6 Economic Analysis of the Merchantable Stand for Unthinned Douglas-fir; 8 years after initial N-application (B. Bare)

In the last economic analysis published by the RFNRP (1976), stands of Douglas-fir were compared using 6-year unthinned and 4-year thinned response data measured in total stem cubic foot volume for the total stand. Also, it was assumed that 200 lbs. of N/acre was applied as urea fertilizer and that the excess wood grown in response to the fertilizer was harvested ten years after the treatment. Results of this and other RFNRP analyses gave highest priority to stands close to final harvest on medium and low sites which were previously thinned.

The present analysis differs from previous analyses in several important respects. First, an 8-year gross merchantable cubic foot volume to a 4-inch top for trees greater than 6.5 inches in diameter is used. Second, only unthinned stands of Douglas-fir are analyzed. Third, treatments of 200 and 400 lbs. of N/acre are included in the analysis and stands may be retained up to two investment intervals (16 years) beyond the treatment date. Fourth, before- and after-tax net present values are calculated to capture the effects of the federal income tax treatment of fertilization. Lastly, both an incremental and absolute form of investment analysis are included to demonstrate the significance of carefully formulating the type of analysis required to answer typical questions posed by management.

Underlying Assumptions

All analyses presented herein assume that stands are considered independently on a per acre basis and that only financial criteria are used in the decision process. In order to simulate a typical corporate land owner, all net present values are expressed using an after-tax cash flow criterion. Fertilization expenditures are capitalized and amortized over a five year period (Bare, 1979). A surplus ordinary income is assumed in calculating the after-tax cash flow. Economic parameters used in the analysis are:

(a) 6 percent real interest rate,

(b) constant real stumpage prices over time,

(c) a fertilization cost of $0.35/lb.N/acre,

(d) estimated current stumpage prices as shown in Table 6-1,

(e) an ordinary federal income tax rate of 46 percent and a long-term capital gains tax rate of 28 percent,

(f) a state yield tax rate of 6.5 percent and

(g) a five year fertilization amortization period.

By expressing all economic parameters in real terms we avoid the necessity of predicting future rates of inflation, thus removing one element of uncertainty from the analysis. Further, since real rates of interest historically have been relatively steady, another element of variation which contributes to uncertainty is removed. The cost of fertilization used in the present analysis (i.e., $0.35/lb.N/acre) represents an average figure. Current stumpage prices represent prices as of July, 1982, and are derived from a 120 quarter data base as compiled by the Washington State Department of Natural Resources.

Mensurational Data

As previously stated, the present analysis uses an 8-year gross merchantable cubic foot periodic annual increment (p.a.i.) for unthinned Douglas-fir stands to measure the physical effects of fertilization. These data come from unthinned RFNRP plots and include trees greater than 6.5 inches in diameter and measure volume to a 4 inch top.

The estimated mean response of 8-year gross merchantable cubic foot volume is shown below:

8-year Response (CF/A/Yr)					
	Site Class				
Treatment	1	2	3	4	All
200 lb. N	19 (5%)	26 (8%)	51 (22%)	40 (22%)	35 (35%)
400 lb. N	29 (8%)	45 (14%)	54 (23%)	66 (36%)	49 (17%)

Previous analyses determined that the trend in 8-year p.a.i. across site class is not statistically significant at the 95% level of confidence. Further, neither the 200 lb. nor the 400 lb. treatment provides a significant response for site class 1 (cf. Sec. 2.2.3). From this we conclude that site class 1 should not be fertilized and that an average 8-year response of 35 and 49 CF/A/Yr can be used for the 200 lb. and 400 lb. treatments, respectively. As reported in the 1978-80 Biennial Report, the 8-year gross p.a.i. was not significantly related to age basal area or site class.

Thus, it follows that the additional merchantable cubic foot volume due to fertilization eight years after treatment is

200 lb. N - 280 CF/A
400 lb. N - 392 CF/A

A BF/CF ratio is used to convert these cubic foot responses to a board foot measure to facilitate the use of stumpage prices listed in Table 6-1. The ratio is a function of average stand diameter and tarif and is shown on p. 12 of Washington State Department of Natural Resources Report No. 20R (Chambers and Wilson, 1972).

Although an average cubic foot volume response to fertilization is used across all site classes, the value of the incremental wood added because of fertilization is computed as a function of the average stand diameter. In order to compute the mean stand diameter 8 years after fertilization the following diameter equation is used:

$$D_8 = f\ (D_0,\ A,\ S,\ N)$$

where

D_8 = Quadratic mean stand diameter 8 years after treatment
D_0 = Initial quadratic mean stand diameter (no treatment)
A = Initial breast-height stand age
S = Kings 50-year site index
N = A dummy variable representing the level of nitrogen fertilization

An additional piece of mensurational data required to perform the investment analysis is the initial merchantable cubic foot volume per acre for non-fertilized stands.

Incremental Net Present Value Analysis

One form of investment analysis often used to evaluate forest management activities is to compare the incremental benefits of an activity against the incremental costs of undertaking the activity. In such an analysis we are only concerned with measuring the change in our measure of economic efficiency as it relates to a single treatment activity. No attention is given to the economic viability of the base investment—only to the incremental costs and benefits. In essence, we compute the incremental net present value as:

$$\Delta\ NPV = (NPV\ of\ \Delta\ Benefits) - (NPV\ of\ \Delta\ Costs)$$

In our analysis, the (NPV of Δ Costs) is simply the NPV of the costs of applying fertilizer. The (NPV of Δ Benefits) is computed as shown below

$$NPV\ of\ \Delta\ Benefits = \frac{Future\ Value\ of\ \Delta\ Benefits}{(1+i)^n}$$

But,

$$\begin{bmatrix}Future\ Value\\ of\ \Delta\ Benefits\end{bmatrix} = \begin{bmatrix}Future\ Value\\ with\ fertilizer\end{bmatrix} - \begin{bmatrix}Future\ Value\\ without\\ fertilizer\end{bmatrix}$$

Now,

$$\begin{bmatrix}Future\ Value\\ of\ \Delta\ Benefit\end{bmatrix} = (V_F \cdot P_F) - (V_N \cdot P_N)$$

Where,

V_F = Cubic foot volume/acre if fertilized
P_F = Price/cubic foot if fertilized
V_N = Cubic foot volume/acre if not fertilized
P_N = Price/cubic foot if not fertilized

However,

$$P_F = P_N + \Delta P$$

And,

$$V_F = V_N + \Delta V$$

Therefore,

$$V_F \cdot P_F = (V_N + \Delta V) \cdot (P_N + \Delta P)$$

So,

Future Value of Benefits

$$= (V_N + \Delta V) \cdot (P_N + \Delta P) - (V_N \cdot P_N)$$

$$= V_N P_N + P_N \Delta V + \Delta V \Delta P + V_N \Delta P - V_N P_N$$

$$= P_N \Delta V + V_N \Delta P + \Delta V \Delta P$$

Then by substitution,

$$\Delta NPV = \left[\frac{(P_N \Delta V + V_N \Delta P + \Delta V \Delta P)}{(1+i)^n}\right] - (NPV\ of\ \Delta\ Costs)$$

In the analyses conducted in this report, n is either 8 or 16 years. Furthermore, all variables in the numerator of the first term of the NPV equation are expressed at the end of the 8- or 16- year investment period.

In order to demonstrate the use of the above procedure for computing incremental net present values, consider the following example. Assume a 40-year old stand growing on site class 2 which is to be fertilized with 400 lb. N at age 40 and harvested at age 48. All economic and mensurational parameters previously discussed are applicable, and both before and after-tax cash flows are shown. A worksheet summarizing the needed calculations is shown in Table 6-2. The procedure shown in Table 6-2 was embodied in a computer program where it was used to explore a number of fertilization treatments.

Results of Incremental Analysis

Using previously presented economic and mensurational parameters, a series of incremental net present value calculations were completed. Two types of fertilization treatments were examined. The first involved one fertilization 8 years prior to final harvest while the second included one or two fertilizations 8 or 16 years prior to final harvest. It was assumed that response to the second fertilization was identical to the first treatment response. Furthermore, only a limited number of treatment schedules were examined. For instance, 24-year old stands were only subjected to one or two treatments before final harvest at age 40. The possibility of extending the rotation to 48 years was not evaluated, as all treatment schedules were limited to either one or two periods. Only rotations

Table 6-1. Estimated Stumpage Prices ($/MBF)-Tractor Logging-
July 1982 (120 qtr. av.)

Quadratic mean stand diameter	$/MBF
8	39.32
9	65.50
10	88.68
11	109.13
12	127.08
13	142.79
14	156.49
15	168.44
16	178.89
17	188.08

Source: Charles Chambers, Washington State Department of Natural Resources, Olympia, August 27, 1982.

Table 6-2. Worksheet for Sample Incremental Net Present Value Analysis ($/A)

End of Year	Item	Cash Flow Before-tax	Cash Flow After-tax	Present Value Before-tax	Present Value After-tax
0	Fertilization	-140.00	-140.00	-140.00	-140.00
1	Fert. Amortization[1]	28.00	12.88	---	12.15
2	Fert. Amortization	28.00	12.88	---	11.46
3	Fert. Amortization	28.00	12.88	---	10.81
4	Fert. Amortization	28.00	12.88	---	10.20
5	Fert. Amortization	28.00	12.88	---	9.62
8	Incr. Harvest Inc.[2]	579.24	417.05	363.42	261.66
8	Incr. Yield Tax[3]	-37.65	-20.33	-23.62	-12.76
Total Incremental NPV				199.80	163.14

1] Annual Fert. Amortization before tax = F/n, where F = Fert. Expenditure and n = Number of years required to amortize expenditure. The after-tax cash flow = F/n *.46

2] Before-Tax Incremental Harvest Income $= P_N \Delta V + V_N + \Delta P + \Delta V \Delta P$
$= (0.50286)(392)+(9629.4)(0.03813)$
$+ (392)(0.03813) = 579.24$

After-Tax cash flow = 579.24 * .72.

3] Before-Tax Incremental Yield Tax = 6.5% of before-tax incr. harvest income. The after-tax cash flow = 0.54 * before-tax value.

of either 40 or 48 years were examined, as the RFNRP data base did not permit extrapolation to 56 years. Tractor logging was assumed for all harvest operations. Results of these calculations are shown in Tables 6-3 and 6-4, where they are summarized by site class and treatment.

By inspecting Tables 6-3 and 6-4 the following conclusions can be verified:

(a) irrespective of fertilization treatment, fertilize site classes 2, 3, and 4 in that order,

(b) site class 4 is not profitable to fertilize under several of the treatment schedules examined,

(c) if only one fertilization is desired, then fertilizations occurring nearest to final harvest are most profitable,

(d) if stands are to be held for two investment periods (i.e., 16 years) then two fertilizations generally are more profitable than one,

(e) older age classes are more profitable to fertilize than younger stands (note: In the analysis, fertilization was only applied to stands between the ages of 24-40 years), and

(f) 400 lb. N/acre generally appears to be more profitable than 200 lb. N/acre but the optimal dosage level decreases across decreasing site class.

Perhaps the most striking results of the incremental net present value analysis in comparison with earlier RFNRP studies are: (a) the recommended treatment of stands growing on high site class over low site class and (b) the recognition that treatments greater than 200 lb. N/acre generate higher incremental net present values than previously acknowledged. The first result follows from assuming constant volume response across site; stumpage prices which increase with increasing diameter; and tree diameters which increase with increasing site class. The second result indicates that the optimum dosage of fertilization is in excess of 200 lb. N/acre. Results indicate that 400 lb. N/acre produces higher incremental net present values than the previously recommended 200 lb. N/acre. However, it is not possible to determine if the optimal dosage level exceeds 400 lb. N/acre or is between 200 and 400 lbs. N/acre. Previous RFNRP results reported in the 1974-76 Biennial Report indicate an optimal application rate of 175 lb. N/acre. This earlier study used 4-year response data where response differed significantly across site class but not between the 200 and 400 lbs. N/acre treatments. Thus, these results are difficult to compare to the results presented in this report.

Results shown in Tables 6-3 and 6-4 apply only if the economic and mensurational parameters used in the analysis remain valid for any particular user. Any change in these parameters is likely to affect results of the analysis. For example, if the cost of fertilizing an acre is reduced from $.35/lb. N/acre to $.28/lb. N/acre, the incremental net present value associated with a single treatment of 400 lb. N/acre eight years prior to final harvest will increase by $17.16/acre on an after-tax basis and $28.00/acre on a before-tax basis. While such a cost change will not alter the priorities shown in Tables 6-3 and 6-4, many of the negative incremental net present values in Table 6-3 become positive at the lower cost. Similar results can be expected as other input parameters used in the analysis are changed.

Absolute Net Present Value Analysis

In an incremental investment analysis such as that discussed above we account only for incremental costs and returns. Accordingly, if incremental returns exceed incremental costs we consider the investment to be worthwhile. This form of analysis is appropriate only if the base investment is worthwhile, or if investment (disinvestment) decisions concerning the base investment are not under control of the manager making the fertilizer decision.

With respect to fertilization, this means we should not fertilize stands with positive incremental net present values unless: (a) the net present value of the base investment is also positive or (b) we have no control over the timing of the final harvest cut in the stand. If we fertilize a stand with a positive incremental net present value but a negative absolute (base) net present value, we are essentially minimizing our losses by spending more funds when we should be harvesting the stand to maximize returns.

Thus, unless one of the two above conditions is assumed, we can not unequivocally make a decision concerning fertilization (or any stand management treatment) unless an absolute net present value analysis is undertaken.

In conducting an absolute investment analysis we attempt to evaluate the total costs and benefits associated with a proposed treatment, and not just the incremental costs and benefits as previously discussed. Only in this manner can we determine if a stand should be fertilized and held for several years, or terminated immediately.

To illustrate the structure of the absolute net present value analysis, consider the 40-year-old stand on site class 2 we previously examined. The incremental net present value analysis has shown that a treatment of 400 lb. N/acre generates a net present value of $163/acre if the stand is harvested at age 48. Thus, if the decision is made to hold the 40-year old stand for 8 more years, we are better off if we fertilize. If we wish to determine if the 40-year old stand should be held 8 more years--with or without fertilization--we then need to undertake an absolute analysis.

Table 6-3. Comparison of Incremental Net Present Value Analyses by Site Class (Tractor Logging: After-Tax)

Current age/ Harvest age	Treatment Schedule	Incremental NPV ($/A) Site Class 2	3	4
32/40	200	95	57	4
	400	131	71	-11
40/48	200	116	82	38
	400	163	109	42
24/40	200/0	51	25	-11
	0/200	59	36	3
	200/200	114	64	-5
	400/0	63	22	-35
	0/400	82	45	-7
	400/400	154	75	-34
	200/400	139	75	-13
	400/200	128	63	-27
32/48	200/0	65	42	12
	0/200	73	51	24
	200/200	141	97	40
	400/0	85	47	2
	0/400	102	69	26
	400/400	194	124	38
	200/400	172	116	45
	400/200	162	104	32

Note: The top portion of the table assumes a fertilization treatment at the current stand age with final harvest eight years later. The lower portion of the table provides for either one or two fertilization treatments. The first may occur at the current stand age or eight years later. If two treatments are specified one occurs at the current stand age and the other eight years later. For example, a 0/200 treatment schedule for a 24 year old stand to be harvested at age 40 indicates a fertilization treatment at age 32 with 200 lb. N.

To begin the absolute analysis, we first wish to determine the best type of management strategy to use to grow future crops of timber on the acre in question. In short, we need to calculate a series of soil expectation values for different management strategies and rotation lengths. In 1980, the Washington State Department of Natural Resources did such an analysis and published a series of soil expectation values (Larson and Wadsworth, 1980). From this analysis we observe that for a 6 percent real rate of interest, forest industry lands are valued at $1212, $499 and $116/acre, for high, medium and low sites, respectively. These after-tax soil expectation values assume a real price and cost appreciation rate increase of 2 percent. Optimal financial rotations range from 55-65 years over the three site classes.

Continuing our illustrative example for the 40-year old stand on site class 2 land, we have three alternatives to examine:

Alternative I: Harvest the 40-year old stand immediately with an absolute NPV of:

$$NPV = \underset{CF}{(8680.4)}\ \underset{\$/CF}{(.39521)} + \underset{\$/A}{1212} = \$4643/acre$$

Alternative II: Hold the present stand for eight years without fertilization:

$$NPV = \left[\frac{(9629.4)\ (.50286)\ +\ 1212}{(1.06)^8}\right] - \left[\frac{4}{.06}\left[\frac{(1.06)^8 - 1}{(1.06)^8}\right]\right]$$

$$= \$3774/acre$$

Note: We have included a $4/acre annual cost for the eight years between fertilization and final harvest. This is the same annual cost included in the soil expectation values.

Alternative III: Fertilize the present stand with 400 lb. N/acre and hold for eight years:

NPV = $3774 + $163 = $3937/acre

Our conclusion now is to harvest the 40-year old stand immediately and forego the fertilization. However, if we must hold the stand for eight more years our incremental net present value is maximized by fertilizing.

Results of Absolute Analysis

Using the above described methodology, a series of absolute net present values were calculated. Treatment opportunities and economic parameters presented earlier for the incremental analysis were used during the absolute analysis. Results are summarized in Table 6-5 where three possible treatments are evaluated for each stand type. The results show that: (a) for site classes 2 and 3--fertilize 24- and 32-year old stands and harvest at age 40; harvest 40-year old stands immediately and carry no stands beyond this age; fertilize 24-year old stands twice before final harvest at age 40; and (b) for site class 4--fertilize 32- and 40-year old stands and harvest at age 48; fertilization in 24-year old stands on site class 4 is marginal if harvested at age 40. However, a different conclusion may be reached if such stands are held until age 48. As discussed earlier, this comparison was not undertaken.

Conclusions

Results presented in Tables 6-3, 6-4 and 6-5 indicate probable financial consequences of fertilizing young-growth stands of Douglas-fir in the Pacific Northwest. These results hold for only the particular input parameters used in the analysis and are likely to change if these parameters change. Thus, readers are cautioned to avoid endorsing the results shown above unless they believe the input parameters apply to their situation. The structure of the two forms of analysis used to derive the financial results are, however, generally applicable to all classes of forest landowners.

Table 6-4. Summary of Results of Incremental Net Present Value Analyses by Treatment (Tractor Logging: After-Tax)

Current age/ Harvest age	Incremental NPV ($/A) Site Class 2	3	4
	One Treatment		
32/40	$131 (4N)	$71 (4N)	$4 (2N)
40/48	$163 (4N)	$109 (4N)	$42 (4N)
24/40	$ 82 (ON/4N)	$ 45 (ON/4N)	$3 (ON/2N)
32/48	$102 (ON/4N)	$ 69 (ON/4N)	$26 (ON/4N)
	Two Treatments		
24/40	$154 (4N/4N)	$ 75 (2N/4N)	$-5 (2N/2N)
32/48	$194 (4N/4N)	$124 (4N/4N)	$45 (2N/4N)

Table 6-5. Comparison of Absolute Net Present Value Analyses by Site Class (Tractor Logging: After-Tax)

Current age/ Harvest age	Alter-native[a]	Treatment Schedule Site Class 2	3	4	Absolute NPV ($/A) Site Class 2	3	4
32/32	I	--	--	--	2889	1394	409*
32/40	II	ON	ON	ON	2888	1475	342
32/40	III	4N	4N	2N	3019*	1546*	346
40/40	I	--	--	--	4643*	2391*	585
40/48	II	ON	ON	ON	3774	2157	844
40/48	III	4N	4N	4N	3937	2266	886*
24/24	I	--	--	--	1740	761	155
24/40	II	ON	ON	ON	1787	901	190T
24/40	III	ON/4N	ON/4N	ON/2N	1869*	946*	193T
32/32	I	--	--	--	2889*	1394T	409
32/48	II	ON	ON	ON	2343	1328	505
32/48	III	ON/4N	ON/4N	ON/4N	2445	1397T	531*
24/24	I	—	—	—	1740	761	155
24/40	II	ON	ON	ON	1787	901	190*
24/40	III	4N/4N	2N/4N	2N/2N	1941*	976*	185
32/32	I	--	--	--	2889*	1394	409
32/48	II	ON	ON	ON	2343	1328	505
32/48	III	4N/4N	4N/4N	4N/4N	2537	1452*	550*

* Denotes best alternative for a given site class-current age-harvest age combination.

T Denotes tie between alternatives for a given site class-current age-harvest age combination.

a I= Harvest Stand at current age - no fertilization

II= Harvest stand at designated harvest age - no fertilization

III= Fertilize as specified and harvest at designated harvest age.

Note: A fertilization treatment schedule of ON/4N for a stand currently 24-years old with a harvest age of 40 means apply one 400 lb. N/acre application at age 32 and harvest in eight years. No fertilizer is applied at age 24.

LITERATURE CITED

Bare, B.B. 1979. Tax Effects of Fertilization, Proc. of Forest Fertilization Conference, Inst. of For. Res. Contr. No. 40, Coll. of For. Res., Univ. of Washington, Seattle, p. 238-242.

Chambers, C. and F. Wilson. 1972. Empirical Yield Tables for the Douglas-fir Zone, Report 20R, Wash. State Dept. of Nat. Res., Olympia, WA, 16 pp.

Larsen, D. and R. Wadsworth. 1980. Land Expectation Values for Western Washington Timber Species, Washington Forest Productivity Study, Phase 3, Part 2, Wash. State Dept. of Nat. Res., Olympia, WA.

Regional Forest Nutrition Research Project, Biennial Report 1976-1978. Inst. For. Res., Contr. No. 39, Coll. For. Res., Univ. of Washington, Seattle, WA.