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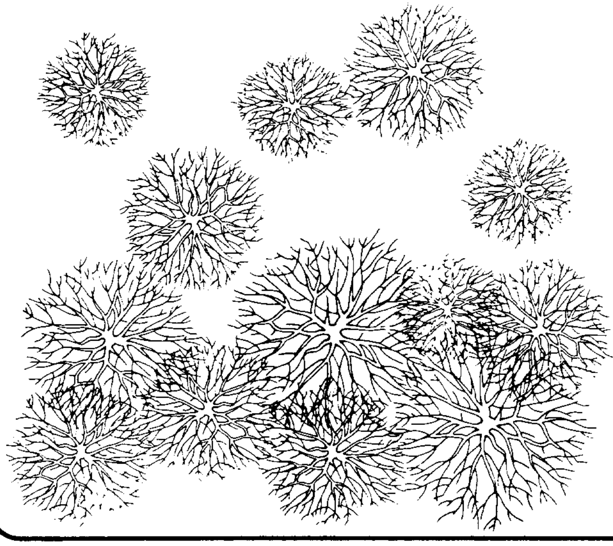

CONVERTING PARTIALLY-STOCKED ASPEN STANDS TO FULLY-STOCKED STANDS IN THE LAKE STATES: AN ECONOMIC ANALYSIS

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Aspen
Birch
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PROGRAM REPORT

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This paper is a contribution from the Aspen-Birch-Conifer Program. The Aspen-Birch-Conifer Program is a coordinated, multidisciplinary research effort. Its mission is to increase and integrate knowledge of the aspen-birch-conifer forests of the northern Great Lakes region in order to better identify and evaluate resource management alternatives.

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CONVERTING PARTIALLY-STOCKED ASPEN STANDS TO FULLY-STOCKED STANDS IN THE LAKE STATES: AN ECONOMIC ANALYSIS

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The 1968 Wisconsin Forest Survey (Spencer and Thorne 1972) shows large areas of aspen type[1] that are not fully stocked. In terms of basal area stocking standards by Kittredge and Gevorkiantz (1929), about 45 percent of the aspen type in Wisconsin is less than 50 percent stocked, and only 29 percent of the aspen type in Wisconsin is more than 75 percent stocked. Future inventory volumes of aspen in Wisconsin can be substantially increased by bringing understocked aspen stands to full stocking.

Stocking of future aspen stands can be increased on aspen lands by careful logging to insure all residual trees are felled or removed (Perala 1977). In cases where competing shrubs and residual trees are not removed during logging, the site must be prepared to insure regeneration of fully-stocked stands of aspen suckers. Shearing is the most successful technique, but chainsaw felling, girdling, and herbicide treatments are also recommended. In certain cases prescribed burning may be successful also. Such treatments will insure fully-stocked aspen stands, but will require some investment.

In this paper we explore the feasibility of investment to improve stocking of good site aspen on aspen lands not currently fully stocked. Our approach is to compare the expected future yield at harvest of fully-stocked to partially-stocked stands on similar sites. The discounted present value of the increase in future yield due to full stocking is an estimate of the amount that can be invested to achieve full stocking at the stated rate of return on the investment. Present values are estimated for both the immediate harvesting and regeneration of existing partially-stocked stands, and for delaying the harvest and regeneration.

[1]*Aspen type is defined as forests in which a mixture of quaking aspen* (Populus tremuloides), *bigtooth aspen* (populus grandidentata), *or balsam poplar* (Populus balsamifera), *singly, or in combination, comprise a plurality of the live tree stocking (Spencer and Thorne 1972).*

ASSUMPTIONS

This analysis is based upon the following assumptions:

1. All stands in the aspen type are essentially pure aspen.

2. With logging and site preparation according to recommendations, formerly partially-stocked aspen stands will regenerate to fully-stocked stands and yields from future rotations will be comparable to the yields of present fully-stocked stands.

3. With logging but no site preparation, partially-stocked aspen stands will regenerate to partially-stocked stands and yields from future rotations will be comparable to existing partially-stocked stands.

4. Growth of aspen stands is dependent on the current age of the stand, and its present basal area, as given by Schlaegel's (1971) basal area growth equation.

5. To be operable for timber products, a stand must have an average diameter of at least 5.0 inches.

6. Only aspen site indices 60 through 80 will be considered, because Schlaegel's growth equation does not apply to lower sites.

ESTIMATING VOLUME YIELDS

Basal area (table 1) estimates reported by Kittredge and Gevorkiantz (1929) for fully-stocked, pure aspen stands were used as standards for determining the productivity potential of fully-stocked stands. The tables presented by Kittredge and Gevorkiantz are widely used to classify site productivity in the Lake States. They were used in our analysis as an optimistic estimate of potential basal area stocking in fully-stocked aspen stands.

Schlaegel's (1971) volume equations for aspen were used to determine stand volume from basal areas given by Kittredge and Gevorkiantz at various stand ages (table 1). The equations used are:

Table 1.—*Expected yields per acre of fully-stocked aspen*

Stand age	Height of dominants	Average d.b.h.	Stand basal area (ft^2)	Total stem vol. (ft^3)	Merch.[1] vol. (100 ft^3)	E.V.I.[2] at discount rate r: 4	6	8	10
				SITE INDEX 80					
20	46	3.3	88	1700	—	—	—	—	
25	53	4.0	99	2200	—	—	—	—	
30	59	4.8	110	2700	—	—	—	—	
35	65	5.6	120	3300	29	10.00	4.30	2.10	1.10
40	71	6.3	129	3800	36	9.50	3.90	1.70	.80
45	76	7.2	136	4300	41	8.50	3.20	1.30	.60
50	80	8.1	143	4800	46	7.50	2.60	1.00	.40
55	84	9.2	148	5200	51	6.70	2.20	.80	.30
60	87	10.3	153	5600	55	5.70	1.70	.60	.20
				SITE INDEX 70					
20	40	2.9	83	1400	—	—	—	—	
25	46	3.8	92	1800	—	—	—	—	
30	51	4.2	102	2200	—	—	—	—	
35	57	4.8	111	2600	—	—	—	—	
40	62	5.4	120	3100	27	7.10	2.90	1.30	.60
45	67	6.2	127	3600	32	6.60	2.50	1.00	.50
50	70	7.0	133	3900	37	6.00	2.10	.80	.30
55	74	8.0	139	4300	41	5.40	1.70	.60	.20
60	76	9.0	144	4600	42	4.70	1.40	.50	.20
				SITE INDEX 60					
20	34	2.5	76	1100	—	—	—	—	
25	39	3.0	86	1400	—	—	—	—	
30	44	3.5	94	1700	—	—	—	—	
35	48	4.0	103	2100	—	—	—	—	
40	53	4.5	110	2400	—	—	—	—	
45	57	5.2	117	2800	23	4.80	1.80	.70	.30
50	60	5.9	122	3100	28	4.60	1.60	.60	.20
55	63	6.7	128	3400	32	4.20	1.40	.50	.20
60	66	7.6	133	3700	36	3.90	1.20	.40	.10

[1]Merchantable volume includes all trees 3.6 inches d.b.h. and larger to a 3-inch top d.i.b. in stands 5.0 inches and larger.

[2]E.V.I. is the Expectation Value Index computed from the Equation $V_o = V_r \left[\frac{1}{(1+i)^t-1}\right]$ and is expressed in units of dollars per dollar of stumpage price per acre.

These values may be used to estimate the optimal rotation age as shown above.

1. Total peeled volume (TV):
$TV = 0.41898(BA)(HT)$ (1)

where:

BA=stand basal area in square feet/acre

HT=the height of dominant and codominant trees

TV=the total volume of the entire peeled stem in trees 0.5 inch d.b.h. and larger, expressed as cubic feet/acre.

Merchantable volumes in table 1 are to a 3-inch top and are determined by the following equation (Schlaegel 1971):

2. Merchantable volume (MV):
$MV = (0.9858 - 5.4737(0.4876)^{(DBH)}(TV)$ (2)

where:

DBH=diameter outside bark at 4.5 feet above the ground for the tree of average basal area for all stems over 0.5 inch.

The Expectation Value Index (EVI) is an index of the present discounted value of all future incomes from the stand, assuming a stumpage price of $1 per unit of yield ouput (in this case, $1 per cunit of merchantable wood).[2] The present value of expected future stand yields is determined by multiplying the EVI by the stumpage price expected at the time of future harvest.

Rotation ages were selected for fully-stocked stands at the age where the EVI (table 1) was greatest. The EVI associated with fully-stocked stands managed on the selected rotations represents an index of the discounted value at a given interest rate, of an unending series of rotations from fully-stocked stands.

GROWTH OF PARTIALLY-STOCKED STANDS

Stands below rotation age may be harvested immediately, or they could be allowed to grow for a period of time until harvested at some rotation age. Thus, it is necessary to estimate both present yields and yields from delayed harvesting of existing partially-stocked stands.

Schlaegel's (1971) basal area growth function was used to estimate the basal area growth for a range of stand basal areas and ages. The equation is:

$BAG = BA(5.3903 - LnBA)A^{-1}$ (3)

where:

BA=basal area of existing stand

A=stand age in years

Ln=natural logarithm

BAG=annual basal area growth

Schlaegel's basal area growth is not a function of site index, and thus implies that basal area growth is the same on all sites. Schlaegel's data, however, included only the better aspen sites, approximately site index 65 and higher. Kittredge and Gevorkiantz (1929) data indicate that on these higher sites, basal area growth rates do not differ markedly from one site to another. On poorer sites (site index 50 and below), however, the rate of basal area growth is substantially less. As a result, only sites 60 through 80 are considered.

Schlaegel's basal area growth equation was applied to site 70 stands to determine a percent of full stocking achieved at various ages by partially-stocked aspen stands. These percents of full stocking, table 2, were also applied to partially-stocked aspen stands on sites 60 and 80, since his equation

Table 2. Expected percent of full stocking achieved by delaying harvest of existing partially-stocked stands [1]

Current stand age	Current percent stocking	Harvest Age 25	30	35	40	45	50
		Percent					
20	25	36	45	51	57	61	65
	50	63	71	76	80	83	85
	75	87	93	96	98	99	100
30	25	—	—	31	37	42	46
	50	—	—	56	62	66	70
	75	—	—	80	84	87	89
40	25	—	—	—	—	30	34
	50	—	—	—	—	55	59
	75	—	—	—	—	78	81

[1]Based on Schlaegel's basal area growth projections on site index 70 lands.

[2]*EVI is calculated as follows: Multiply the expected harvest yield by the appropriate discount rate multiplier for a perpetual series of periodic incomes for a specified stand age and discount rate. Lundgren (1966) presents a more detailed discussion.*

is independent of site. The results provide an estimate of basal area at the time of delayed harvest for partially-stocked stands. Applying these percentages to the merchantable yields from fully-stocked stands in table 1 gives expected yields of partially-stocked stands, shown in table 3.

Table 3. *Expected merchantable 1 volume yields in cunits per acre from partially-stocked aspen stands for a range of sites, ages, stocking percents, and rotations*

Existing stands age	Full stocking	Harvest Age 20	25	30	35	40	45	50
Site Index 80								
	Percent	*Hundreds of cubic feet*						
20	25	—	—	—	14.8	20.5	25.0	29.9
	50	—	—	—	22.0	28.8	34.0	39.1
	75	—	—	—	27.8	35.3	40.6	46.0
30	25	—	—	—	9.0	13.3	17.2	21.2
	50	—	—	—	16.2	22.3	27.1	32.2
	75	—	—	—	23.2	30.2	35.7	40.9
40	25	—	—	—	—	9.0	12.3	15.6
	50	—	—	—	—	18.0	22.6	27.1
	75	—	—	—	—	27.0	32.0	37.3
Site Index 70								
20	25	—	—	—	—	15.4	19.5	24.1
	50	—	—	—	—	21.6	26.6	31.4
	75	—	—	—	—	26.5	31.7	37.0
30	25	—	—	—	—	10.0	13.4	17.0
	50	—	—	—	—	16.7	2.1	25.9
	75	—	—	—	—	22.7	24.2	32.9
40	25	—	—	—	—	6.8	9.6	12.6
	50	—	—	—	—	13.5	17.6	21.9
	75	—	—	—	—	20.2	25.0	30.0
Site Index 60								
20	25	—	—	—	—	—	14.0	18.2
	50	—	—	—	—	—	19.1	23.8
	75	—	—	—	—	—	22.8	28.0
30	25	—	—	—	—	—	9.7	12.9
	50	—	—	—	—	—	15.2	19.6
	75	—	—	—	—	—	20.0	24.9
40	25	—	—	—	—	—	6.9	9.5
	50	—	—	—	—	—	12.7	16.5
	75	—	—	—	—	—	17.9	22.7

[1]Stands are not considered merchantable until they reach an average d.b.h. of 5.0 inches and larger.

EVALUATION METHODS

Our analysis was designed to determine how much could be spent to achieve full stocking, rather than to estimate returns realized for an investment of some specified dollar amount. Cost of treatments required to improve stocking are available, but a great deal of variation is encountered when specific cases are reviewed. Stumpage prices also vary widely. Therefore, results are presented as discounted returns per acre, per dollar of stumpage price, at various discount rates. These are, in effect, the Expectation Value Index (EVI) (Lundgren 1966), and may be used in specific cases given the stumpage price per unit. Multiplying the EVI by the stumpage price per unit gives the gross return per acre. Net returns may then be determined by subtracting the discounted costs from the gross discounted returns. The units of output presented are cunits (100 ft^3 of solid wood). Since a cunit represents approximately 25 percent more wood than a cord, the price per cunit is approximately 25 percent greater than the price per cord.

RESULTS

Table 4 presents the margin for investment index (MII) for converting partially-stocked aspen stands to fully-stocked aspen stands. Economic rotation ages are shown for both fully- and partially-stocked stands. The column "MII" presents the difference between the expectation value index for an infinite series of economic rotations of fully-stocked stands, and an infinite series of economic rotations of partially-stocked stands, on similar sites. Economic rotations were selected at the age at which the EVI was highest. Margin for investment indexes were determined for a range of discount rates from 4 to 10 percent.

The margin for investment represents an *index* of the maximum that could be spent to convert partially-stocked aspen stands to full stocking and still realize some specified rate of return. The actual breakeven dollar amount that could be invested to achieve full stocking can be estimated by multiplying the column labeled "MII" by the expected stumpage price. The highest potentials for investment are shown by poorly-stocked, older age stands. Table 4 shows that if costs are the same the best conversion opportunities exist on site index

Table 4. *The Margin for Investment Index (MII)*[1] *for converting partially-stocked aspen stands to full stocking for various sites, stand descriptions, and discount rates*

Site Index 80

Initial stand age	Discount rate	Initial stocking[2] (25 percent) Rotation age: Partially-stocked	Fully stocked	MII	Initial stocking 50 percent Rotation age: Partially-stocked	Fully stocked	MII	Initial stocking 75 percent Rotation age: Partially-stocked	Fully stocked	MII
	4	40	35	4.60	40	35	2.40	35	35	.60
20	6	35	35	2.10	35	35	1.00	35	35	.10
	8	35	35	1.00	35	35	.50	35	35	.10
	10	35	35	.60	35	35	.30	35	35	.10
	4	45	35	6.40	40	35	4.10	40	35	2.10
30	6	40	35	2.90	35	35	1.90	35	35	.80
	8	35	35	1.40	35	35	.90	35	35	.40
	10	35	35	.80	35	35	.50	35	35	.20
	4	50	35	7.40	40	35	5.30	40	35	2.90
40	6	40	35	3.30	40	35	2.40	40	35	1.40
	8	40	35	1.70	40	35	1.20	40	35	.80
	10	40	35	.90	40	35	.70	40	35	.50
Site Index 70										
	4	40	40	3.10	40	40	1.40	40	40	.10
20	6	40	40	1.20	40	40	.60	40	40	.10
	8	40	40	.60	40	40	.30	40	40	.00
	10	40	40	.20	40	40	.10	40	40	.00
	4	50	40	4.30	40	40	2.70	40	40	1.10
30	6	40	40	1.80	40	40	1.10	40	40	.50
	8	40	40	.80	40	40	.50	40	40	.20
	10	40	40	.40	40	40	.20	40	40	.10
	4	50	40	5.00	45	40	3.50	40	40	1.80
40	6	45	40	2.20	40	40	1.50	40	40	.70
	8	40	40	1.00	40	40	.70	40	40	.30
	10	40	40	.40	40	40	.30	40	40	.10
Site Index 60										
	4	50	45	1.80	45	45	.80	45	45	.10
20	6	45	45	.70	45	45	.30	45	45	.00
	8	45	45	.20	45	45	.10	45	45	.00
	10	45	45	.10	45	45	.00	45	45	.00
	4	50	45	2.70	50	45	1.60	45	45	.70
30	6	45	45	1.00	45	45	.60	45	45	.20
	8	45	45	.40	45	45	.20	45	45	.10
	10	45	45	.20	45	45	.10	45	45	.00
	4	50	45	3.20	50	45	2.10	50	45	1.10
40	6	50	45	1.20	45	45	.80	45	45	.40
	8	45	45	.50	45	45	.30	45	45	.10
	10	45	45	.20	45	45	.10	45	45	.10

[1]MII is found by subtracting the E.V.I. for partially-stocked stands from the E.V.I. of fully-stocked stands on the same site, and is expressed as dollars per acre per dollar of stumpage price for a cunit of timber.

[2]Stands are described in terms of the percent of full stocking they have achieved at the specified age.

80 stands that have only 25 percent of full stocking at age 40. The next best opportunity exists on site 80, age 30, 25 percent stocked stands, followed by stands 50 percent of full stocking at age 40, and lastly, stands 25 percent of full stocking at age 20. The other sites also follow the same pattern.

DELAY OF HARVEST OF PARTIALLY-STOCKED STANDS BEFORE INVESTMENT TO ACHIEVE FULL STOCKING

Presumably, the landowner (based on table 4) would be willing to convert partially-stocked stands to full stocking at any time that the cost of conversion was less than the margin for investment. The landowner would be indifferent towards conversion opportunities where the margin for investment was equal to the cost of conversion, and would not undertake those projects where conversion costs exceed the margin available. For example, if the landowner expected a 4 percent rate of return on his investments and had an aspen stand that had achieved 25 percent of full stocking by age 30 on site index 80 lands, his available margin for investment is $6.40 per dollar of stumpage price, per acre (table 4). If the stumpage price for aspen were $4.50 per cunit, the landowner could invest up to $28.80 per acre to convert his partially-stocked stands to full stocking. If his conversion costs were higher than $28.80 per acre, he would not earn his desired 4 percent rate of return; if less, he would earn at *least* his desired 4 percent return.

The difference between the margin for investment at a given interest rate and the cost of conversion is the net present value of the returns the landowner would receive from conversion (NPVC). Where the net present value is positive, partially-stocked stands should be converted to full stocking at the point in time where the present value of the existing partially-stocked stand plus the net present value of conversion is maximized at a specified rate of interest. This occurs when the rate of increase in the net value of the existing stand plus conversion falls below the desired interest rate.

Mathematically, the rule is given by the following equation:

Harvest in year t when:

$$\frac{FVPS + NPVC}{PVPS + NPVC} = (1+r)^t \qquad (4)$$

where:

PVPS = Present value of existing partially-stocked stand
= Present yield volume × stumpage price (from table 3)

FVPS = Future value of existing partially-stocked stand in t years
= Future yield volume x stumpage price (from table 3)

NPVC = Net present value of conversion to fully-stocked stands
= EVI_{FS} × stumpage price − conversion cost (from table 1)

r = interest rate desired

This equation is the future value of the yield of an existing partially-stocked stand grown for t years and then harvested, plus the net value of the site for production of an infinite rotation of fully-stocked stands, divided by the present value of the existing partially-stocked stand if harvested today plus the net value of the site. When the ratio is equal to, or falls below the interest rate, r, the present value has been maximized and the stand should be harvested. As an example, consider the case of an aspen site index 80 stand that has reached 25 percent of full stocking by age 30. The tabulation below shows yields in cunits per acre that would be expected:

Stand age	*Merchantable volume* [3]cunits/acre
30	0
35	9.0
40	13.3
45	17.2
50	21.2

Assume also the following:

1. stumpage price . . . $4.50/cunit (constant relative to inflation)
2. Conversion cost . . . $25.00/acre (constant relative to inflation)
3. desired rate of return . . . 4 percent

Solving equation (4) is a stepwise process as follows:

[3] *Source: Table 3.*

Step 1: Check rate of value growth from stand age 30 to 35 years

The yield volume from this 30-year-old partially-stocked stand is 0 cunits (table 3). Thus:

PVPS=0 ×$4.50/cunit=0

The yield volume from this stand when it is 35 years old will be 9.0 cunits. Thus:

FVPS=9.0 cunits ×$4.50/cunit=$40.50

The expectation value index for a fully-stocked stand on this site with a 4 percent discount rate and a rotation age of 35 years is 10.00.

Thus:

NPVC = 10.00 cunits × $4.50/cunit −$25.00 = $20.00

Putting this together:

$$(1+r)^5 = \frac{\$40.50+\$20.00}{0+\$20.00} = 3.025$$

$$r = 24.8 \text{ percent}$$

Obviously, the annual rate of increase in value by delaying harvest of the existing partially-stocked stand is higher than the desired 4 percent rate of return. The decision would be to delay harvest and conversion for at least 5 years.

Step 2: Check rate of value growth from stand age 35 to 40 years.

Repeating the procedure outlined above, the anticipated value growth of delaying harvest from 35 to 40 years is 1.32, an annual rate of 5.7 percent. This exceeds the alternative rate of value growth, so the stand should not be harvested at age 35.

Step 3: Check value growth from stand age 40 to 45.

Value growth of delaying harvest from age 40 to 45 is 1.22, just slightly above the desired rate. The owner could harvest the stand at age 40, or wait until age 45 when the anticipated value growth will fall below the desired 4 percent rate of return.

In this example, the landowner would hold his existing partially-stocked stand until it is 45 years old (15 additional years) before harvesting and converting the stand to full stocking. Summarizing the analysis in step 1, he found that the rate of value growth from stand age 30 to stand age 35 exceeded his desired rate of return, and he determined to hold it at least until it was 35 years old. In step 2, he found that the rate of value growth from stand age 35 to stand age 40 was still in excess of his 4 percent alternative rate of return, and he again determined to hold the stand. In step 3, the landowner found that the rate of value increase from stand age 40 to stand age 45 was just equal to his desired rate of return. He therefore determined to hold his partially-stocked aspen stand 15 years until it reached a stand age of 45 years, at which time he will invest in silvicultural treatments to insure that future stands will be fully stocked.

CONCLUSIONS

This analysis presents a methodology useful in making a quick estimate of the economic potential for conversion of partially-stocked aspen stands to full stocking. Expectation value indices allow application of the results of this paper to local areas where stumpage prices and treatment costs are known. The margin available for investment when converting partially-stocked aspen stands to full stocking is small, especially at higher interest rates and on lower sites. Conversion opportunities are best for poorly-stocked older stands, since their yields at economic maturity are much less than the yield of fully-stocked stands. Poorly-stocked young stands will tend to approach the yield of fully-stocked stands over time, and at economic maturity their yields will more closely approximate the yields of fully-stocked stands on the same sites.

Where converted to full stocking, existing partially-stocked stands should be harvested when the present value of the stand plus the net value from conversion is maximized. This paper presents a means of estimating when this value will be maximized. The method is based on the rate of value growth when harvesting is delayed for a given period. The time of delayed harvest will vary depending upon stumpage price, interest rate, and the profit realized from converting partially-stocked stands.

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The 1968 Wisconsin Forest Survey showed large areas of aspen type that are not considered fully stocked. The economic feasibility of converting partially-stocked stands to full stocking is examined, and a rule presented for determining when a partially-stocked stand should be harvested to maximize its present value.

OXFORD: 624.3:651.7:176.1 *Populus tremuloides* (77). KEY WORDS: Investment analysis, timber growth, yield.

Shhhh...noise pollutes, too!