions<sup>1/</sup>

Red alder/ Douglas-fir site classes	Present age (years) of red alder stands	3-percent rate of return and stumpage prices <sup>2/</sup>			6-percent rate of return and stumpage prices <sup>2/</sup>			9-percent rate of return and stumpage prices <sup>2/</sup>		
		A \$7.50/\$21 \$55/\$70	B \$7.50/\$21 \$20/\$30	C \$1.50/\$4 \$18/\$22.50	A \$7.50/\$21 \$55/\$70	B \$7.50/\$21 \$20/\$30	C \$1.50/\$4 \$18/\$22.50	A \$7.50/\$21 \$55/\$70	B \$7.50/\$21 \$20/\$30	C \$1.50/\$4 \$18/\$22.50
70/IV	15	20	20	R	20	20	R	20	20	R
	25	10	10	R	10	10	R	10	10	R
	35	0	0	R	0	0	R	0	0	R
	45	0	0	R	0	0	R	0	0	R
	55	0	R	R	0	R	R	0	0	R
65	0	R	R	R	R	R	R	R	R	R
90/III	15	0	20	20	20	20	R	20	20	R
	25	0	10	10	10	10	R	10	10	R
	35	0	0	0	0	0	R	0	0	R
	45	0	0	0	0	0	R	0	0	R
	55	0	0	0	0	0	R	0	0	R
110/III	15	0	0	0	0	0	R	10	20	R
	25	0	0	0	0	0	R	0	10	R
	35	0	0	0	0	0	R	0	0	R
	45	0	0	0	0	0	R	0	0	R
	55	0	0	0	0	0	R	0	0	R

NOTE: An "R" means that red alder should be managed in perpetuity.

<sup>1/</sup> High annual management costs (\$1.60 per acre for Douglas-fir, \$1 per acre for red alder) and high costs of conversion (as in table 4) are assumed.

<sup>2/</sup> Stumpage prices are read, for example, as "Schedule A red alder: \$7.50 per cord and \$21 per M bd. ft.; Douglas-fir: \$55 per M bd. ft. for thinnings and \$70 per M bd. ft. for final harvests."



For determination of the significance of the effect of the site equivalence assumptions on our retain or replace recommendations, it is useful to calculate a value for each Douglas-fir site class. All thinning volumes in the basic yield table (Appendix A, table 14) were multiplied by 0.78, the average ratio of thinning-to-clearcut prices (table 6), to convert them to clearcut equivalents. Discounting the individual yields and summing them gives the discounted volumes of table 9. Since all assumed stumpage prices are constant over time, the present value of future rotations may be calculated by multiplication of these discounted volumes by any price per thousand board feet of clearcut stumpage that is appropriate (Lundgren 1966, p. 6). The important point here is that the relative advantage of one Douglas-fir site class over another can be exactly expressed without worry about prices. Further, since the discounted volumes are all for a common year (the conversion year), they reflect relative values even if there is a 10- or 20-year delay before conversion.

The pattern of relative values is clear. Good sites, of course, are worth more than poor sites. However, as the discount rate increases so that still more emphasis is placed on early returns, the best sites quickly increase their relative advantage.

What is the effect of assuming a lower than justified Douglas-fir site class for ground now supporting red alder? Any dollar advantage of conversion to Douglas-fir will appear smaller than it really is, and red alder will be retained too often. The upper part of table 10 shows that this would sometimes occur if an assumed 70/IV equivalence should have been 70/III. The difference in value between Douglas-fir yields produced by site III and by site IV is, in these instances, greater than the difference between present net worths of retaining red alder and replacing it with Douglas-fir, if site IV productivity is assumed.

What is the effect on the conversion decision if a higher than justified Douglas-fir site class were assumed? Conversion would be suggested more often than warranted. The lower part of table 10 shows the direction of changes that would be required in our recommendations in the case of an error as just hypothesized. Because the adjusted entries would be based on a 90/IV site equivalence, there would be more R's than in the (original) upper table, which is based on a 70/IV site equivalence, somewhat less favorable to red alder.

Table 9.--Discounted volumes per acre<sup>1/</sup> produced by a continuous series of Douglas-fir rotations<sup>2/</sup>

Guiding rate of return (percent)	Douglas-fir site class		
	IV	III	II
3	4.7	10.9	19.9
6	.7	2.2	4.7
9	.1	.7	1.6

<sup>1/</sup> Thinning yields were multiplied by 0.78 and harvest yields by 1.00, the products were discounted to the beginning of the rotation and summed, and the sum was adjusted for a continuous series of rotations.

<sup>2/</sup> Based on appendix table 14.

Table 10.--Conversion recommendations that would be changed if the estimated productivity of Douglas-fir on a given red alder site were changed<sup>1/</sup>  
 (Number of years to wait<sup>2/</sup>)

Red alder/ Douglas-fir site class	Present age (years) of red alder stand	Guiding rate of return												
		3 percent			6 percent			9 percent						
		High con- version costs	Medium con- version costs	Low con- version costs	High con- version costs	Medium con- version costs	Low con- version costs	High con- version costs	Medium con- version costs	Low con- version costs				
70/IV	15	R	20	0	R	R	20	R	R	R	20	R	R	20
	25	R	10	0	R	R	10	R	R	10	R	R	R	10
	35	R	0	0	R	R	0	R	R	0	R	R	R	0
	45	R	0	0	R	R	0	R	R	0	R	R	R	0
	55	R	0	0	R	R	0	R	R	R	R	R	R	R
	65	R	0	0	R	R	0	R	R	R	R	R	R	R
90/III	15	20	0	0	R	R	10	R	R	10	R	R	R	20
	25	10	0	0	R	R	10	R	R	0	R	R	R	10
	35	0	0	0	R	R	0	R	R	0	R	R	R	0
	45	0	0	0	R	R	0	R	R	0	R	R	R	0
	55	0	0	0	R	R	0	R	R	0	R	R	R	0
	55	0	0	0	R	R	0	R	R	0	R	R	R	0

If a red alder site 70 is actually a Douglas-fir site III rather than IV, the shaded R's should be numbers--convert to Douglas-fir

If a red alder site 90 is actually a Douglas-fir site IV rather than III, the shaded numbers should be R's--do not convert to Douglas-fir

NOTE: Shaded recommendations would be reversed if an error were made in estimation of Douglas-fir site productivity.

<sup>1/</sup> Table entries were extracted from table 7; conversion cost levels are defined in table 4; the high management costs and low prices are defined in table 6.

<sup>2/</sup> Before conversion of red alder to Douglas-fir. An "R" means that red alder should be managed in perpetuity.

At several earlier points in this paper, it was noted that the retain or replace decision is most sensitive at the lower stumpage price levels. For this reason, the forecasting of Douglas-fir productivity is most critical when future prices are expected to be low relative to future costs. Any assumptions other than the high costs and low prices of table 10 lead to fewer changes in the retain or replace decision when site equivalents are varied.

### CONTRASTING DOUGLAS-FIR MANAGEMENT WITH AND WITHOUT THINNING

To explore the impact of thinning Douglas-fir stands on the conversion decision, we have adopted a yield table for unthinned stands (Appendix A, table 15). The conversion decision is not particularly sensitive to the decision to thin. It is true that differences in present worths between Douglas-fir and red alder are substantially increased if a thinning regime is assumed, but the preferred time of replacement is unaffected in most cases shown in summary table 7 if thinning incomes are eliminated.

When both stumpage prices and conversion costs are either high or low, recommendations on conversion do not differ much between the two styles of management, i. e., with or without Douglas-fir thinnings. Similarly, few changes occur under high prices and low cost assumptions with the elimination of fir thinnings. On the other hand, as we have noted before, when both prices and costs are unfavorable, the conversion decision is quite sensitive to reductions in Douglas-fir value yields. The trend away from Douglas-fir management when the value yields are reduced by elimination of thinnings is summarized in table 11.

### THE INFLUENCE OF TAXES

A shortcoming of our analytical model for some readers will be its failure to consider the effect of taxes on the conversion decision. Our rationale is simply that this expense is unique to each individual or firm ownership situation, depending upon such factors as its taxable income bracket and the composition of its business (Williams 1964, 1967).

Due to differences in the form of taxation ordinarily employed at the Federal, State, and local levels, such taxes may each be expected to have different effects on forest management in general and on the choice between Douglas-fir and red alder management in particular. The tax impact may even be great enough to alter the conversion decision.

In respect to the Federal income tax, since we have included more initial costs in the relatively intensive management programs of Douglas-fir, a large share of such costs would have to be capitalized and therefore could not be written off before the end of the rotation. This would constitute a disadvantage for the Douglas-fir management regime relative to the red alder. On the other hand, annual management costs can be expensed against other firm incomes subject to taxation yearly; hence the impact of such out-of-pocket costs ordinarily would tend to be reduced, thereby favoring Douglas-fir over red alder.

Table 11.--Optimal number of years to wait before converting red alder to Douglas-fir when Douglas-fir management does and does not include thinnings<sup>1/</sup>

Red alder/ Douglas-fir site class	Present age (years) of red alder stand	Guiding rate of return					
		3 percent		6 percent		9 percent	
		Thinning	No thinning	Thinning	No thinning	Thinning	No thinning
70/IV	15	20	20	30	R	30	R
	25	10	10	20	R	20	R
	35	0	0	10	R	10	R
	45	0	0	0	R	0	R
	55	0	0	R	R	R	R
	65	0	0	R	R	R	R
90/III	15	0	20	20	20	20	R
	25	0	10	10	10	10	R
	35	0	0	0	0	0	R
	45	0	0	0	R	0	R
	55	0	0	R	R	R	R
110/II	15	0	0	0	R	20	R
	25	0	0	0	R	10	R
	35	0	0	0	R	0	R
	45	0	0	0	R	R	R

NOTE: An "R" means that red alder should be managed in perpetuity.

<sup>1/</sup> High annual management costs and medium stumpage prices (see table 6) and high costs of conversion (see table 4) are assumed. Yields without thinning are presented in Appendix A as table 15.

In contrast, the effects of the Federal income tax rate alone tend to favor the lower valued red alder. This is the reason: in our basic analysis, we ascribed the importance of stumpage price levels, as they influence the retain or replace decision, primarily to the assumed price differentials between species. If stumpage revenues are subject to, say, a 25-percent capital gains tax, then these relative differentials between species will be reduced and in the direction of delaying conversion or retaining red alder. For example, in table 6 the price differential in favor of Douglas-fir for clearcut sawtimber drops from \$49 to \$36.75 at the highest level of prices and from \$18.50 to \$13.88 at the lowest level.

It may occasionally be possible to adapt our before-taxes analysis to making the equivalent of after-tax comparisons. For instance, our "low level" costs might be about the same as the reader's after-taxes "high level" costs. In addition, one of the sensitivity analyses might suggest which differences are most likely to be critical. If neither of these approaches is adequate, computer programs, available on request to this Station, can be used to make specialized analyses.

## SCHEDULING STAND CONVERSION

When we turn from considering stands in isolation to the problem of scheduling the conversion of a large number of stands, we often find that the recommended time of conversion cannot be followed.

A hypothetical management unit of red alder stands grouped into six stand categories (A through F) is presented in table 12. Site indexes and age classes are as indicated, high management and conversion costs and high stumpage prices (tables 4 and 6) are assumed, and a 6-percent guiding rate of return is considered.

Each entry in the fifth column of the table expresses the advantage of converting a particular red alder stand to Douglas-fir. For instance, to convert a 25-year-old category B stand would be foolish, for the stand is worth \$47.19 per acre more as red alder. If the stand were kept in red alder until age 35, however, and then liquidated and replaced with Douglas-fir, the landowner would be ahead by \$37.63 per acre, in terms of dollars discounted to the present. Further delays in conversion would be expensive: waiting another 10 years until age 45 would reduce the conversion advantage on each acre from \$37.63 to \$23.80, a loss of \$13.83.

So long as it is possible to convert the red alder stands to Douglas-fir at the times of greatest advantage, the forest manager is assured of earning the highest possible return from the land. Moreover, the positive conversion advantages assure that any out-of-pocket capital investments required for conversion would earn at least the 6 percent assumed as the guiding rate of return.

Given that red alder stands are to be replaced with Douglas-fir and the optimal times of replacement are known, budget and manpower limitations may force postponing some conversion beyond the most advantageous time. The problem becomes one of setting priorities. In the sixth column of table 12, the priorities reflect the relative sizes of the conversion advantages. If, for example, just two categories of stands were to be converted every 10 years, conversion could most advantageously be carried out as shown in the last column.<sup>6</sup> The cost of this constraint on conversion can be calculated if the differences between the optimal and the realized conversion advantages are weighted by the number of acres in each stand category and summed. Whether the reasons for such a limitation on conversion could justify this cost would be a fundamental policy question in a firm's operations.

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<sup>6</sup>This is true because the sum of the conversion advantages that would be realized exceeds the sum of all other possible combinations of conversion advantages. Where more categories of stands or more complex constraints must be considered, some type of mathematical programming analysis might be required to determine the optimal schedule.

Table 12.--*Illustrative priorities in scheduling conversion  
of red alder stands to Douglas-fir*

Hypothetical stand category	Red alder site index	Present age of stand	Possible conversion ages	Possible conversion advantages	Conversion priority	Time of conversion
		<i>Years</i>	<i>Years</i>	<i>Dollars per acre</i>		
A	70	15	15	-119.80	6	In 20 years
			25	-26.36		
			35	$\frac{1}{21.01}$		
B	70	25	25	-47.19	5	In 10 years
			35	$\frac{1}{37.63}$		
			45	23.80		
C	70	35	35	$\frac{1}{67.38}$	3	In 10 years
			45	42.62		
			55	8.63		
D	90	15	15	-4.89	4	In 20 years
			25	42.04		
			35	$\frac{1}{56.08}$		
E	90	35	35	$\frac{1}{179.86}$	2	Now
			45	76.76		
			55	5.31		
F	110	25	25	$\frac{1}{220.02}$	1	Now
			35	150.84		
			45	51.73		

$\frac{1}{}$  Conversion advantage at optimal conversion age.

## CONCLUDING COMMENTS

It is again stressed that the assumptions, including both particular values and relationships among variables (e. g., future prices will rise or fall together), imply definite limitations on the applicability of the analysis. Certainly, the reader should thoroughly understand the procedures that have been employed before relying heavily on the results. However, we feel that those managers who can furnish their own experience data will likely find the general model an appropriate guide for analyzing red alder conversion problems.

The basic analysis clearly showed that it would be advantageous to convert red alder to Douglas-fir in most instances, and to do it now. Why, then, aren't more forest managers rushing to convert their stands? A few of the many possible answers are:

1. Managers may be partially or wholly unaware of the potential advantages of conversion.

2. Owners may prefer a passive type of management consisting of simply holding their red alder stands:

- a. in preference to liquidating their investment and incurring a tax liability;
- b. on the speculation that alder stumpage prices will increase significantly in the not too distant future;
- c. in preference to actively seeking out markets for the alder since these markets are not as general or as active as the markets for conifers;
- d. with the thought that more valuable coniferous species will eventually win control of the site without any help; or
- e. on a speculative basis, reasoning that the land will soon be too valuable for other uses to consider any forest management schemes requiring capital investments.

3. The average ownership might be of low-site red alder stands, with little potential for supporting Douglas-fir.

4. Red alder markets and prices may not be as strong throughout the region as assumed.

5. Conversion costs may actually be higher than assumed.

It will be recalled that red alder management was generally recommended when sites were poor, stumpage prices low, and costs high. This is the combination of factors where very little capital can be generated by liquidating the existing alder stand, but it is also the combination which requires the highest capital investments in conversion to Douglas-fir. Staying with red alder and avoiding out-of-pocket costs is much more attractive. However, under somewhat more favorable conditions (better sites, higher stumpage prices, and lower costs), much of the capital necessary for establishing Douglas-fir might be internally accumulated by a delay of the conversion for 10 or 20 years. And under the best conditions (good site, low costs, and high prices), the income generated from harvesting the existing red alder stand plus the promise of a substantial return on investment from a new Douglas-fir stand are enough to suggest immediate conversion.

If one adds a high guiding rate of return to the set of circumstances outlined above as favoring alder retention, retention still tends to be recommended, but not because of high costs of conversion. Instead, the high cost of holding Douglas-fir growing stock on the stump (forest capital) now rules in favor of the alder.

Some readers might be concerned about the general implications of this study for the red alder industry of the Pacific Northwest. If alder stands were to be replaced by Douglas-fir on all ownerships to the extent we have suggested would be profitable, severe adjustments could be expected. But several factors make such a drastic change unlikely.

First, if alder conversion were begun on a large scale, the abundance of red alder offered for sale would quickly drive down stumpage prices. The immediate advantage of conversion would be reduced (although, in the long run, such an increase in supply might well generate its own demand).

Perhaps of greater importance is the apparent slowness of investors to respond to profitable investment opportunities in forestry. Moreover, it appears that a large share of private forest owners do not respond at all. This suggests that, since most of the better red alder sites are privately owned, a large share of the future supply of such timber is likely to continue to be produced in spite of the greater profits available from converting to Douglas-fir management.

Given these factors working against conversion plus the occasions where red alder management is advantageous, a great reduction in the future red alder supply does not appear likely, even in the long run. In fact, since a large share of the present alder acreage is in the younger age classes, some increase in supply could be expected in the next several decades even if most forest owners were to respond to the investment opportunities suggested by this study.

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## APPENDIX A

### ASSUMED PHYSICAL YIELD TABLES

The red alder physical yields assumed in this study are given in table 13 and the calculated value yields in table 3 (p. 4).

Table 13.--*Expected red alder yields from clearcutting*<sup>1/</sup>

Age of stand (years)	Red alder/Douglas-fir site classes					
	70/IV		90/III		110/II	
	Pulpwood	Sawtimber	Pulpwood	Sawtimber	Pulpwood	Sawtimber
	<i>Cords</i>	<i>M bd. ft.</i>	<i>Cords</i>	<i>M bd. ft.</i>	<i>Cords</i>	<i>M bd. ft.</i>
15	5.22	0	10.00	0	14.66	0
25	16.66	0	25.55	0	34.44	0
35	25.78	0	38.89	0	13.11	13.28
45	32.78	0	10.55	13.68	9.11	21.52
55	9.44	9.60	7.00	19.20	--	--
65	6.44	12.08	--	--	--	--

<sup>1/</sup> Yields developed from tables 6, 11, 12, and 13 in Worthington et al. (1960). Conventions used in the derivation are:

- a. yields are 80 percent of tabled values;
- b. 1 cord = 72 cubic feet;
- c. in stands where d.b.h. of the average tree is less than or equal to 10.5 inches, only pulpwood is produced;
- d. in stands where d.b.h. of the average tree is greater than 10.5 inches, just pulpwood is produced by trees 9.5 inches in d.b.h. and smaller and just sawtimber by larger trees.

Physical yields with thinnings assumed for Douglas-fir management are shown in table 14. These yields were synthesized from both published and unpublished data from plantations in the Pacific Northwest and elsewhere. Compared with yields of natural stands that have not been thinned, e. g., Worthington and Staebler (1961), these synthesized yields might appear to be optimistic. It should be remembered, however, that these estimates are for future managed stands rather than for wild stands on which normal yield tables are based. The authors are of the opinion that genetic improvements in planting stock and improvements in planting and seeding techniques will improve both survival and

growth rates, even over that found in existing plantations. In addition, the increasing utilization of smaller materials and a large proportion of all raw materials being processed promises an increased merchantable yield from all stands.

Table 14.--Expected Douglas-fir yields from thinnings and final harvests

Stand age (years)	Red alder/Douglas-fir site classes		
	70/IV	90/III	110/II
	-----M bd. ft. per acre <sup>1/</sup> -----		
25	0	2.3	9.7
40	3.3	12.5	17.1
55	5.4	13.4	20.5
70	11.0	14.2	51.8
85	7.8	33.2	--
100	23.9	--	--

<sup>1/</sup> International rule, 1/4-inch kerf. All trees 6.6 inches and larger d.b.h. to a minimum top diameter of 5 inches. In each column, all yields are thinnings except the bottom one, which is the final yield for a rotation in that site class.

Physical yields to be expected from Douglas-fir management without thinnings are given in table 15.

Table 15.--Expected Douglas-fir yields without thinning

Stand age (years)	Red alder/Douglas-fir site classes		
	70/IV	90/III	110/II
	-----M bd. ft. per acre <sup>1/</sup> -----		
25	0	0	0
40	0	0	0
55	0	0	0
70	0	0	80.5
85	0	<sup>2/</sup> 74.2	--
100	52.6	--	--

<sup>1/</sup> International rule, 1/4-inch kerf. All trees 6.6 inches and larger d.b.h. to a minimum top diameter of 5 inches. From table 33, p. 117, of Worthington and Staebler (1961).

<sup>2/</sup> Linear interpolation between volumes of 80- and 90-year-old stands.

## APPENDIX B

### CALCULATION OF A SAMPLE PROBLEM

The following exercise was included to clear up as many ambiguities as possible in the descriptions of the calculating procedures used in this study.

We have chosen to illustrate our procedures by presenting the detailed calculations necessary to solve a conversion problem; the resulting recommendations are presented as part of table 7. This particular problem is based on the best site class, a 9-percent discount rate, high conversion costs, medium stumpage prices, and low management costs. Costs and prices were taken from tables 4 and 6 and value yields from tables 3 and 5. The following calculations, which are necessary to contrast the value of retaining red alder to that of immediately converting a 15-year-old stand, consider all of the elements outlined in table 1 (inside front cover) and precisely follow the equations presented in the section entitled "The Analytical Model and Assumptions."

#### The Present Net Worth of Retaining Red Alder

$$\begin{aligned} \left[ \begin{array}{l} \text{Present value of} \\ \text{perpetual series} \\ \text{of red alder yields} \end{array} \right] &= (299.23) \left[ \frac{(1.09)^{45}}{[(1.09)^{45} - 1] (1.09)^{45-15}} \right] \\ &= \$23.03 \\ \left[ \begin{array}{l} \text{Present value of} \\ \text{annual red alder} \\ \text{management costs} \end{array} \right] &= (0.50) \left[ \frac{1}{0.09} \right] \\ &= \$5.56 \\ \left[ \begin{array}{l} \text{Present net worth} \\ \text{of retaining} \\ \text{red alder} \end{array} \right] &= \$23.03 - \$5.56 = \boxed{\$17.47} \end{aligned}$$

#### The Present Net Worth of Replacing Red Alder With Douglas-Fir

$$\begin{aligned} \left[ \begin{array}{l} \text{Present value of} \\ \text{existing red} \\ \text{alder stand} \end{array} \right] &= (66.01) \left[ \frac{1}{(1.09)^0} \right] \\ &= \$66.01 \end{aligned}$$

$$\begin{aligned}
& \left[ \begin{array}{l} \text{Present value of} \\ \text{annual red alder} \\ \text{management costs} \end{array} \right] &= (0.50) \left[ \frac{(1.09)^0 - 1}{0.09(1.09)^0} \right] \\
& &= \$0.00 \\
& \left[ \begin{array}{l} \text{Present net worth} \\ \text{of existing red} \\ \text{alder stand} \\ \text{BEFORE CONVERSION} \end{array} \right] &= \$66.01 - \$0.00 = \$66.01 \\
& \left[ \begin{array}{l} \text{Present net worth} \\ \text{of site preparation} \\ \text{costs at CONVERSION} \end{array} \right] &= (70.00) \left[ \frac{1}{(1.09)^0} \right] \\
& &= \$70.00 \\
& \left[ \begin{array}{l} \text{Present value of} \\ \text{cost of periodically} \\ \text{establishing Douglas-fir} \end{array} \right] &= (80.00) \left[ \frac{(1.09)^{70}}{[(1.09)^{70} - 1](1.09)^0} \right] \\
& &= \$80.19 \\
& \left[ \begin{array}{l} \text{Present value of} \\ \text{cost of periodic} \\ \text{brush control} \end{array} \right] &= (40.00) \left[ \frac{(1.09)^{70}}{[(1.09)^{70} - 1](1.09)^{0+5}} \right] \\
& &= \$26.06 \\
& \left[ \begin{array}{l} \text{Present value of} \\ \text{annual Douglas-fir} \\ \text{management costs} \end{array} \right] &= (0.60) \left[ \frac{1}{0.09(1.09)^0} \right] \\
& &= \$6.67 \\
& \left[ \begin{array}{l} \text{Present value of} \\ \text{perpetual series of} \\ \text{Douglas-fir yields} \end{array} \right] &= \left[ \frac{(1.09)^{70}}{[(1.09)^{70} - 1](1.09)^0} \right] \left\{ \left[ \frac{436.50}{(1.09)^{25}} \right] + \left[ \frac{769.50}{(1.09)^{40}} \right] \right. \\
& &\quad \left. + \left[ \frac{922.50}{(1.09)^{55}} \right] + \left[ \frac{3,180.00}{(1.09)^{70}} \right] \right\} \\
& &= \$90.86 \\
& \left[ \begin{array}{l} \text{Present net worth of} \\ \text{perpetual Douglas-} \\ \text{fir management} \\ \text{AFTER CONVERSION} \end{array} \right] &= \$90.86 - \$80.19 - \$26.06 - \$6.67 = -\$22.06 \\
& \left[ \begin{array}{l} \text{Present net worth} \\ \text{of converting red} \\ \text{alder to Douglas-fir} \end{array} \right] &= \$66.01 - \$70.00 - \$22.06 = \boxed{-\$26.05}
\end{aligned}$$

These calculations lead to the two boxed figures, the present worths of retaining red alder and of replacing it immediately with Douglas-fir. The first is entered in the fourth column of table 16 and the other in the third column. Since the options of waiting 10, 20, or 30 years before conversion must also be considered, it is necessary to run through three more series of calculations and add the present worths of delayed conversions to column 3. Now it becomes obvious that if one is going to convert to Douglas-fir, it should be done in 20 years, at age 35. Comparing this present worth to that of retaining red alder indicates that the stand should be converted. The positive conversion advantages of the fifth column are simply the differences between the values in columns 3 and 4.

Repeating these types of calculations for the different present stand ages led to the recommendations in the last column. Notice the negative conversion advantage for a 45-year-old stand. This indicates that red alder should be retained. Since a 10-percent change in either of the present worths of retaining red alder or converting to Douglas-fir could change the conversion advantage to a positive value, this is a "borderline" case as defined in the section entitled "A General Sensitivity Analysis." Therefore, the corresponding R appears in boldface type in the bottom row of the medium-price and low-cost section of table 7.

The time-consuming nature of calculations like these that were required for our analysis led to the development of specialized computer programs (see footnote 2, p. 2).

Table 16.--*Summarizing the calculations necessary to decide whether a single red alder stand should be converted to Douglas-fir<sup>1/</sup>*

Present age of red alder stand	Age when conversion is possible	Present worth of conversion to Douglas-fir	Present worth of retaining red alder	Advantage of conversion to Douglas-fir	Recommendation
-----Years-----		-----Dollars per acre-----			
15	15	-26.05			Convert in 20 years
	25	23.37			
	35	30.41	17.47	12.94	
	45	15.75			
25	25	62.92			Convert in 10 years
	35	79.59	48.96	30.63	
	45	44.89			
35	35	196.02	123.51	72.51	Convert now
	45	113.87			
45	45	277.17	300.00	-22.83	Retain red alder

<sup>1/</sup> Reported in table 7. Assumptions are a red alder/Douglas-fir site class of 110/II, a 9-percent guiding rate of return, medium stumpage prices, and low annual management costs (as defined in table 6), and high conversion costs (table 4).





Yoho, James G., Chappelle, Daniel E., and Schweitzer, Dennis L.  
1969. The economics of converting red alder to Douglas-fir.  
USDA Forest Service Res. Pap. PNW-88, 31 pp.  
Pacific Northwest Forest & Range Experiment Station,  
Portland, Oregon.

This study defines those conditions where it is more profitable to replace red alder stands with Douglas-fir than to manage for red alder. Under most of the circumstances analyzed, red alder stands should be immediately converted. In order of importance, the critical variables in this decision were found to be the discount rate, site productivity, expected stumpage prices, the present age of the existing red alder stand, costs of conversion, and annual management costs. Sensitivity analyses suggest how these variables influence the conversion decision.

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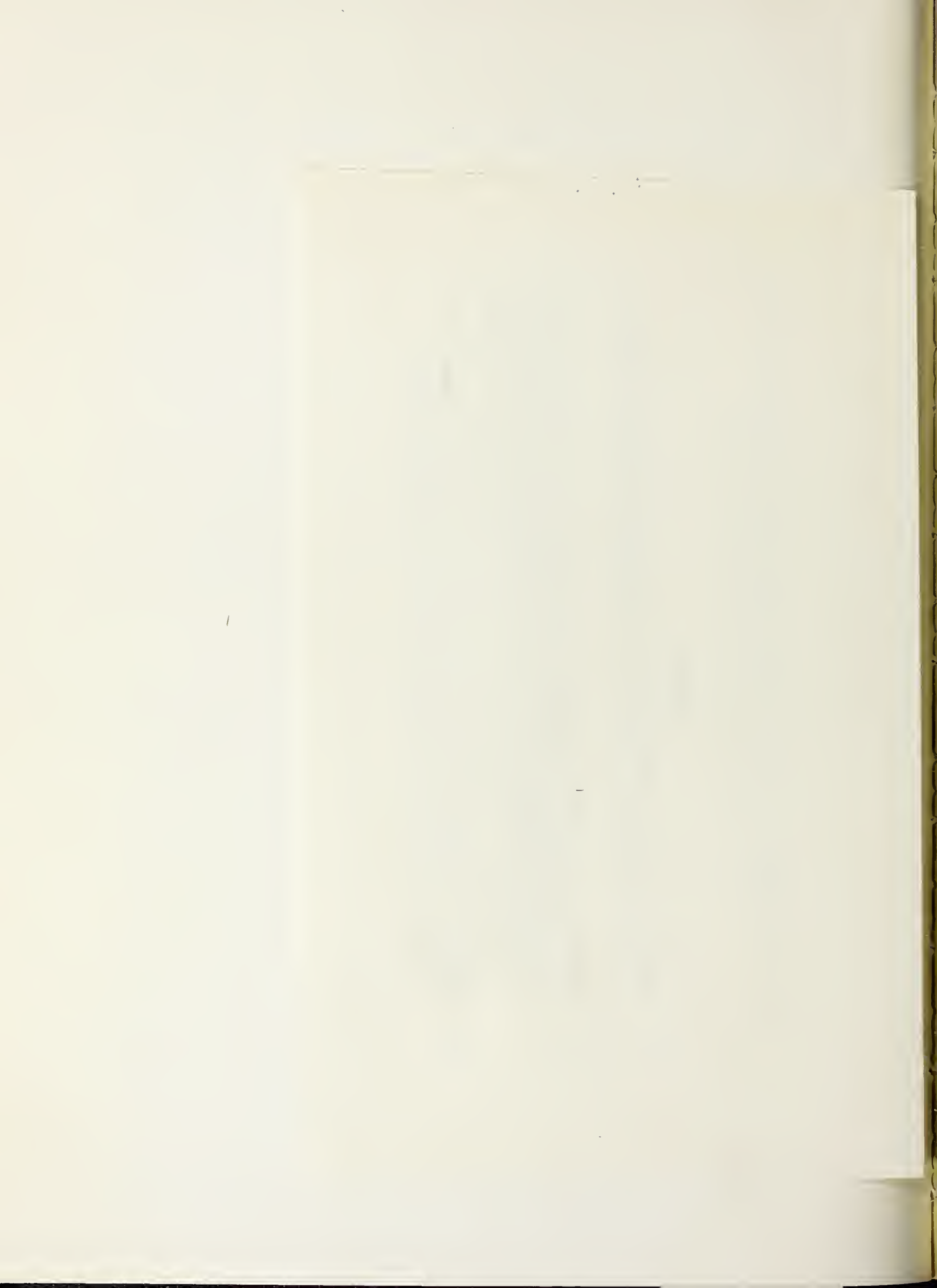
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THE ECONOMICS OF CONVERTING RED ALDER TO DOUGLAS-FIR  
USDA Forest Service Research Paper PNW-88

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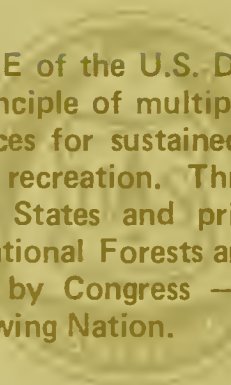
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