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RAPID ECONOMIC ANALYSIS OF NORTHERN HARDWOOD STAND IMPROVEMENT OPTIONS

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Abstract. Data and methodology are provided for projecting basal area, diameter, volumes, and values by product for northern hardwood stands, and for determining the rate of return on stand improvement investments. The method is rapid, requires a minimum amount of information, and should prove useful for on-the-ground economic analyses.

Economic analysis of silvicultural options must be based on two types of information: stand responses to various treatments, and price and cost data. Although both types of information are available for northern hardwoods in New England, we lack a system for analyzing investment possibilities that can be used readily by consultants, county foresters, and industrial foresters—those who make rapid, on-the-ground economic evaluations.

Efforts have been made to assemble growth response information for northern hardwoods and related types in the form of computerized systems or fairly complex tabulations (Alimi and Barrett 1977; Solomon 1977a). Such systems are not always suited to the needs of field foresters who may need to make economic evaluations on the ground. Available economic studies provide general guidelines on the feasibility of certain practices (Manthy 1970; McCauley and Marquis 1972), but do not account for specific stand conditions or economic factors applicable to a given property.

The purpose of this paper is to provide some growth factors for essentially even-aged northern hardwood stands and a method for using them to make rapid economic analyses of silvicultural investments. The approach is applicable to those owners who are already committed to managing their forests and are considering fairly small investments in timber stand improvement.

APPROACH

Three main steps are suggested for evaluating stand improvement options:

1. Inventory current stand conditions.
2. Project stand composition by products if it is treated and if it is not treated.
3. Evaluate future volume and value added by the treatment in terms of rate of return on the treatment cost.

As an example, let's assume that a consultant is faced with evaluating the economics of a precommercial thinning and stand improvement operation in a 25-year-old stand of paper birch, red maple, oak, and aspen. We'll not discuss measurement or estimation techniques in detail, but we suggest taking a few prism plots to estimate the mean diameter of the main stand and the basal areas (and percentages) of species and potential products. A few increment borings to estimate current diameter growth would also be helpful. Procedures would be similar to those outlined in most silvicultural guides (e.g. Leak et al. 1969).

Stand Inventory

Measure or estimate basal area per acre (100 ft^2 in this example) and mean stand diameter (3 inches) of the main stand (main crown canopy), and record them on a tally sheet (Fig. 1) on lines 1 and 3 for the untreated stand at year 0. Measure or estimate the potential product composition of the stand and record on lines 5 through 10. This is a very critical step in the analysis. Because of large differences in product utilities and values, northern hardwood stands require a very careful analysis of the product mix to assess their economic possibilities. In the example given, we'll assume that 40 percent of the stand basal area is paper birch of potential boltwood quality, and that 20 percent of the basal area is accounted for by each of the following:

Figure 1.—Economic evaluation sheet.

Stand Location__________ Age_____ Date_______

	If stand is untreated		If stand is treated	
	Year 0	Year 20	Year 0	Year 20
1. Basal area (ft^2)	100	132	60	120
2. Prospective basal area growth (ft^2)	1.6		3	
3. Mean dbh (inches)	3	5.1	3	6.6
4. Prospective mean dbh growth (inches)	.105		.18	
Potential Products (%):				
5. Pulpwood	40	40		
6. Fuelwood	20	20	33	33
7. Boltwood	40	40	67	67
8. Softwood logs				
9. Hardwood logs				
10.				
11. Future basal area from Line 1:	132		120	

VOLUME AND VALUE AT YEAR 20
(in 1980 dollars)

	Percent	Basal Area (ft^2)	Volume (ft^3 or fbm)	Price ($)	Value ($)	Percent	Basal Area (ft^2)	Volume (ft^3 or fbm)	Price ($)	Value ($)
12. Pulpwood	40	53	795 ft^3	.035	28					
13. Fuelwood	20	26	390 ft^3	.118	46	33	40	720 ft^3	.118	85
14. Boltwood	40	53	795 ft^3	.353	281	67	80	1440 ft^3	.353	508
15. Softwood logs										
16. Hardwood logs										
17.										

Untreated Value (UV) = $355 Treated Value (TV) = $593 limby oak (fuelwood), red maple sprouts (pulpwood, or perhaps home-owner fuelwood), and aspen (pulpwood).

Stand Projection

The first step in stand projection is to characterize the treated stand—or several treated stands if several treatment options are to be compared. One possibility is to remove the potential pulpwood-quality material and to concentrate growth on the boltwood and fuelwood. Under this option, the basal area of the treated stand would be 60 ft^2 (line 1), and the mean dbh (line 3) would be carried as 3 inches. Sometimes, the initial mean diameter of the treated stand should be increased or decreased to reflect the immediate effect of the treatment: for example, a thinning from above of overtopping aspen would immediately reduce the initial mean diameter of the treated stand.

Prospective basal area growth (line 2) of the treated and untreated stand can be estimated from the growth factors in Table 1; actual growth data seldom are available for specific stands. We'll use 1.6 and 3.0 ft^2 for the untreated and treated stand, and we'll project for a 20-year period (line 1). This projection period should (1) meet the planning horizon of the owner, (2) not greatly exceed the duration of the available growth data, and (3) be long enough to provide an opportunity for the proposed treatment effects to be expressed. Twenty or thirty years probably is the longest period we can safely use.

Table 1.—Basal area growth[a] of northern hardwoods related to initial stand age and residual basal area

Initial stand age	Residual basal area	Basal area growth
years	ft^2	ft^2
25	100	1.6
	72	2.6
	56	3.0
50[b]	100	1.2
	75	2.0
	60	2.4
70	100	.9
	80	1.4
	60	1.7
	40	1.2

[a] For the 25-year-old stand, basal area growth consists of 16-year net change in basal area of the potential crop trees in the stand (app. 400 per acre); (data from additional measurements on a thinning study reported by Marquis 1969). In the 70-year-old stand, growth consists of 10-year accretion minus mortality, thus excluding ingrowth into the 5-inch class (based on the 45 percent sawtimber treatment reported by Solomon 1977b).

[b] The values for the 50-year stand are approximate averages of the figures for the 25- and 70-year-old stand.

Changes in stand diameter can be estimated from the growth factors in Table 2. Increment borings can be used to estimate current diameter growth of the stand; however, factors such as those in Table 2 will be needed to project the response of the treated stand. Since the stand has a high proportion of paper birch and red maple, we'll use prospective growths of .105 and .18 for the untreated and treated stand (line 4), and project for the 20-year period (line 3).

Table 3 provides some additional growth data for white pine stands. Diameter responses of thinned white pine stands are not well documented, but we do know that thinned young stands can double or triple in diameter growth rate. Tables 1 through 3 do not provide a complete range of data; I suggest that they be used simply as a guide to developing estimates on the ground.

Potential product percentages (lines 5 through 10) for the untreated stand are kept constant for the 20-year period. For the treated stand, product percentages are recalculated to reflect the removal of the pulpwood-quality stems. This would leave 60 ft^2 of basal area, 1/3 in fuelwood and 2/3 in boltwood.

Future Volume and Value

Future basal area and product percentages are recorded in lines 11 and 12 through 17. These two types of entry are then used directly to calculate basal areas by products in the second and seventh columns of lines 12 through 17 for both the treated and the untreated stand. To convert basal areas to volumes (third and eighth columns of lines 12 through 17), I'll suggest using the conversion factors in Table 4. The cubic foot/

Table 2.—Annual diameter growth (in inches)[a] by species, stand age, and residual basal area. Site index 55 to 65

Species	25-Year stand Residual basal area (ft^2)			50-Year stand[b] Residual basal area (ft^2)			70-Year stand Residual basal area (ft^2)			
	100	72	56	100	75	60	100	80	60	40
Beech	.04	.07	.11	.06	.08	.12	.08	.10	.12	.14
Yellow birch	.06	.08	.12	.06	.07	.10	.05	.05	.08	.16
Sugar maple	.06	.09	.12	.05	.07	.10	.04	.04	.07	.13
Red maple	.10	.15	.19	.08	.13	.16	.07	.11	.13	.17
Paper birch	.11	.16	.17	.08	.12	.13	.06	.07	.09	.07
White ash	.18	.20	.20	.14	.17	.18	.11	.14	—	.21
Hemlock	—	—	—	—	—	—	.16	.18	.24	.30

[a]From additional measurements on Marquis' (1969) study and from Solomon (1977b).
[b]Values for the 50-year stand are approximate averages of the 25- and 70-year-old stand figures.

basal area ratios are quite consistent. The board foot/basal area ratios tend to be variable for small mean stand diameters since they change with small variations in diameter distribution. These conversions are for stands on average sites of about 55 to 65 feet site index. On much better or poorer sites, the

Table 3.—Annual basal area and diameter growth of white pine; site index 60. (Alimi and Barrett 1977; Gevorkiantz and Zon 1930)

Stand age	Residual[a] stocking	Annual basal area growth	Annual dbh growth
		ft²/acre	*inches*
20	Full	2.3	0.18
	Thinned	4.5	—
40	Full	1.5	.13
	Thinned	3.5	—
60	Full	1.2	.09
	Thinned	3.0	—
80	Full	1.0	.08
	Thinned	2.6	—

[a]"Full" and "thinned" refer to A-line and B-line stocking respectively, as defined in the standard stocking guides.

Table 4.—Ratios of cubic feet and board feet per square foot of basal area by mean stand dbh

Mean dbh (inches)	Cubic feet per square foot	Cubic feet per square foot	
		Hardwoods	Softwoods
5.0	15	—	—
6.0	17	—	—
7.0	19	17	32
8.0	21	37	46
9.0	24	50	65
10.0	25	75	80
11.0	27	90	95
12.0	28	105	109
13.0	29	120	122
14.0	30	122	135

From basal area and yield figures in Leak et al. 1969, Leak et al. 1970, and Dale 1972, revised using additional information from volume tables and local plot information. Cubic feet to a 3.0-inch dib; board feet to a dib of 6.0 inches for softwoods and 8.0 inches for hardwoods.

Corrected page 4 (table 4)

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Red maple	.10	.15	.19	.08	.13	.16	.07	.11	.13	.17
Paper birch	.11	.16	.17	.08	.12	.13	.06	.07	.09	.07
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7.0	19	17	32
8.0	21	37	46
9.0	24	50	65
10.0	25	75	80
11.0	27	90	95
12.0	28	105	109
13.0	29	120	122
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conversions should be multiplied by a factor equal to actual site index divided by 60. For example, for a stand of site index 80, multiply the values in Table 4 by 80/60 or 1.333.

Future prices (columns 4 and 9 of lines 12 through 17) should be estimated as stumpage value in current (e.g. 1980) dollars—ignoring inflation. Market experience and published market information (Engalichev and Sloan 1979) are useful aids in developing appropriate price information. Price expectations can be incorporated into the future price figures, as well as owner preferences. For example, some owners who cut their own fuelwood may value this material at higher than the usual stumpage price. We'll use prices of $3.00, $10.00, and $30.00 per cord for pulp, fuel, and boltwood respectively, converting these to prices per cubic foot by dividing by 85. Multiplying volume times price gives value per product for both the untreated and the treated stand (columns 5 and 10 in lines 12 through 17). When summed, these provide future stand values for the untreated (UV) and treated (TV) stand.

The formula for the compound interest ratio (found in compound interest tables) is

$$(TV - UV)/C$$

where TV is the prospective value of the stand if treated, UV is its prospective value if untreated, and C is the cost of treatment. This cost should be estimated as the actual cost to the landowner, plus any fees (including consultant's fees or inventory costs) and minus any amounts received as incentive payments or from sale of the removed material. In this example, and assigning a treatment cost of $50, the compound interest ratio is

$$(593 - 355)/50 = 4.76$$

If n is the number of years, the nth root of the value of this equation will be 1 + p, where p is the compound interest rate of return. It can be computed easily on many hand calculators. In this example

$$\sqrt[20]{4.76} = 1.081$$

and the rate of return is 8.1 percent over a 20-year period.

This rate of return can be compared with those of other treatment options and with the owner's preference. In comparing rates of return with returns from nontimber investments, remember that these computations were all in constant 1980 dollars, whereas a monetary investment pays back in inflated dollars, so its real rate of return is the stated rate minus inflation. A real rate of return of 8 percent compares favorably with the returns of bonds, savings certificates, etc. but timber investments are subject to risks of fire, insect damage, disease, and market fluctuations.

If there is some return from the proposed treatment, it can be subtracted from the initial cost (thus reducing the cost) and the analysis can proceed as described above. However, if the initial return exceeds the cost (i.e., if there is a net gain), the best approach is to project future volumes and values of the treated and untreated stand as described above, then discount these future values to their present values by dividing them by the appropriate compound interest ratio. These ratios for various interest rates and time periods are shown in Table 5. The chosen interest rate should reflect the owner's minimum acceptable rate of return in constant dollars. Then, add the initial net

Table 5.—Values of treatment gain (treated stand value minus untreated stand value) divided by treatment cost for various compound interest rates and time periods

Compound interest rate %	Time period 10 years	20 years	30 years
3	1.34	1.81	2.43
4	1.48	2.19	3.24
5	1.63	2.65	4.32
6	1.79	3.21	5.74
7	1.97	3.87	7.61
8	2.16	4.66	10.06
9	2.37	5.60	13.27
10	2.59	6.73	17.45
12	3.11	9.65	29.96
14	3.71	13.74	50.95
16	4.41	19.46	85.85
18	5.23	27.39	143.37
20	6.19	38.34	237.38

return to the discounted value of the treated stand. The treatment or nontreatment option that produces the highest present value is the most profitable one to adopt.

DISCUSSION

Once the user gains some familiarity with the system, and the basic inventory information is obtained, an economic evaluation can be made in just a few minutes with a hand calculator. The results appear to be reasonably accurate. McCauley and Marquis (1972) analyzed in detail the costs and returns from thinning a 25-year-old northern hardwood stand on the Bartlett Experimental Forest, and calculated a 9.9 percent return on investment from a light thinning. Using the same price and cost assumptions, I calculated a 9.5 percent return on investment for the light thinning by following the procedure described here. Note that the growth information in Tables 1 and 2 is derived from the same study analyzed by McCauley and Marquis. So this comparison indicates that by using average growth factors and the volume conversions in Table 4, we can fairly well duplicate the results of a more detailed analysis.

When the procedure outlined in this paper is applied to other stands, additional uncertainties arise. First, the stand response information is not complete, and best applies to average sites with site indexes of 55 to 65 feet. More response information should be added to the data base as it becomes available. Conversions to volume also are approximate; not nearly as accurate as can be made with computer systems that project diameter distribution and height.

The economic analysis deals with the simple alternative of treating or not treating a given stand, where the only variable input is treatment cost. This system does not consider alternatives such as selling or leasing timber land, nor does it consider the influence of a timber stand improvement decision upon the owner's entire financial situation. The approach should be useful in assigning limited funds among alternative stands and treatment options.

The advantages of this approach are rapidity, simplicity, and adaptability to given stand conditions and economic situations. The method can be understood and applied by field foresters, and demonstrated step by step to owners interested in the economic evaluation of their silvicultural options.

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