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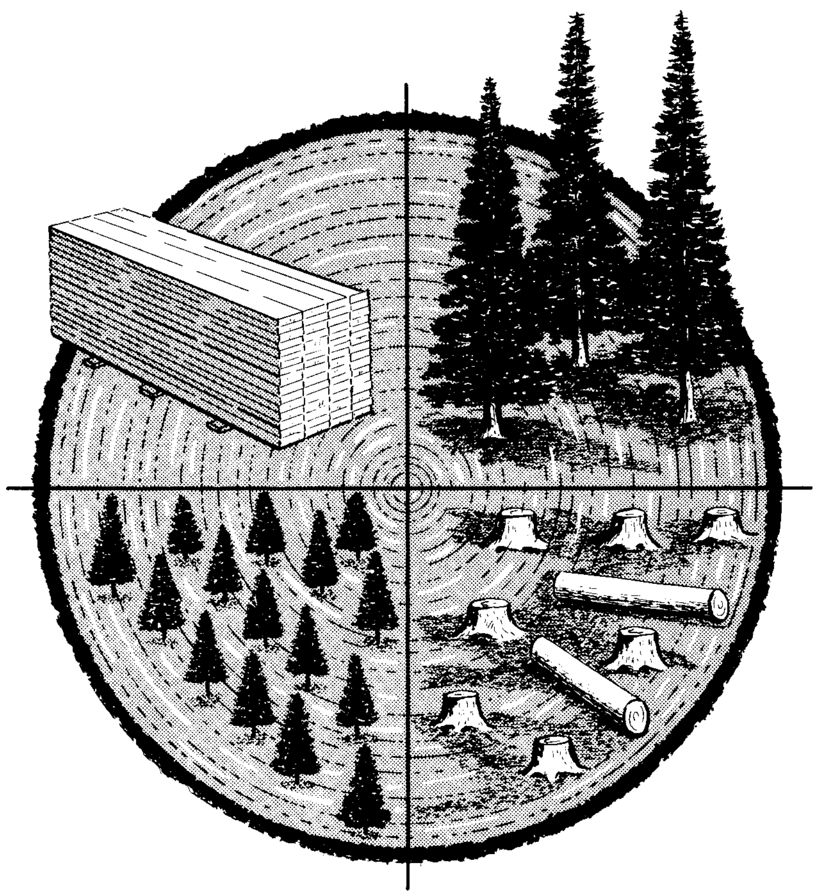
ECONOMICS OF REPLACING YOUNG-GROWTH PONDEROSA PINE STANDS

. . . a case study



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Pacific Southwest Forest and Range Experiment Station
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Economics of Replacing Young-Growth Ponderosa Pine Stands . . . a case study

DENNIS E. TEEGUARDEN

Contents

The Author

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Acknowledgments

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Stands of young-growth ponderosa pine *(Pinus ponderosa)* grow on 1½ million acres of California's forest lands. How best to manage these stands is of concern to both public and private forest managers. Research aimed at developing the best silvicultural techniques is being done by both public and private agencies.

At the Pacific Southwest Station's Challenge Experimental Forest, Yuba County, California, researchers are studying methods of managing young-growth ponderosa pine stands at the lower elevations of the Sierra Nevada. Their work is directed at finding effective, low-cost techniques of regenerating pine and associated conifers after a harvest cut.

Many stands on the Experimental Forest are 80 to 90 years old. They are growing below the rate that yield studies suggest might be expected on comparable sites elsewhere. Their age, the large capital investment represented by growing-stock, and the presence of trash hardwoods that preempt growing space in some stands have raised questions about when the aging stands should be replaced with a new tree crop.

This paper reports a study of selected young-growth ponderosa pine stands on the Challenge Experimental Forest—how much they grow in value and when would be the best time to replace them. Specifically, the study sought an answer to the question: Is the best financial alternative to: (a) harvest the stands now, replacing them with new tree crops, or (b) hold the stands without thinning or pruning for harvest in the future? Because of the already advanced age of the stands, the alternative of holding them with a regime of thinning or pruning to increase earning rate on the growing-stock investment was not considered in this study. The method used in the study may prove useful in planning young-growth forest management. The specific technique of evaluating stand growth performance can be applied to many management situations and to any type of forest stand.

Challenge Experimental Forest

The Challenge Experimental Forest lies on the west side of the Sierra Nevada, about 38 miles east of Marysville, California, at elevations ranging from 2,500 to 3,600 feet. The terrain is generally gentle to moderately sloped. Soils are deep, well-drained, and of the Aiken series. The forest is primarily young-growth, with a few residual old-growth trees in some stands. About 55 percent of the forest's 3,520 acres are classified as pine type, 20 percent as pine-Douglas-fir, and 19 percent as pine-Douglas-fir-fir.[1] Black oak, tanoak, and Pacific madrone grow in varying degree throughout the Experimental Forest. Site index ranges from 100 to 170 feet.[2]

Cutting in the vicinity of the Experimental Forest first began about 1855, when the first sawmill was built. Old-growth stands were often clearcut to provide lumber for local gold mines and new settlements. Some areas were burned and subsequently invaded by brush. The Experimental Forest apparently developed by natural regeneration on such heavily cutover or burned areas. Remnants of old fence lines indicate portions of the Forest had been grazed or farmed and later abandoned.

Re-establishment of the Forest began in the 1870's. Apparently the ground was restocked naturally over a period of years in "waves" of regeneration that coincided with good seed crops and favorable soil moisture conditions. After the first "wave," others were less successful owing to the presence of established trees. Ages of 144 trees on three adjacent stands cut in 1963 ranged from 52 to 100 years; 63 percent, however, were in the 71-90 year age-class; they averaged 75 years. Owing to initial open condition of the forest, there is substantial hardwood stocking in many stands.

[1] Based on type classifications defined by Society of American Foresters. *Forest cover types of Western North America.* pp. 24-29. Washington, D.C., 1945.

[2] The index is in terms of the average total height of dominant ponderosa pine trees at a base age of 100 years measured at breast-height. Based on Arvanitis, L.G., *et al. Site index curves for even-aged young-growth ponderosa pine of the west-side Sierra Nevada.* Calif. Forestry and Forest Products 35, Univ. Calif. School of Forestry, Berkeley, Calif. 1964.

Economic Criteria for Replacement Decisions

The decision to replace a timber stand arises because assets in the form of growing-stock eventually are subject to diminishing productivity. For example, growing-stock of an even-aged forest increases over time as annual growth accumulates. Growth in a given time-period is the output which results from an investment of growing-stock and of land at the beginning of the period. This output is "stored" on the starting growing-stock and becomes part of it for the following growth period. Eventually, as the stand ages, growth diminishes relative to the input of growing stock. One element of urgency to replace the stand arises from the declining productivity of accumulated growing-stock. As the earning-rate on additional investment in growing-stock declines over time, the question arises as to when the stand should be replaced, or the rotation ended.

Typically, the forest manager has not one but many stands in different age-classes, on sites of varying productivity, and characterized by different degrees of stocking. His replacement problem is similar to that of an investor in corporate stocks or bonds who periodically examines his portfolio to determine which assets have prospective earning-rates below a minimum acceptable rate—possibly a rate which capital funds can earn in alternative investments. Similarly, the forest manager can review his portfolio of growing-stock assets to determine which trees or stands offer prospective earning-rates which have fallen to unacceptable levels. By replacing such assets, he improves productive efficiency of invested capital.

One approach to determining the best time to replace an aging stand stems from the view of forestry as a problem in capital management. The criterion for replacement is: harvest if the stand's prospective value growth-percent is less than the guiding minimum acceptable rate, or symbolically:

Harvest if: $$\frac{dg}{G} < p \qquad (1)$$

in which: dg prospective 1-year growth in value (dollars per acre)

G = present capital value of stand (dollars per acre)

$\frac{dg}{G}$ = prospective value growth-percent, or stand earning rate expressed as compound interest

p = alternative rate of return.

The value growth-percent (dg/G) measures how efficiently the stand accumulates capital values. It is obtained for a 1-year period by expressing stand value growth as a percent of the value of the stand. Closely related to value growth percent is the volume growth percent, which is a measure of how efficiently the stand accumulates board feet, cubic feet, or other physical units of product.

The alternative rate of return is the rate of interest that the timber owner expects for the use of his capital. It can be considered a *performance standard.* It is the highest interest rate that can be earned on funds removed from the stand and placed in another investment that is equivalent in risk. Or it can be the annual percentage at which an individual discounts future values in his decisions about current versus future consumption. In this study, an alternative rate of return of 4 percent is used as the standard for evaluating stands on the Experimental Forest.

The simple replacement decision model (Equation No. 1) implies that the only cost of delaying a timber harvest is the income foregone from alternative use of capital invested in growing-stock. But a decision to postpone harvest involves committing *two* resources to use by the stand for another period: (a) growing-stock capital; and (b) land or the site. And both land and growing-stock capital may earn income in alternative uses, including growing future crops of trees. This potential income from alternative land-uses is an implicit cost of postponing harvest which must be entered in the replacement model on the cost side. It then follows that *the optimum time to replace the stand is when its prospective value growth equals the alternative return on the invested capital in growing stock plus the annual rental value of the site.*[3] This criterion is expressed symbolically as:

Harvest if: $$dg < Gp + a \qquad (2)$$

in which: Gp = stock-holding cost, expressed as interest charges on present growing-stock investment in dollars per acre

a = land-holding cost, expressed as the annual rental value of the site in dollars per acre.

The expanded replacement model says the following: compare the anticipated income from the

[3] For a more complete explanation of the model, see: Bentley, William R., and Teeguarden, Dennis E. *Financial maturity: a theoretical review.* Forest Sci. 11:76-87, 1965.

present stand to the anticipated income from alternative use of growing-stock capital and land; if the latter is greater, the stand should be replaced because net revenue can be increased by releasing capital and land for more profitable uses. For example, suppose the growing-stock capital for a given stand is valued at $1,000 at the beginning of a season's cutting period, and value-growth forecast for the next year is $60. Earning-rate on growing stock capital s $\frac{60}{1000}$, of 6 percent. If the alternative rate of return is 5 percent, and if rental value of the land is zero, the stand should be held, since income is greater under this plan ($60) than in the alternative investment ($1000 X .05 $50). Suppose, however, the annual rental value of the site is $15. Then cost of postponing harvest is $50 (implicit interest charges on growing-stock capital) plus $15, or $65, a sum greater than value growth of the present stand. Thus the stand should be scheduled for replacement.

Land-holding cost is determined by the owner's alternative opportunities for use of the land. If the "best" use of the land is for timber growing, land-holding cost is the annual equivalent of the net income earned from growing future crops of trees. In this paper, we show how estimates of site rent may be derived and present estimates for young-growth ponderosa pine under certain specific assumptions. On the other hand, if best use is some non-timber activity such as agriculture, the value of land for such use is entered in the decision equation. This change may imply ultimate shift of the land to non-timber uses. In this study, we assumed that land at the Experimental Forest will continue to be devoted to growing timber, and thus site rent is taken as the annual equivalent of net income from growing future tree crops.

This study explores the economics of replacing young-growth pine stands using the expanded replacement model. To answer the question "Should the stands be replaced, or should they be held for harvest at some future date?", the expected value growth of each stand under alternative future stumpage price levels is compared with the cost of delaying harvest, i.e., the sum of anticipated stock-holding and land-holding costs.

Growth Performance of Selected Stands

Five stands whose growth performance raises questions concerning their replacement are evaluated in this paper. The stands are similar to others on the forest *(table 1).*

First, growth performance of each stand will be evaluated by comparing the anticipated earning-rate on growing stock capital with the alternative rate of return. An earning-rate on growing stock investment below 4 percent indicates the best plan is to replace the stand. But any higher rate would call for further analysis to consider land-holding cost.

In the study, we assumed that the decision to hold or replace is based on anticipated growth in capital values during the planning period 1963 to 1969. As background for the analysis, we studied actual stand growth performance for the period 1959-1963.

The Period 1959-1963

In 1959, inventories of the five stands ranged from 19,109 board feet per acre (Stand A) to 43,897 board feet per acre (Stand C) *(table 1).* Capital values averaged $276 per acre and ranged from $174 to $419 per acre. Species composition of the stands was as follows:

	Stand				
	A	B	C	D	E
Species:	(percent of inventory)				
Ponderosa pine	84	71	70	*72*	80
Sugar pine		11	2	5	3
White fir	5	1	--	2	1
Douglas-fir	2	3	20	20	*7*
Incense-cedar	9	14	8	1	9
Totals:	100	100	100	100	100

Stand volume growth performance in the period 1959-1963 ranged from 629 to 953 board feet per acre per year *(table 1).* Current research on young-growth ponderosa pine yields suggests that in stands 75 years old on site index 157, stocking averages 77,710 board feet per acre, annual growth over the life of the stand averages 1,036 feet per acre, and current 1-year growth is 630 board feet per acre.[4] Against this standard, current

[4] Provided by James L. Lindquist, School of Forestry and Conservation, University of California, Berkeley.

Table 1.--*Characteristics and volume growth performance of selected young-growth ponderosa pine stands, Challenge Experimental Forest, California, 1959 and 1963*[1]

Stand[2]	Area	Age[3]	Trees per acre		Average d.b.h.		Basal-area per acre 1959[4]	Total volume per acre		Average annual growth per acre	Volume growth percent[5]
			1959	1963	1959	1963		1959	1963		
	Acres	*Years*			*Inches*		*Sq. ft.*	*Bd. ft. Scribner*		*Bd. ft. Scribner*	
A (33B)	5.00	76	47	50	18.1	18.6	84	19,109	21,859	687	3.42
B (33A)	5.00	70	50	50	20.6	21.2	116	27,614	30,117	626	2.19
C (12)	2.64	70+	77	78	20.2	20.6	171	43,879	47,694	953	2.11
D (7)	3.00	70+	40	39	23.3	24.0	119	34,538	37,321	695	1.96
E (30A)	2.00	*75*	70	70	19.8	20.3	150	36,689	39,558	716	1.90

[1]Site index is 157 based on average height of dominant ponderosa pine trees at 100 years.
[2]Numbers in parentheses refer to compartment designation. Data for stands C and D are for permanent growth plots.
[3]Average age of trees 20 inches d.b.h. and larger at end of 1963.
[4]Trees 11 inches d.b.h. and over.
[5]Defined as the percentage rate, expressed as compound interest, at which beginning volume grows to equal ending volume.

Table *2.--Value growth performance of selected young-growth ponderosa pine stands, Challenge Experimental Forest, California, 1959 to 1963*

Stand	Inventory value[1]		Volume growth	Value growth 1956 to 1963[2]
	1959	1963		
	Dollars		*Percent*	*Percent*
A	869	651	3.42	-6.9
B	1,196	889	2.19	-7.1
C	1,107	854	2.12	-6.3
D	1,018	777	1.96	-6.5
E	686	497	1.90	-7.7

[1]Calculated using stumpage price schedules A and B, Appendix A and inventory data in Table 7.

[2]Defined as the percentage rate, expressed in compound interest, at which beginning inventory value grows to equal ending inventory.

Table 3.--*Inventory,* by *species, in selected young-growth ponderosa pine stands, Challenge Experimental Forest, California, 1959 and 1963*

Species	Stand A 1959	Stand A 1963	Stand B 1959	Stand B 1963	Stand C 1959	Stand C 1963	Stand D 1959	Stand D 1963	Stand E 1959	Stand E 1963
	Board feet Scribner									
Ponderosa pine	80,446	92,109	98,049	106,798	82,184	88,690	74,537	79,290	58,669	63,016
Sugar pine	--	--	15,791	17,334	1,643	1,845	4,709	5,374	1,987	2,140
Douglas-fir	1,836	2,343	3,567	3,897	23,137	25,734	20,875	23,367	5,547	6,149
White fir	4,820	5,089	1,313	1,553	175	209	2,319	2,689	375	416
Incense-cedar	8,443	9,754	19,347	21,006	8,703	9,435	1,175	1,245	6,802	7,395
Totals	95,545	109,295	138,067	150,588	115,842	125,913	103,615	111,965	73,380	79,116

Table 4.--*Projected inventory in 1969*, by *species, selected young-growth ponderosa pine stands, Challenge Experimental Forest, California*

Stand	1969 Inventory: Ponderosa pine	Sugar pine	Douglas-fir	White fir	Incense-cedar
	Volume in board feet Scribner				
A	109,603	--	3,103	5,492	11,720
B	117,671	19,648	4,392	1,913	23,494
C	98,444	2,148	29,629	260	10,533
D	86,419	6,371	27,105	3,244	1,350
E	69,536	2,369	7,052	477	8,284

stands on the Experimental Forest are sub-stocked and have produced only 28 to 61 percent of the volume typically found on comparable sites. Although average annual growth per acre was still relatively high, volume growth relative to starting inventory investment during 1959-1963 ranged from 1.9 to 3.4 percent.

Growth in capital value.—If stumpage prices had remained stable, the rate of capital value-growth of the stands between 1959-1963 would be about the same as the volume growth percents shown in table 1. If we apply a 4 percent criterion, all five stands apparently had passed financial maturity by or before 1959. But if we apply a 3 percent rate, only stand A (with an earning rate of 3.3 percent) had not passed financial maturity.

In fact, the market situation deteriorated drastically during the period 1959-1963. At the Experimental Forest, prices received for young-growth pine stumpage averaged $3.88 per thousand board feet (MBF) less in 1963 than in 1959—a drop of 37 percent. During the same period, prices for old-growth ponderosa pine stumpage sold by the U.S. Forest Service in California declined an average of $4.80 per MBF, or by 23 percent.

Inventory values were drastically reduced by the decline in stumpage prices—more than enough to offset increases in physical inventory from stand growth *(table 2).* In 1959, inventory values ranged from $686 (Stand E) to $1,196 (Stand B); in 1963, the range was $497 to $889. Reduction of capital values ranged from $43 per acre (Stand A) to $97 per acre (Stand C), and averaged $69 per acre for all stands. With the benefit of hind sight, it is clear all stands should have been replaced in 1959 if the planning period was 1959-1963.

The Period 1963-1969

In the future, stand volume growth-percent will decline because of further increases in growing stock and the likely reduction of growth. And unless the stand is pruned, prospects for significant improvement in quality are dim. Given this outlook in 1963, should the stands be replaced or held for future growth? Future stumpage prices obviously are a key factor that bears on the decision. If the prospects are for either constant or falling stumpage prices, all five stands should be replaced, for earning-rate on growing-stock investment in each case will be well below 4 percent. On the other hand, if prices are expected to rise, it may be advantageous to hold some or all stands in the light of anticipated growth in capital values. It is assumed that an increase in stumpage prices is more likely than constant or falling prices. Accordingly, interest centers on the relationship between stand earning-rates and possible increases in stumpage prices.

Lacking precise knowledge of future stumpage prices, analysis of the replace-or-hold decision might proceed in one of two ways. The first approach is to estimate the earning-rates from specific forecasts of future stumpage price levels. The replace-or-hold decision would then be made after comparing forecasted earning-rate with the alternative rate of return. The second approach is to find the level of stumpage prices necessary at some specific future date to make each stand's earning-rate equal the test criterion. Then the decision to hold or cut a stand could be based on the decision-maker's judgment as to future price levels.

Because the second approach is consistent with the decision criteria to be applied, and at the same time treats stumpage price as a variable, it is followed here.

Assumptions.—Earning-rate on initial capital value was computed for each stand for various price levels and for estimated volume growth rates. We assumed that:

1. The decision to replace or hold the stand is based on the prospective earning-rate on growing-stock capital during the planning period 1963-1969. A decision to hold could be revised at any time after 1963, of course, if anticipated conditions were to change. But a decision to cut, if carried out, is irrevocable.
2. The stands, and individual species components, grow in volume at the average annual rate experienced during the period 1959-1963 *(tables 3, 4).*
3. Administrative, overhead, and property tax costs can be ignored because they are unaffected by the decision to cut or hold the stands.
4. Stumpage prices (a) remain constant at the 1963 level during the period; or (b) increase up to a maximum of 50 percent over their 1963 level, with the exception of white fir and cedar prices, which remain constant.
5. For a private owner, income from selling stumpage is subject to a 25 percent capital gains income tax. Selling costs are $0.50 MBF, and are deducted from gross stumpage value in calculating taxes. The depletion basis is assumed to be zero.

Stand earning-rate was estimated by obtaining

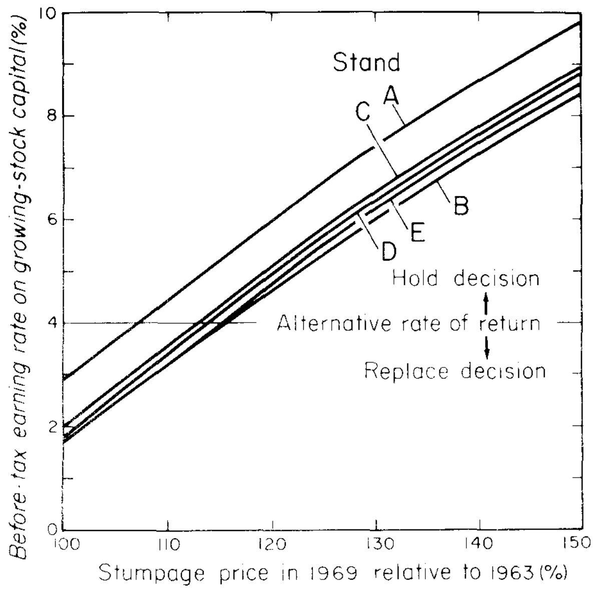

Figure 1.—*Earning-rate on growing-stock capital for the period 1963-1969.*

from a compound interest table the rate of interest corresponding to the value given by the following equation:

$$\sqrt[n]{V_n / V_o} \quad 1 \tag{3}$$

in which: n = 6. number of years in the planning period

V_n = value of inventory in 1969, dollars per acre

V_o = value of inventory in 1963. dollars per acre

Compound interest rates corresponding to different values of n and V_n/V_o may be found in many publications.

Financial analysis.—Each stand's prospective growth performance under the foregoing assumptions was computed *(fig. 1; table 5).* The following discussion considers the before-tax case, appropriate to a public owner.

If no change in stumpage prices is assumed, none of the stands have earning rates greater than 4 percent. Thus if the 4 percent return criterion is applied, the decision would be to replace all stands. If a 3 percent return is the standard, stand A might be held, but only if land-holding cost—potential net annual income from a future crop of trees—is zero.

If we assume prices will increase by 25 percent, growth in stand capital values range from 5.3 to 6.7 percent *(table 5).* If the criterion of a 4 percent return is applied under this price outlook, then all stands should be held at least until 1969. Further analysis, however, is required to take account of land-holding cost.

If, as appears to be the case, stumpage prices will probably increase rather than remain constant, a critical factor is the minimum increase in stumpage prices required to justify holding the stands rather than replacing them. The critical price can be found by determining the relative price level in 1969 that is associated with a prospective stand earning-rate just equal to the alternative rate of return *(fig. 1).* Consider stand C, in which a 13 percent price increase yields an earning-rate equal to 4 percent. Should the decision-maker anticipate that stumpage prices will rise this much, stand C would be held for cutting sometime after 1969. In contrast, stand A requires only a 7 percent price increase by 1969 to justify a holding decision. To justify holding all stands, a stumpage price increase of at least 15 percent must be anticipated by 1969.

The decision-maker may wish to plan his timber operations without regard to the influence of price changes on capital values. But if he does so, he is essentially acting as if prices will remain constant. And under this outlook all stands would be replaced. A possible upward drift in stumpage prices appears to be the only reason for delaying their replacement.

To sum up, an *increase* in stumpage prices (ponderosa pine, sugar pine, and Douglas-fir) of about 15 percent is necessary to justify delaying replacement of stands B, C, D, and E; stand A requires only a 7 percent increase. Prices probably will increase by these amounts and possibly more. Before a decision can be made, however, land-holding cost must also be considered. Accordingly, the next step is estimate this second type of holding cost.

Potential Net Income from Future Crops

The first step in analyzing timber replacement decisions is to estimate the value growth of the stand. Sometimes the decision to hold or cut a stand can be based solely on its prospective earning-rate, given the rate of return criterion. This decision may be made if the earning-rate on growing-stock investment is below the alternative rate of return, or if there is no land-holding cost arising

Table 5.--*Prospective growth in value, selected young-growth ponderosa pine stands, Challenge Experimental Forest, California 1963 and 1969*

Stand	Inventory value 1963[1]	Inventory value 1969[2]	Value growth Before taxes	Value growth After taxes[3]	Earning-rate[4] Before taxes	Earning-rate[4] After taxes
	Dollars per acre				*Percent*	
CONSTANT STUMPAGE PRICES						
A	130.46	155.60	25.14	17.30	2.9	3.0
B	177.93	197.22	19.29	14.22	1.7	1.7
C	323.75	363.59	39.84	27.74	2.0	1.9
D	259.35	289.30	29.95	20.83	1.8	1.8
E	248.65	275.88	27.23	18.82	1.7	1.7
STUMPAGE PRICES RISE 10 PERCENT OVER 1963 LEVEL BY 1969						
A	130.46	169.38	38.92	27.63	4.4	4.6
B	177.93	214.58	36.65	27.24	3.2	3.3
C	323.75	397.68	73.93	53.30	3.5	3.6
D	259.35	316.89	57.54	41.59	3.4	3.5
E	248.65	300.88	52.23	37.64	3.2	3.4
STUMPAGE PRICES RISE 25 PERCENT OVER 1963 LEVEL BY 1969						
A	130.46	192.29	61.83	44.81	6.7	7.0
B	177.93	243.05	65.12	48.60	5.3	5.6
C	323.75	453.66	129.91	95.28	5.8	6.0
D	259.35	362.06	102.71	75.47	5.7	6.0
E	248.65	342.46	93.81	68.74	5.5	5.8
STUMPAGE PRICES RISE 50 PERCENT OVER 1963 LEVEL BY 1969						
A	130.46	228.73	98.27	72.14	9.8	10.3
B	177.93	228.93	111.00	83.00	8.4	8.9
C	323.75	539.31	215.56	159.53	8.9	9.3
D	259.35	431.43	172.08	127.49	8.8	9.3
E	248.65	407.74	159.09	117.71	8.6	9.1

[1]Inventory values in Table 2 divided by stand area.
[2]Computed by applying stumpage prices schedules B, C, D, and E in Appendix to projected inventories in Table 4.
[3]Computed by subtracting selling costs of $0.50 per MBM and 25 percent capital gains tax from inventory values and subtracting 1963 after-tax inventory value from 1969 after-tax inventory value.
[4]Calculated by solving equation 3 (see text).

from continued use of the site. On the other hand, if future use of the site for other tree crops promises revenues greater than production costs, then the forgone net income should be considered in deciding to hold or to replace the present stand. This section attempts to obtain estimates of landholding costs under specific assumptions regarding income-determining factors.

Method of Analysis

Given the management practiced, net income from future crops of ponderosa pine will depend on: (a) physical yields of saleable products, (b) prices, (c) initial costs of regeneration, (d) annual cashflow [expressed as the difference between intermediate annual receipts and expenses for administration, protection, taxes, etc.], (e) interest rate, (f) income taxes [for the private owner], and (g) the rotation or replacement period.

In this study we assumed that future timber growing practices will be about what they have been in the recent past. Thus, we assume that stands will be regenerated within 1 or 2 years after final harvest; protected from fire, disease, and insects; and neither thinned nor pruned between regeneration and final harvest.

Management practices may be more intensive than this in the future. But, at present, thinning and pruning ponderosa pine stands are not widely practiced in California. More important, there is not enough experience now as to the effects of these practices on yields or costs on which estimates of net income under more intensive management can be based. Presumably, thinning or pruning programs will be adopted if they can increase net income from managing ponderosa pine. Thus the estimates provided here should be viewed under the specific assumptions made. Furthermore, they should be considered an indication of minimum income levels which might be achieved under management policies similar to those in the past.

Net income from future crops of ponderosa pine was calculated by using a model in which the future rotation period is chosen to maximize the capitalized value of net incomes occurring every *t* years (*t* is a rotation period). This capitalized net income is also called *soil expectation value.* It may be converted to its annual cash-flow equivalent by multiplying it by the interest rate. In equation form:

$$SEV = \frac{NI_t}{(1+p)^t \quad 1} \qquad (4)$$

$$ACE = SEV\,(p) \qquad (5)$$

in which: SEV = soil expectation value (dollars per acres);
NI_t = periodic net income occurring every t years (dollars per acre);
t = rotation. or replacement period (in years since stand establishment);
ACE = annual cash-flow equivalent of the soil expectation value (dollars per acre per year).

This model allows for interest charges on timber investments and for the influence of postponing fu-ture crops on the optimal rotation period. It, in effect, defines the future optimum rotation in terms which are consistent with the replacement model given earlier.[5] It assumes that all future crops are identical as to yields, costs, values, and other in-come-determining factors. And it assumes that the owner can borrow or invest capital funds at the interest rate used in the model.

The soil expectation value represents the capitalized surplus of revenue over costs (including interest charges on investment). A positive value indicates the maximum price which could be paid for bare land and still cover all investment and other carrying charges plus earnings equivalent to the interest rate. A negative value indicates, for the assumptions made, that revenue is less than prospective production costs, i.e., the site is marginal for timber production.

The following model was used for computing periodic net income for alternative rotation periods:

$$NI_t = R_t - C_h - C_r\,(1+p)^t - C_a\,\frac{[(1+p)^t \quad 1]}{p} - T_x\left(R_t - C_h - C_r - \sum_{K=O}^{t} C_{aK}\right) \qquad (6)$$

in which: R_t = gross revenue from final harvest cut in year t, in dollars per acre. Computed by multiplying yields by unit price;
C_r = initial regeneration costs. dollars per acre;
C_a = annual fixed cash costs for administration. protection; and ad valoreum taxes;
T_x = capital gains or income tax rate, whichever is lower, expressed as a decimal;
C_h = harvesting costs, including marketing, selling, and supervision costs, dollars per acre. Computed by applying harvesting costs per thousand board feet to physical yield schedule;

and in which NI_t, and p are defined as above.

This model reflects the assumption of no thinning or pruning. Thus the only intermediate expenditures are the fixed annual costs for administration, protection, taxes, and other chargeable items.

The model includes explicit allowance for the capital gains or income tax. To compute the tax the appropriate tax rate is applied to the difference between gross stumpage receipts and harvesting costs plus depletion allowance. The depletion allowance is assumed to consist of initial regeneration costs (C,) and accumulated annual expenses $\left(\sum_{K=O}^{t} C_{aK}\right)$. If these annual expenses are "charged off" against other current income in years when they occur, then they can be omitted from the tax calculation. Under Federal tax law, regeneration expenses must be carried in the depletion basis and recovered as a depletion allowance at final harvest.

For an owner subject to 50 percent income tax, cost items charged off against current income are equivalent to a real cost of $0.50 on the dollar because $1.00 so charged off reduces current income taxes by that amount. To take this figure into account in the model, the analyst may enter annual charged-off costs at one-half their actual sum.

[5] Bentley and Teeguarden, *op. cit.*

Table 6.--*Physical and value production schedules for young-growth ponderosa pine (site index 157)*

Age of stand	Average d.b.h.[1]	Yields per acre[2]	Stumpage price, schedule 1	Stumpage price, schedule 2	Stumpage price, schedule 3	Value production, schedule 1	Value production, schedule 2	Value production, schedule 3
		Bd. ft. Int.1/4	*Dollars per MBF*			*Dollars per acre*		
30	12.7	34,310	13.00	9.75	6.50	445.97	334.48	222.98
31		35,860	13.20	9.90	6.60	473.33	355.00	236.67
32		37,360	13.40	10.05	6.70	500.66	375.49	250.33
33	--	38,820	13.60	10.20	6.80	527.96	395.97	263.98
34	--	40,230	13.80	10.35	6.90	555.24	416.43	277.62
35	13.6	41,610	14.00	10.50	7.00	582.51	436.88	291.25
36	--	42,940	14.20	10.65	7.10	609.78	457.33	304.89
37		44,240	14.40	10.80	7.20	637.06	477.79	318.53
38		45,500	14.60	10.95	7.30	664.35	498.26	332.18
39	--	46,730	14.80	11.10	7.40	691.66	518.75	345.83
40	14.5	47,930	15.00	11.25	7.50	719.00	539.25	359.50
41	--	49,100	15.15	11.37	7.58	743.91	558.11	372.01
42		50,240	15.30	11.48	7.65	768.74	576.91	384.47
43		51,360	15.45	11.60	7.73	793.50	595.67	396.90
44	--	52,450	15.60	11.71	7.80	818.19	614.38	409.31
45	15.2	53,510	15.75	11.83	7.88	842.83	633.06	421.68
46	--	54,550	15.90	11,94	7.95	867.41	651.38	433.92
47		55,570	16.05	12.05	8.03	891.95	669.65	446.14
48		56,570	16.20	12.16	8.10	916.44	687.89	458.33
49	--	57,550	16.35	12.27	8.18	940.89	706.10	470.50
50	15.9	58,500	16.50	12.38	8.25	965.32	724.28	482.66
51	--	59,440	16.60	12.45	8.30	986.74	740.29	493.37
52		60,360	16.70	12.53	8.35	1,008.05	756.22	504.02
53		61,260	16.80	12.60	8.40	1,029.24	772.05	514.62
54		62,150	16.90	12.68	8.45	1,050.33	787.81	525.17
55	16.2	63,020	17.00	12.75	8.50	1,071.33	803.49	535.66

[1]Trees 4.5 inches d.b.h. and larger. Calculated with equation:

$$-69.59157 - 13.54381 \log_{10} (\text{age}) + 27.84599 \log_{10} (\text{age X site index}) \quad (R^2 = .68).$$

[2]Calculated using the following empirical yield equation:

$$Y = -546173.69\ 1\ 109078.0 \log_{10} (\text{age}) + 190973.0 \log_{10} (\text{site index})$$

where:

Y = yields in board feet (International 1/4-inch log scale), trees 10 inches d.b.h. and larger, to 6-inch top.

To solve the soil expectation equation, an iterative procedure was followed. For each set of income-determining factors, the soil expectation value was obtained for alternative rotations ranging from 30 to 55 years. The procedure permitted selection of the rotation yielding the maximum capitalized value of periodic net incomes.

Assumptions

Physical Yields

Yields of sawtimber for site index 157 are the best available estimates *(table 6)*. They were computed with the following preliminary empirical yield equation for young-growth ponderosa pine:[6]

[6]Provided by James L. Lindquist, School of Forestry. and Conservation, University of California, Berkeley.

$$Y = -546173.69 + 109078.0 \log_{10}(\text{age}) + 190973.0 \log_{10}(\text{site index})$$

in which: Y = yields in board feet, international ¼ inch log scale, for trees 10 inches d.b.h. and larger to 6 inch minimum top diameter.

The equation is for stands with a basal area composition that averages about 85 percent ponderosa pine. It is based on data from 204 sample plots located in the Sierra Nevada.

Site index is estimated to be 157, the average index computed from a sample of 27 trees taken in four stands on Challenge Experimental Forest. It is based on average total height of dominant ponderosa pine at 100 years, with age measured at d.b.h.

Average stand d.b.h. of trees 4.5 inches and larger was computed with the following equation which is based on data from the same 204 plots used to develop the yield equation:

$$\text{d.b.h.} = -69.59157 - 13.54381 \log_{10}(\text{age}) + 27.84599 \log_{10}(\text{age x site index}).$$

Stand Composition

Ponderosa and sugar pine were assumed to constitute 85 to 90 percent of stand volume indicated by yield equation, and Douglas-fir the balance.

Prices

Three stumpage price schedules *(table 6)* were examined. Schedule 3 assumes that prices of ponderosa pine stumpage (in 1963 dollars) for stands averaging 18-21 inches d.b.h. will increase to about their 1959 level—$10 per MBF—in the next 30 years and then remain constant. This assumption may be somewhat conservative. Schedule 2 assumes that stumpage prices will increase to a level of $15 per MBF (50 percent greater than in 1959) in 30 years and then remain constant. Schedule 1 assumes stumpage prices will increase to $20 per MBF in 30 years and then remain constant. Prices are net of selling costs.

None of these stumpage prices actually appears in *table 6* because they are for the 80-year-old stand anticipated to average 19 inches d.b.h. The basic prices were adjusted to reflect higher conversion costs in younger, smaller-diameter stands. Adjusted prices are shown only for ages up to 55 years. From a study by Baker,[7] we calculated stumpage prices for stands averaging 10 inches d.b.h. at one-half the assumed price for a 19-inch d.b.h. And we assumed that prices for intermediate diameters would increase linearly to the price levels of $10, $15, and $20 per MBF established for a stand averaging 19 inches d.b.h. Pine prices were also applied to Douglas-fir.

Interest Rate

The basic interest rate is the 4 percent alternative rate of return adopted previously. But net incomes were also computed for rates of 3.5, 4.5, 5.0, and 5.5 percent.

Costs

Five levels of regeneration cost were examined: $30, $60, $70, $90, and $120 per acre. This range corresponds to actual costs of seeding and planting new tree crops in California, where seeding generally ranges from about $30 to $60 per acre, and planting from $60 to $120, depending on amount of site preparation and other factors. In spite of cost differences, planting is now the preferred regeneration technique. It is estimated that slash disposal and planting under conditions at the Experimental Forest would now cost about $90 per acre. This figure is close to the lowest cost of slash disposal and planting 436 trees per acre in group selection cuttings in 1963 in the adjacent La Porte Ranger District, Plumas National Forest. Cost of direct seeding with prior slash disposal on the Challenge Experimental Forest ranges from $30 to $70 per acre.

Annual carrying costs for protection, administration, ad valorem taxes, and road maintenance are calculated at two levels: $0.50 and $1.00 per acre per year. For a private owner in the 50 percent income tax bracket, who charges off such costs against current income, equivalent *actual* annual costs are one-half the levels used in the analysis.

Income Taxes

Net income estimates were made under the assumption of no income tax and of a 25 percent capital gain income tax. In the latter case, it was further assumed that annual fixed costs are charged off rather than being added to the depletion basis. It should be emphasized that the optimal rotation periods are not indications of the rotations which should or may in fact be practiced 30 or more years from now. Their chief importance here is the basis they provide for estimating soil expectation values.

Results

For a range of assumptions regarding stumpage prices, regeneration costs, and annual carrying costs, we estimated the annual cash-flow equivalent (ACE) of soil expectation values *(figs. 2, 3)*. The estimates assume a 4 percent alternative rate of return. For brevity, ACE estimates for other interest rates are omitted from this publication.[8] The following summarizes results.

For a 4 percent rate of return and no capital gains income tax, ACE ranges from $5.82 to -$3.28 per acre depending on the other determinants of net revenue *(fig. 2)*. With taxes deducted,

[7] Baker, Vernon W. *Economic guides to young-growth ponderosa pine management.* U.S. Dep. Agr. Soil Conservation Serv. SCE-TR-133, 1958. (Unpublished.)

[8] Tables giving estimates of annual net cash-flow equivalent (ACE) and optimal rotations may be obtained by writing to the Director, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, California 94701.

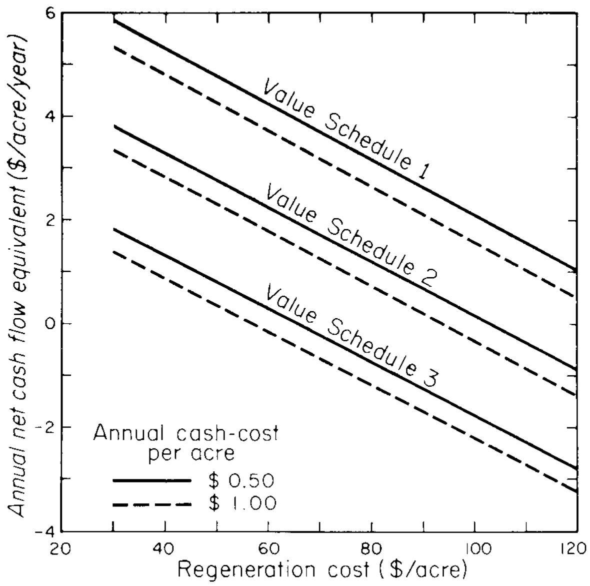

Figure 2.—*Relationship between annual net cash-flow equivalent, regeneration cost, value schedule, and annual cash-cost under assumption of 4 per cent and no income tax.*

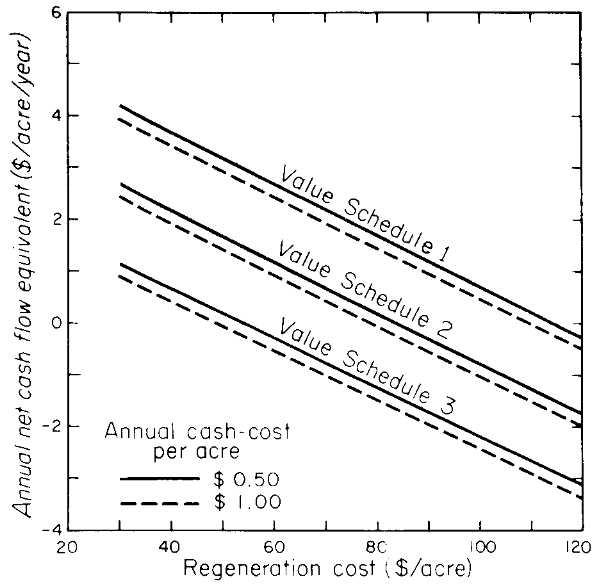

Figure 3.—*Relationship between annual net cash-flow equivalent, regeneration cost, value schedule, and annual carrying cost under assumption of 4 per-cent return and 25 per cent income tax.*

ACE ranges from $4.19 to —$3.41 per acre *(fig. 3).* We found that ACE is especially sensitive to initial regeneration cost and to the stumpage price level.

Optimal rotation periods will be of interest to many forest managers who are responsible for planning young growth timber production. Under the assumptions noted previously, optimal rotations ranged from 30 to 40 years. In general, rotations increase as regeneration cost increases, as interest rate decreases, and as stumpage prices decrease.

Optimal rotation periods under a 4 percent rate of return ranged from 33 to 38 years. These rotation lengths imply growing future ponderosa pine stands on site index 157 to an average diameter of about 13.5 inches d.b.h. (stems 4.5 inches and larger), which is below current merchantability standards. For trees 11 inches and larger, however, average diameter will probably be closer to 16 inches d.b.h. The trend is toward using smaller diameter material, so these future tree sizes perhaps are not unrealistic. In any case, even after allowing for higher unit value as stand diameter increases, rotation periods of 33 to 38 years maximize ACE. To assume stands should be grown to older ages and larger diameters would imply less efficient use of capital in growing stock and land.

The Replacement Decision

To illustrate how the replace-or-hold decision was evaluated in view of both stock-holding and land-holding costs, we will use an example. In *table 7,* column 2 shows each stand's prospective capital-value growth during the planning period. This growth is the result of volume growth and increases in stumpage prices. Because the Experimental Forest is publicly owned, we assumed that there is no capital gains income tax. Stock-holding cost, (column 3) is the income that could be earned if the growing stock capital in 1963 were invested in some other investment that yields a 4 percent return. This cost, accumulated for 6 years, was computed as follows:

$$G_o(1+p)^n - G_O \qquad (7)$$

G„ is beginning inventory value in 1963 (from table 5), p is the alternative rate of return expressed as a decimal (0.04), and n is the planning period (n=6). The term $G_o(1 + p)^n$ determines the value of the beginning inventory, G_o, at the end of n years if it were invested at p interest. G_o subtracted from this value gives income from the alternative investment.

Land-holding cost (column 4) is an estimate of net value which could be produced if the site were released for use by new regeneration. The decision to hold the present stand until at least 1969 requires that its value growth be at least equal to stock-holding cost *plus* land-holding cost.

Land-holding cost for the planning period was computed as follows:

$$\frac{a(1+p)^n \quad 1}{p} \qquad (8)$$

in which a is the annual cash-flow equivalent (ACE) of soil expectation value, as estimated in figure 2 under various assumptions, plus annual fixed cash costs, C_a. Annual fixed cash-costs must be incurred regardless of whether the current stand is replaced or held, and therefore must be added to ACE to estimate annual land-holding cost. Assuming value schedule 1, $60 regeneration cost, annual carrying costs of $0.50 per acre, and no tax on income, ACE is $4.19 *(fig. 3).* Adding $0.50 yields an annual land-holding cost of $4.69 per acre. Equation (8) accumulates annual land-holding cost for n years to determine total land-holding cost for the planning period. Substituting $4.69 for a, land-holding cost for the 6-year period under a 4 percent return is $31.05.

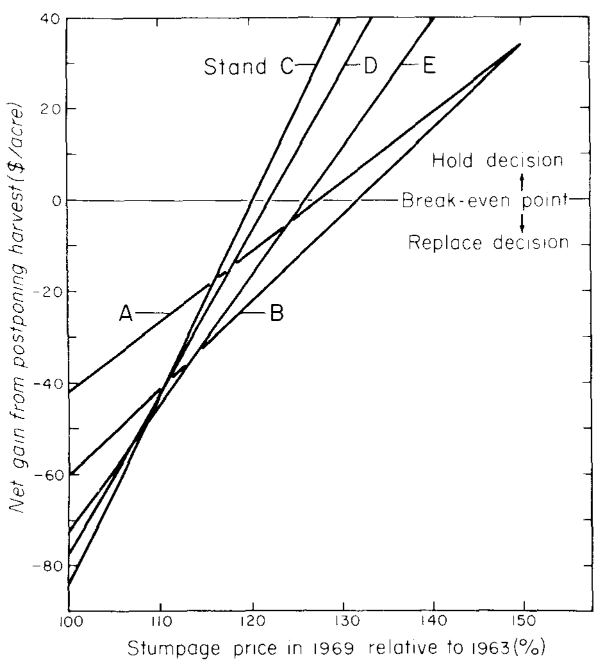

Figure 4.—*Relationship between net gain from postponing harvest and prospective change in stumpage prices.*

To determine the net gain from holding a stand until 1969, the sum of stock-holding and land-holding costs is subtracted from expected value growth (column 2 less column 5). A positive figure (column 6) indicates that the most profitable plan is to hold the stand until at least 1969.

The analysis suggests that all five stands should be replaced if stumpage prices are expected to rise by only 10 percent or less. But if prices are expected to rise by 25 percent over their 1963 level, the decision is to hold stands C and D.

The relationship between net gain from holding each stand and stumpage prices ranging from an index of 100 (constant prices) to 150 percent (1969 prices 50 percent higher than in 1963) is shown in *figure 4.* By reading-off along the break-even line the price index which produces a net gain from holding just equal to zero, the minimum price increase required for a holding decision can be determined. Take stand A as an example. Unless prices rise by at least 28 percent above their 1963 level, the costs of holding stand A will exceed value growth by an amount that depends on the actual price level in 1969. But if prices remain constant, holding cost will exceed anticipated value growth by about $42 per acre. Price increases which lead to a holding decision are:

Stand:	Minimum price increase to justify holding (percent)
A	28
B	32
C	20
D	22
E	26

Recommended Management Plan

The recommended management plan is to schedule stands A, B, and E for replacement and to hold stands C and D for harvest sometime after 1969. This plan assumes application of a criterion of 4 percent return. And it further assumes that a $60 per acre regeneration cost is a reasonable outlook considering recent experience with direct seeding, that stumpage prices for future tree crops will in 30 years reach the $20 level, and that prices during 1963-1969 will increase by 25 percent. Any indication that prices may not attain expected levels is enough reason to reconsider the plan to hold stands C and D.

If stands A, B, and E cannot all be harvested in the first year of the planning period, cutting priorities should be established so that stands with the largest *negative* net gain from holding are replaced first. In this way the cost of postponing their harvest is minimized. Thus *figure 4* indicates stand B should be replaced first, followed by A and then E. However, if the prospective stumpage price increase is less than 25 percent replacement priority changes.

To explore the sensitivity of the replace-or-hold decision to determinants of land-holding cost analyses similar to *figure 4* were made under alternative assumptions regarding regeneration cost and prices for future tree crops.[9] Other factors were held fixed at the levels assumed in the recommended plan. The results indicate the best plan is sensitive to prospective outlays to establish regeneration and to future prices:

[9] These analyses used data from *table 5* and *figure 3*. The analysis may be replicated by following procedures described in the section on *The Replacement Decision.*

If regeneration cost is	*Replace stands*
$90	B
60	A, B, E
30	A, B, E, D

Under value schedule	*Replace stands*
1	A, B, E
2	B
3	(hold all stands)

Low regeneration costs favor a replacement decision because land-holding cost—the cost of delaying the start of a new tree crop—is correspondingly higher. Unless the prospective value growth of the current stand is great enough, a decrease in regeneration cost may shift a stand from a holding to a replace decision, as in the case of stand D when assumed regeneration cost is $30 per acre rather than $60. Conversely, a holding decision is favored by the prospect of low prices for future tree crops because land-holding cost is correspondingly lower. This is why all stands shift to a holding decision if value schedule 3 is in prospect.

A private timber owner may wish to know how a 25 percent capital gains tax on net revenue would affect the replace-or-hold decision. Using

Table *7.--Analysis of the replacement decision*

STUMPAGE PRICES INCREASE 10 PERCENT OVER 1963 LEVEL BY 1969

Stand	Capital value growth 1963 to 1969	Opportunity costs at 4 percent interest			Net gain from holding	Decision
		Stock-holding cost	Land-holding cost	Total cost		
	Dollars per acre					
A	38.92	34.84	31.05	65.89	-26.97	Replace
B	36.65	47.15	31.05	78.20	-41.55	Replace
C	73.93	85.79	31.05	116.84	-42.99	Replace
D	57.54	68.73	31.05	99.78	-42.24	Replace
E	52.23	65.89	31.05	96.94	-44.71	Replace
STUMPAGE PRICES INCREASE 25 PERCENT OVER 1963 LEVEL BY 1969						
A	61.83	34.84	31.05	65.89	-4.06	Replace
B	65.12	47.15	31.05	78.20	-13.08	Replace
C	129.91	85.79	31.05	116.84	19.67	Hold
D	102.71	68.73	31.05	99.78	9.53	Hold
E	93.81	65.89	31.05	96.94	-3.13	Replace

[1]Computed at $4.69/acre per year accumulated with interest for period 1963 to 1969. Based on stumpage value schedule 1; $60 regeneration cost; annual cash-cost of $0.50 per acre; and no tax on income. Fixed annual cash cost is added back into ACE since it is common to present and future stands and thus need not be taken into account.

data from *table 5* and *figure 3* as the basis for decision, if a tax must be paid on present and future harvests the recommended plan is to schedule stands A and B for replacement and to hold stands C, D, and E.[10] Thus the effect of considering the income tax is to shift stand E from a replace to a holding decision.

On the Experimental Forest land-holding cost is a significant element in the economics of replacing pine stands. For example, if only stock-holding cost is considered, stand B requires a 15 percent price increase to raise the net gain from holding above the break-even line *(fig. 1).* But if land-holding cost is also considered, stand B requires a 30 percent increase in price to justify delaying its replacement.[11] Total cost of holding stand B is $78.20 per acre, $31.05 of which is land-holding cost *(table 6).* For all stands examined land-holding cost ranges from 26 to 47 percent of total holding cost *(table 7).*

Land-holding costs were estimated under the assumption of a management policy involving neither thinning nor pruning. Such practices would be adopted if they increase soil expectation value, i.e., if they add more to prospective revenues than to costs. Thus expected increases in future net income arising from thinning and pruning programs in effect raise the cost of delaying replacement of current stands. Given such an outlook, the decision to hold the stand may have to be reconsidered, particularly in instances where the net gain from holding appears relatively small.

[10] Assumes $60 regeneration cost, value schedule 1, and $0.50 per acre per year carrying cost.

[11] This figure assumes $60 per acre regeneration cost, value schedule 1, no tax, and annual carrying charges of $0.50 per

Summary

To sum up, all five stands should be scheduled for replacement unless stumpage prices are anticipated to increase during the planning period 1963-1969. Under a constant-price outlook, earning-rates on growing-stock capital and land values are well below the 4 percent alternative rate of return. It appears likely, however, that prices may increase 25 percent or possibly more. Thus the recommended plan is to replace stands A, B, and E and to hold stands C and D. This plan is based on specific assumptions regarding factors which influence the replace-or-hold decision. Should the outlook be different than the assumptions which have been made, the recommended replacement schedule should be reconsidered.

Appendix

Stumpage Price Schedules Used in Computing Current Stand Values

To estimate stand capital values in 1959 and 1963, prices paid for stumpage sold on the Challenge Experimental Forest in these years were applied to stand inventories shown in *table 3*. Stumpage price schedules used (schedules A and B) are as follows:

	1958	1963	1969		
	A	B	C	D	E
Species:	(dollars)				
Ponderosa pine	10.27	6.39	7.00	8.00	9.60
Sugar pine	7.30	6.20	6.80	7.70	9.30
Douglas-fir	10.15	9.69	10.70	12.30	14.50
White fir	1.79	2.71	2.71	2.71	2.71
Cedar	1.79	2.71	2.71	2.71	2.71

Prices are gross prices, rather than net of road building, slash disposal, or erosion control costs paid to the buyer. Schedules C, D, and E were computed assuming 10, 25, and 50 percent stumpage price increases from the 1963 base year. These schedules were applied to inventory data in *table 4* to obtain stand values in 1969 *(table 5)*.

GPO 976-117

Teeguarden, Dennis E.

1968. **Economics of replacing young-growth ponderosa pine stands . . . a case study.** Berkeley, Calif., Pacific SW. Forest & Range Exp. Sta. 16 pp.. illus. (U.S. Forest Serv. Res. Paper PSW-47)

Compares the expected capital value growth of five ponderosa pine stands (70 to 80 years old) on the Challenge Experimental Forest, Yuba County. Calif., with the cost of delaying harvest (defined as sum of stock-holding and land-holding costs). Suggests that replacement of all five stands would be financially desirable under constant stumpage prices. Recommends replacing three stands and holding two—at least until the end of the planning period—assuming that prices will increase 25 per cent.

Oxford: 64:613:232:174.7 *Pinus· ponderosa:* (794).

Retrieval Terms: rotation age, forest appraisal; forest business economics forest regeneration (artificial); Challenge Experimental Forest; California.

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