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THINNING HIGHLY PRODUCTIVE RED PINE PLANTATIONS

An Interim Evaluation

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Following the turn of this Century thousands of acres of commercial northern hardwood forest land in the Western end of the Upper Peninsula of Michigan were converted to farmland or their forests denuded by poor cutting practices of fire. During the last forty years, especially the last 25 years, some of this land was reforested by planting red pine (*Pinus resinosa* Ait). Many of these plantations have been found to have a site index of 80 (in fifty years). However, very little information is available concerning the best approach to thinning red pine plantations growing on sites higher than S.I. 70 in the Lake States Region. Most thinning studies conducted in the Lake States Region concern stands having a site index at 50 years of 45 to 70 (3,4,10) and therefore may not be applicable to red pine growing higher sites. Furthermore, these studies do not provide any information as to the economic returns that red pine growing on high sites can provide. Therefore, the objectives of this paper are to evaluate the short-term biological response and economic relationships that have resulted 3 years after thinning an 18 year old red pine plantation growing on a high site, so that tentative thinning guides can be developed.

THE PLANTATION

The study is being conducted in the William Payne La Croix red pine plantation located approximately 5 miles southwest of Houghton, Mich. The plantation was established by the Copper Range Co. in 1954 using 2-0 seedlings. The seedlings were machine planted on an approximate 6 x 6 foot spacing with all first year mortality being replanted by hand the following year. Topography in the plantation is flat but well drained and the soil consists of a Hiawatha loamy sand with a fragipan at about 18 to 24 inches. Site index of red pine in the plantation is 81 (at a total age of 50 years).

THINNING TREATMENTS

A cooperative agreement was made between the Forestry Department at Michigan Technological University and Copper Range Company to conduct a series of thinning studies in the Copper Range Company plantation. Twenty four one-tenth acre plots (plus a 12 foot buffer) were established in the 18 year old plantation using a randomized complete block design with 3 plots per treatment. Treatments included:

- 1) Control
- 2) Free thinning with residual basal area = 60 ft.²/acre
- 3) Free thinning with residual basal area = 90 ft.²/acre
- 4) Free thinning with residual basal area = 120 ft.²/acre
- 5) Row thinning by removing every 2nd row,
- 6) Row thinning by removing every 3rd row,
- 7) 20 percent of height, and
- 8) 30 percent of height

These thinning treatments most closely duplicate the more important treatments tested by Day and Rudolph (4) in a 25 year old plantation red pine having a site index of about 70. In the percent of height treatments, the number of trees in the desired residual stand is determined by the following equation (5,10):

$$n = \frac{43560}{(hf)^2}$$

where n = the desired number of trees per acre after thinning

h = the total height in feet of the average dominant trees in the stand.

f = the desired average spacing in the stand after thinning, expressed as a percent of the dominant tree height.

The actual selection of trees to be cut or left in any free or percent of height thinning was based on spacing, condition, vigor, and general appearance.

Prior to and after thinning, and again at age 21 (three growing seasons after thinning) the diameter of all trees were measured at breast height, and merchantable height was estimated to a 3 inch top. Total height was measured on 5 dominant trees within the plot and site index was calculated using the procedure outlined by Geovorkiantz (6) and Alban (1).

RESULTS

Growth Evaluation

By age 18 the number of trees in the plantation had decreased to about 900 from the approximately 1200 trees established at the time of planting (Table 1). Thinning further reduced the stocking to a low of 267 trees for the 60 ft.² residual basal area thinning, and to a high of 620 for the 120 ft.² residual basal area thinning. No trees were removed from the 20 percent of height treatment because the prescription called for 1100 trees to be left per acre.

Table 1. Average number of trees per acre before and after thinning and mortality since thinning.

Treatment	Number of Trees per Acre			Mortality
	Before Thinning	After Thinning	At age 21	
Control	907	907	890	17
60 ft. ² B.A.	873	267	267	0
90 ft. ² B.A.	810	463	457	6
120 ft. ² B.A.	993	620	620	0
Every 2nd Row	1010	510	507	3
Every 3rd Row	847	553	547	6
20% Height	900	900	880	20
30% Height	880	537	537	0

As expected, mortality was closely related to the number of trees per acre following thinning; the higher the number of trees per acre the greater the mortality. Therefore, the highest mortality occurred in the control and 20 percent of height treatments with none occurring in the 60 ft.² residual basal area per acre treatment (Table 1). It should be noted that the mortality in the 90 ft.² residual B.A. treatment was the result of snow damage, while mortality in the control and 20 percent of height treatments was primarily caused by natural suppression of the smaller trees.

Diameter at breast height (d.b.h.) averaged about 5.3 inches before thinning. As would be expected, the change in average diameter after thinning was largest in the 60 ft.² basal area treatment, where the few remaining trees were

all large trees (Table 2). The greater increase in diameter following thinning for the 120 ft.² basal area vs. the 90 ft.² basal area treatments was caused primarily by the fact that only small trees were removed to achieve 120 ft.² per acre. Conversely both large and small trees had to be removed to achieve 90 ft.² per acre and still maintain spacing.

Diameter growth was greatest for the 60 ft.² basal area treatment and lowest for the control and 20 percent of height treatments (Table 2 and Figure 1). An analysis of variance showed these differences to be highly significant at the .01 level. Although diameter growth was highly related to residual basal area, there were also some individual treatment effects (Figure 1). For the same residual basal area per acre, the row thinnings had less diameter growth than the free or percent of height treatments. This was also noted by Day and Rudolph (4) and is a result of a higher proportion of small diameter trees in the row thinnings compared to other treatments having comparable residual basal area. Since these small trees are generally of lower vigor, their thinning response is not as likely to be as great as in larger, more vigorous trees.

Table 2. Effects of thinning on average diameter and diameter growth.

Treatment	Average Diameter (inches at B.H.)			
	Before Thinning	After Thinning	At Age 21	3 Year Growth
Control	5.2	5.2	5.8	.57
60 ft ² B.A.	5.3	6.4	7.6	1.17
90 ft ² B.A.	5.6	5.9	6.8	.96
120 ft ² B.A.	4.9	5.9	6.6	.69
Every 2nd Row	5.0	5.2	6.0	.81
Every 3rd Row	5.3	5.2	6.0	.76
20% Height	5.1	5.2	5.8	.60
30% Height	5.4	5.9	6.7	.75

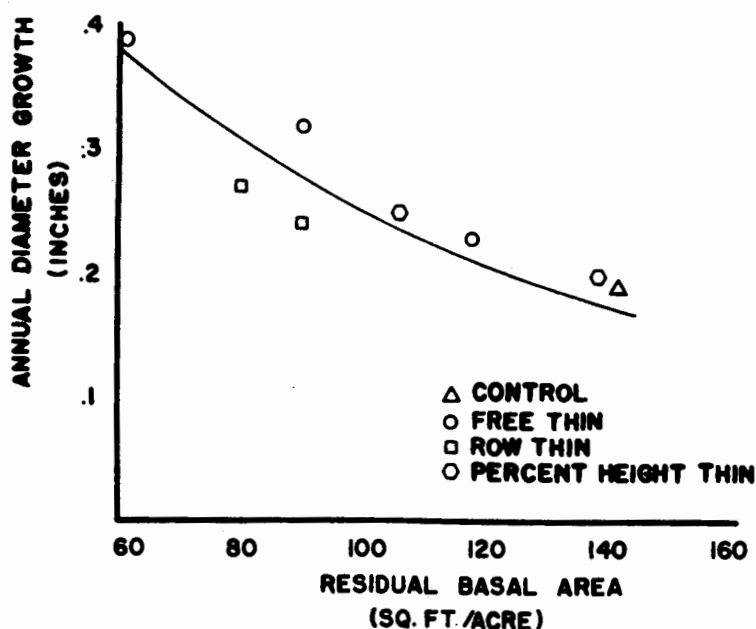


Figure 1. Annual diameter growth response to residual density following thinning.

Basal area growth is also influenced by thinning, with the greatest growth (10.2 ft.²/Ac./Yr.) occurring with the 120 ft.² basal area treatment (Table 3, Figure 2). Although no significant differences existed, treatments having either higher or lower residual basal areas than 120 ft.² had reduced basal area growth. These results are in agreement with Day and Rudolph (4) who found that for a seven year period following thinning, basal area growth peaked at 90 to 100 ft.² of residual basal area. Although basal area growth peaked at a higher residual basal area in our study, the difference could be accounted for by the period of time since thinning. It is entirely possible that basal area growth for the 120 ft.² B.A. plot in our study will decrease over the next few years as it becomes overstocked, while increasing for the 90 ft.² B.A. as it achieves full stocking. As noted by Day and Rudolph (4) and Wilson (11) heavy thinning increases diameter growth disproportionately to height growth thereby increasing the taper in the heavier thinnings. This should result in optimum basal area growth occurring in progressively heavier thinned plots the longer the period between thinning.

Table 3. Effects of thinning on basal area and basal area growth.

Treatment	Average Basal Area per Acre (Ft ²)				3 Year Growth	Total production for 21 years
	Before Thinning	Removed in Thinning	After Thinning	At Age 21		
Control	144.2	0	144.0	171.0	27.0	171.0
60 ft ² B.A.	141.5	81.6	59.9	84.1	24.2	165.7
90 ft ² B.A.	160.0	71.3	88.7	117.4	28.7	188.7
120 ft ² B.A.	147.3	28.7	118.6	149.1	30.5	177.8
Every 2nd Row	141.9	61.9	80.0	103.3	23.3	165.2
Every 3rd Row	141.7	51.40	90.3	117.4	27.1	168.8
20% Height	139.9	0	139.8	169.2	30.4	169.2
30% Height	145.2	39.2	106.0	133.4	27.4	172.6

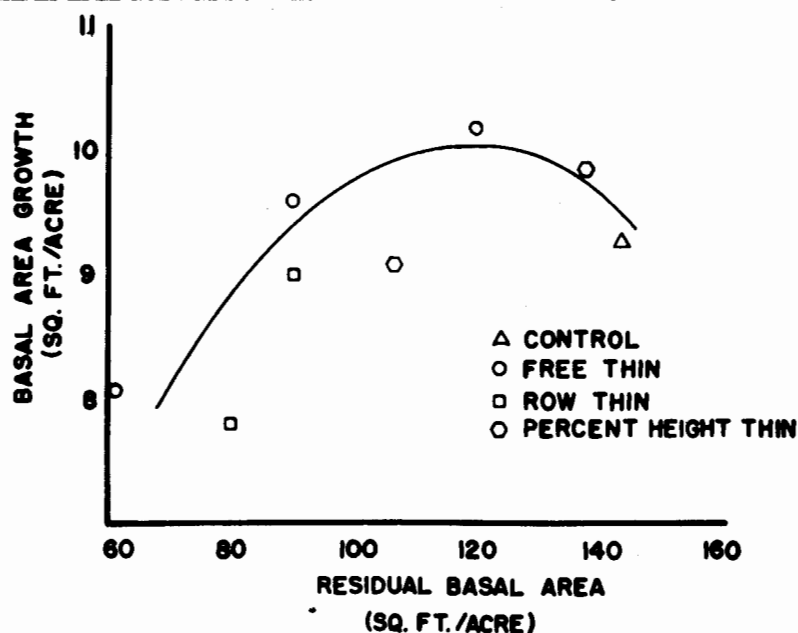


Figure 2. Annual basal area growth response to residual density following thinning.

Volume growth was significantly (at the .01 level) reduced by thinning (Table 4 and Figure 3). This results from a reduction in growing stock and an insufficient period of time for the residual trees to expand their roots and crowns to take full advantage of the increased availability of light and soil moisture. As the length of time since thinning increases, the trees in the thinned plots will more fully occupy the site and the differences in volume growth should decline. This relationship was apparent in the results of Day and Rudolph (4). Furthermore, if the unthinned stand remains unthinned, overstocking will eventually occur which should not only reduce gross volume growth but also net volume growth caused by increased mortality.

Table 4. *Effects of thinning on volume and volume growth*¹.

Treatment	Average Volume per Acre (cords)					Total production for 21 years
	Before Thinning	Removed in Thinning	After Thinning	At Age 21	3 Year Growth	
Control	16.1	0	16.4	27.8	11.4	27.8
60 ft ² B.A.	18.4	9.8	8.6	16.4	7.8	26.2
90 ft ² B.A.	20.5	9.3	11.3	20.4	9.1	29.7
120 ft ² B.A.	16.5	1.5	15.0	25.6	10.6	27.1
Every 2nd Row	17.0	7.5	9.4	16.9	7.5	24.4
Every 3rd Row	18.5	8.2	10.3	18.8	8.5	27.0
20% Height	16.6	0	16.4	27.4	11.0	27.4
30% Height	18.5	4.0	14.4	23.1	8.7	27.1

¹ Ingrowth accounted for less than 1 percent of the volume growth and was therefore included in the growth data with no further discussion.

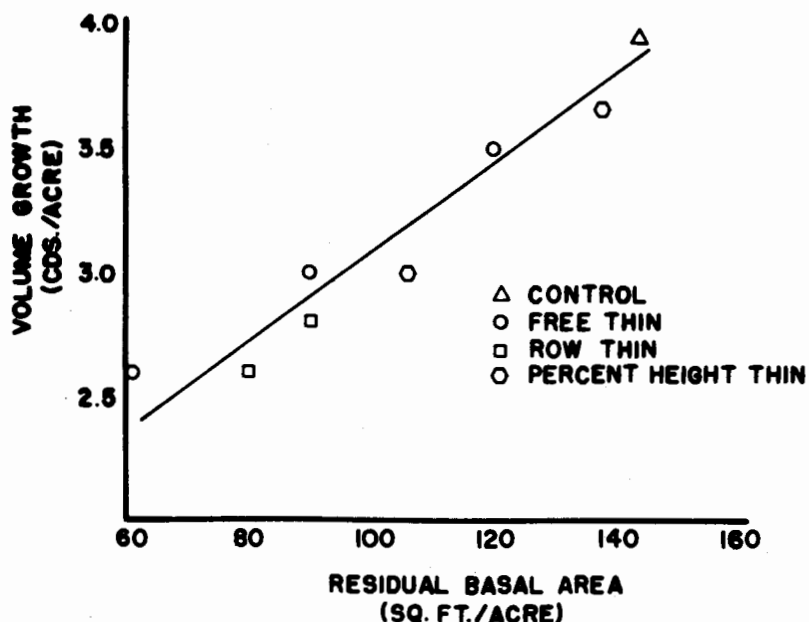


Figure 3. *Annual volume growth response to residual density following thinning.*

It should be noted that although volume growth for the three year period is highest for the control plots, there is no significant difference in total volume production (i.e. the volume removed at age 18 plus the residual volume at age 21) (Table 4). This is in general agreement with the results of Wilson (11). However, the lower residual densities (i.e. 60 ft.² B.A. and every 2nd row treatments) did have somewhat lower total volume productions than the remaining treatments. Day and Rudolph (4) found that the lower residual densities (generally below 85 ft.² basal area per acre) had significantly lower total volume production than that of higher residual densities.

Table 5. *Effects of thinning on average height and height growth.*

Treatment	Average Height (feet)		
	At age 18	At age 21	3 Year Growth
Control	30.5	38.0	7.5
60 ft ² B.A.	29.7	37.0	7.3
90 ft ² B.A.	30.4	37.6	7.2
120 ft ² B.A.	31.3	38.4	7.1
Every 2nd Row	30.4	37.4	7.0
Every 3rd Row	30.4	37.1	6.7
20% Height	30.0	37.6	7.6
30% Height	30.7	37.1	6.4

Height growth did not appear to be influenced by thinning, regardless of the treatment (Table 5). Although Day and Rudolph (4), and Wilson (10,11), did find significant differences in height growth between treatments, the differences were in either higher or lower residual basal area levels than were tested in this study.

Financial Evaluation

To evaluate the financial relationships of these thinning treatments, the rate of return that the plantation has earned to age 21 was calculated using two sets of costs. The first set of costs include only the planting costs (\$15 per acre) as reduced by discounted thinning returns using a discount rate of 8 percent. The second set of costs also include the cost of land and annual expenses (including taxes) paid by the Copper Range Company. The procedures followed in discounting land costs and annual expenses are discussed in detail by Lundgren (8).

These costs (for 21 years) are as follows:

Item		Net Cost at year 0 at 8% interest
Land	\$15.00 ¹	\$13.19 ²
Establishment	15.00	15.00
Annual Expenses	0.40	4.00
	Total	\$32.20

¹Land Expectation Value

²Present Net Worth

The present tree sizes in the plantation limit the evaluation to a pulpwood product. Therefore, all pulpwood removed at age 18 was valued at \$3/cord. The value of the residual stand at age 21 was computed using a value per cord equal in dollars to the average stand d.b.h. (eg. the volume of a stand having an average diameter of 6.2 inches had a value of \$6.20 per cord). This is similar to the procedure used by Buckman and Wambach (2) and Day and Rudolph (4) and is in keeping size-value relationships common to most stumpage price structures.

Evaluation Using Only Establishment Costs

The first investment consideration, that of considering costs of establishment only, assumes that land and annual costs are not charged to this investment. This could apply to a governmental agency, or a company or individual that either does not have these costs or is charging them to other alternatives.

Under the pulpwood value conditions mentioned above, the initial \$15 establishment investment has earned a 12% rate of return in 21 years, even without thinning (Table 6). However, each thinning treatment returned enough cordwood value to help pay off part of the initial \$15 planting investment. This in turn resulted in a higher rate of return for the thinning treatments than the controls (Table 6). For instance, by thinning to 90 ft² residual basal area per acre at age 18, \$6.75 of the initial \$15 planting investment was repaid thereby resulting in a 14.4 percent rate of return at age 21 (Table 6). Day and Rudolph (4) found that financial returns are optimized when utilizing a 30 percent of height thinning. However, their 30 percent of height thinning left 88 ft.² of residual basal area per acre while ours left 106 ft.² per acre. Therefore, the results are not comparable. Others (2,3,9) have also found that a residual of approximately 90 ft.² of residual basal area per acre optimized financial and/or biological returns, regardless of site. Although returns are considerably less for plantations growing on poorer sites, the proportionate growth relationship between treatments on the same site is apparently not related to site quality.

Although much of the increase in rate of return can be attributed to the partial repayment of the establishment costs by thinning at age 18, part of the increase is also caused by a higher stumpage return per cord for those treatments having a larger average diameter at age 21. In his discussion of financial evaluations Lundgren (9) stresses the importance of increased diameter growth to assure the highest financial returns on conifer plantations. A given volume in large trees is often worth many times an equal volume in smaller trees.

Evaluation Using Establishment, Land, and Annual Costs

The second investment consideration assumes that land and annual costs are to be charged as an investment. This evaluation would effect all land owners that have to consider land and annual costs in deciding various investment alternatives. Although the rate of return drops dramatically when these costs are included, the return is still earning a satisfactory interest (Table 6).

Table 6. Per acre compound rate of return three years after first thinning at age 18.

Treatment	Value of Cordwood Removed At age 18 Discounted to @ \$3/cd. Year 0 @ 8%	Residual Stand Value at age 21 @ \$ (dbh)/cd.	Investment Type			
			Establishment Only		Establishment & Land & Annual Costs	
			Cost Minus Discounted Cordwood Value @ 8% to Year 0	Rate of Return for 21 Years	Cost Minus Discounted Cordwood Value @ 8% to Year 0	Rate of Return for 21 Years
Control	\$ 0	\$161.24	\$15.00	12.0%	\$32.20	8.0%
60 ft ² B.A.	29.40	124.80	7.64	14.2	24.84	8.0
90 ft ² B.A.	27.60	138.72	8.09	14.5	25.29	8.4
120 ft ² B.A.	4.50	168.96	13.87	12.6	31.07	8.4
Every 2nd Row	22.50	101.40	9.37	12.1	26.57	6.6
Every 3rd Row	24.60	114.68	8.84	13.0	26.04	7.3
20% Height	0	158.92	15.00	11.9	32.00	7.9
30% Height	12.00	154.77	12.00	13.0	29.20	8.3

However, because the same discounted thinning returns have disproportionately less effect when costs increase uniformly, the rate of return for several thinning treatments drops below that for the unthinned stands. Nonetheless, the 90 ft.² residual basal area treatment still has one of the highest rates of returns of all treatments.

IMPLICATIONS

The results of this study clearly show that thinning red pine on high sites to a residual basal area of 90 ft.² per acre returns the greatest benefit. Although these treatment results are substantially the same as other red pine thinning studies conducted on sites having a lower site index, the financial returns are considerably larger and are very encouraging.

It must be noted that this evaluation is based on three year results and may change as the length of time since thinning increases. Although thinning to 90 ft.² residual basal area per acre appears best, thinning to 60 ft.² also shows good results. In fact, Cooley (3) suggests that since diameter growth is maximized at 60 ft.² of basal area per acre without a detrimental reduction of basal area growth, a long term evaluation may reveal that residual densities of 60 ft.² would optimize financial returns.

In making long term evaluations, however, the end product must be considered. Presently in the Upper Peninsula of Michigan the product having the highest value for red pine is utility poles and piling. Since pole and piling grades are based on minimum taper, periodic thinning to 60 ft.² per acre will likely produce poles with too much taper, even if total volume production is comparable to that produced by periodically thinning to 90 ft.² residual basal area. The 60 ft.² thinning treatment in this study has already resulted in an 12 percent increase in taper compared to the 90 ft.² treatment.

One consideration not made in this analysis is access into the stand from established road systems. It would be somewhat difficult to maneuver even a small skidder in a stand having 900 trees per acre without damage to the residual trees. Although row thinning is the classic approach to gain access into a plantation, the results of this analysis show it to be one of the poorest alternatives. This is primarily the result of lower residual quality (i.e. the same proportion of small, low vigor trees exist in the residual stand as were in the original stand, there are just fewer trees), which results in proportionately lower diameter growth (Table 2 and Figure 1). However, this problem can be circumvented by removing one to two rows every 7th to 10th row with the residual stand in between thinned to 90 ft.² residual basal area per acre as suggested by Wilson (11). This approach would not only open the stand for access, but would also improve the quality and growth of the residual stand between the cut rows compared to the classic row thinning which does not have any thinning applied between the rows. Although the trees next to the cut rows would have considerably more growing space than found in interior rows, observation has shown that these trees are growing under conditions similar to those of a 60 ft.² residual basal area thinning. As just noted, this may have somewhat undesirable effects. However, the effects created by the rows would be short lived, since subsequent thinnings would not remove any more rows. In fact, the rows may not even be discernable after the second or third thinning. Any undesirable increase in taper occurring after the first thin should be negligible by the end of the rotation.

Finally, it should be noted that although the rate of return on all investment costs is quite good at age 21, it should be even better if the plantation is allowed to grow long enough to produce a utility pole product. Although future growth is difficult to predict, the use of a newly developed simulation model that projects annual growth of red pine growing on different sites and having different thinning treatments does provide tentative answers. For example, by thinning every six to seven years and leaving 90 ft.² residual basal area per acre, there should be a yield of 8 to 9 cords per acre from each thinning, and a final harvest of approximately 50 utility poles 35 feet long (to a 7 inch top) and 100 utility poles 40 feet long, at age 36 to 38. Using this data and progressive stumpage values of \$3 to \$5 for each successive thinning, discounted (at 8%) thinning returns would be worth \$16.50 at age 0. Stumpage for utility poles is worth \$5.50 and \$10.50 apiece in today's market for 35 and 40 foot poles respectively. Considering an annual value increase of 4 percent (this is the minimum historic increase in stumpage prices for forest products - see Gregersen (7)) utility poles will be worth a minimum of \$11 and \$20 apiece (for 35 and 40 foot poles respectively) by the time the stand is 37 years old. If only establishment costs are considered, the \$15/acre investment will pay a 24.6 percent rate of return. If land and annual costs are also considered total costs would increase to \$34.52 (this considers the complete 37 year rotation) and this investment minus the discounted thinning returns would pay a 12.3 percent rate of return.

Although the above estimates are tentative, and would change if the assumed conditions did not actually occur, it does show that the potential returns on investments made in plantation red pine growing on these high sites is quite large. In fact it compares favorably with the growth rates of the much 'talked about' high site southern pines. Finally, it should be considered that plantation establishment and other costs are much higher today than 21 years ago. However, stumpage prices are also proportionately higher. Since there is no evidence that future costs will increase at a significantly faster rate than stumpage prices (7), similar returns can be expected on investments made today or in the near future.

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