Growth and financial yield of unthinned red pine planted at various stocking levels in Michigan's eastern Upper Peninsula after 34 years.

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Abstract

Diameter, basal area, and volume growth was examined in 2 unthinned plantations of red pine, planted at various stocking levels, after 24 and 34 years in Michigan's eastern Upper Peninsula. Diameter growth decreased and basal area growth increased with increasing stocking as expected. Merchantable volume growth increased significantly as stocking increased from 200 to 400 stems per acre but did not increase significantly above that stocking. Financial return on investment was computed for a range of stockings from 220 trees per acre to 820 trees per acre. Given local conditions and markets, a maximum rate of return on investment of 5.65% was achieved at 400 stems per acre after 34 years.

Introduction

During the first half of this century pine plantations were established at high densities (800 to 1200 trees per acre) repeating what was observed in natural stands of the region (Eyre and Zehngraff, 1948). Many trees tended to capture and use a site's resources more efficiently than fewer trees – maximizing basal area and biomass production. By the middle of the century, evidence showed that merchantable volume yield was maximized at much lower initial stocking levels (400 to 600 trees per acre) because individual trees became marketable (larger) sooner at these stocking levels (Byrnes and Bramble, 1955 and Lemmien and Rudolph, 1959). Within the last 20 years forest economists' models have suggested that although more wood can be grown per acre at moderate stocking levels, *e.g.* 500 stems per acre, more money can be grown at low stocking levels, *e.g.* 200 stems per acre (Lundgren, 1981).

This study was begun in 1968 to examine the growth of red pine at various stocking levels over time. A range of stockings (from 220 to 820 trees per acre) were chosen for examination, based on work being done at that time. There have been many stocking/density studies of red pine, but this one is among a minority that have remained unthinned. Neary, et al. (1972), presented early results from this study. The analysis presented here will not add new insights into the management of red pine but rather, will provide another data point to be used by modelers and managers.

Study Area and Design

The plantations of this study are on the Lake Superior State Forest, about 20 miles north of the Straits of Mackinac in Michigan's eastern Upper Peninsula. The area is nearly level with sandy soils of the Kalkaska series. Summers are mild and winters are cold, with a growing season of 120 to 130 days. Site index for red pine is between 65 and 70.

The planting site had been cleared of northern hardwoods in 1885, farmed for 15 years, and then left fallow for about 60 years until the trees were planted. The study was established in two phases on sites that are immediately adjacent to one another. Both plantings were established with similar seedling stock and using similar techniques although nine years elapsed between the planting of the first and second phases.

Phase I was installed into an existing plantation of red pine. The Michigan Department of Natural Resources had planted 3-0 nursery stock in the fall of 1962 at an average stocking of 900 trees per acre. Study plots were established in the summer of 1968 (6 growing seasons later) by cutting trees from areas within the plantation. Five stocking level treatments (220, 320, 420, 620, and 820 trees per acre) were applied to 1/10-acre plots with adequate isolation zones between them. Four replications of each treatment were installed in a randomized block design. Crown closure had not yet occurred in 1968 and it was assumed that the first six years growth at 900 trees per acre would not effect subsequent development. This assumption was tested in the analysis reported here.

Phase II was installed in the spring of 1971. 3-0 nursery stock was machine planted at each of six stocking levels (363, 435, 454, 545, 605, and 726 trees per acre). These odd numbers result from planting at regular spacings of 12’ x 10’, 10’ x 10’, 12’ x 8’, 10’ x 8’, 12’ x 6’, and 10’ x 6’ respectively. Tenth-acre plots with adequate isolation zones were arranged into four replications using a split-plot randomized block design. The main plot effect was spacing between planted rows and the sub-plot effect was distance between trees within rows. Seedlings that died were replaced with border trees during the first three growing seasons.

Growth and Yield Analysis

Diameters of all trees in both Phases (the 1962 planting and the 1971 planting) of the study were measured in the summers of 1986 and 1996. Tree heights averaged 53’ in the 1962 plantation and 37’ in the 1971 plantation in 1996. Net merchantable cubic foot volume was computed for each tree using an equation for red pine developed by G. K. Raile, *et al.* (1981). Plot averages were computed and statistical analysis was performed to detect differences among treatments in diameter, basal area, and volume growth.

Growth after 24 years in the 1962 plantation was compared with growth after 25 years in the 1971 plantation to test the assumption that 6 years growth at 900 trees per acre had no lasting effect on the treatment plots of the 1962 plantation. Comparisons were made between diameter, basal area, and volume growth and no differences were found (Figs. 1, 2, & 3). Most of the data points for the 1971 plantation at age 25 are slightly above those of the 1962 plantation at age 24. Undoubtedly the curves would have been closer had the tree ages been identical.

Diameter and basal area growth differed significantly among stocking treatments in both plantations at both measurement times (Figs. 1 & 2). Diameter decreased and basal area increased as stocking increased. This result was entirely expected and sheds no new light on red pine management.

Note that the average diameter in the lower stocking treatments was 9-10 inches at age 34-years. Although some individuals within these plots had entered the “small sawtimber” product class, all volumes were computed as cubic foot volumes. This depressed the value of these plots in subsequent financial calculations below.

Significant differences in volume growth did not appear until age 34 in the 1962 plantation (Fig. 3). Volume growth increased with stocking as predicted by Lundgren (1981) (*i.e.* volume increased significantly from 200 to 400 stems per acre but was essentially unaffected at higher stockings).

Financial Return on Investment

The main rational for planting red pine at lower stocking is to maximize financial returns by: minimizing establishment costs, maximizing individual tree growth, and shortening rotations. A financial analysis was performed with these data to determine which stocking level produced the highest return on investment after 34 years.

All costs and returns were based on prevailing prices for this area and were expressed in 1997 dollars. Site preparation costs, including machine and chemical use, were assumed to be $110 per acre and did not vary with stocking level. Planting costs were assumed to be $140 per thousand seedlings and varied with the number of seedlings planted. Establishment costs for each stocking level were computed based on these rates.

Gross revenue was computed for each plot using a price of $30.00 per cord (80 ft^3). Land taxes were computed (assuming an annual CFA tax rate of $1.10 per acre) and removed from gross revenue to determine net revenue. Return on investment at age 34 was maximized at 5.65% when stocking was kept at 400 stems per acre. The rate of return declined markedly as stocking increased or decreased (Fig. 4).

Changes to the price of pulpwood or to cost of site preparation will cause proportional changes in the rate of return (moving the curve up and down) but not the relationships between stocking levels (the shape of the curve does not change).

Greater seedling and planting costs are felt more strongly at higher stocking levels. This changes the relationship between stocking levels and therefore the shape of the curve. High planting costs will depress the right side of the curve while lower planting costs will increase that side.

The curve's shape also changes when individual trees make a jump in value by changing product class. A 12" tree is worth about $6.75 as pulpwood but is worth $16.50 as sawtimber. Plots with more sawtimber trees (low-density plots) will have higher revenue than plots containing mostly pulpwood trees (high-density plots). This raises all points on the left side of the curve (low stocking) while leaving the right side of the curve (high stocking) unchanged.

As this plantation ages and more trees become sawtimber-sized, the maximum return on investment will be found at lower and lower stocking levels. Problems like large branches and more juvenile wood within the bole may reduce the value of trees grown at these lower stocking levels (Morrow, 1966). Product quality assessments will need to be included the next time these plantings are measured.

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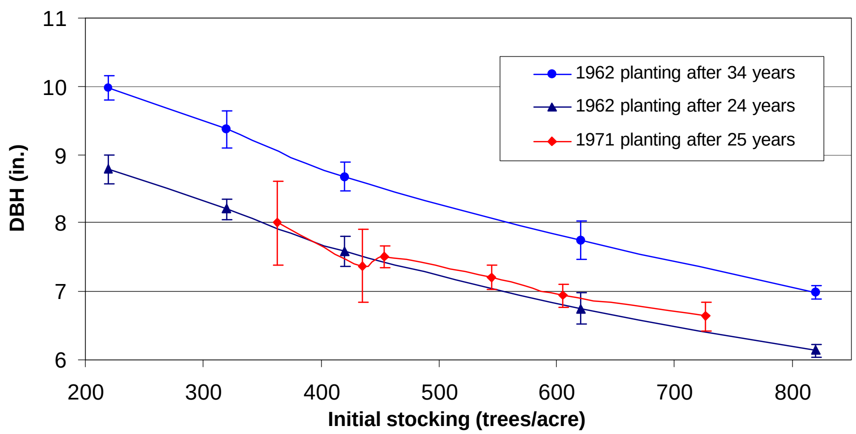

Figure 1. Diameter of unthinned red pine planted at various stockings in Michigan's eastern Upper Peninsula
(Error bars represent 2x Standard Error of the Mean)

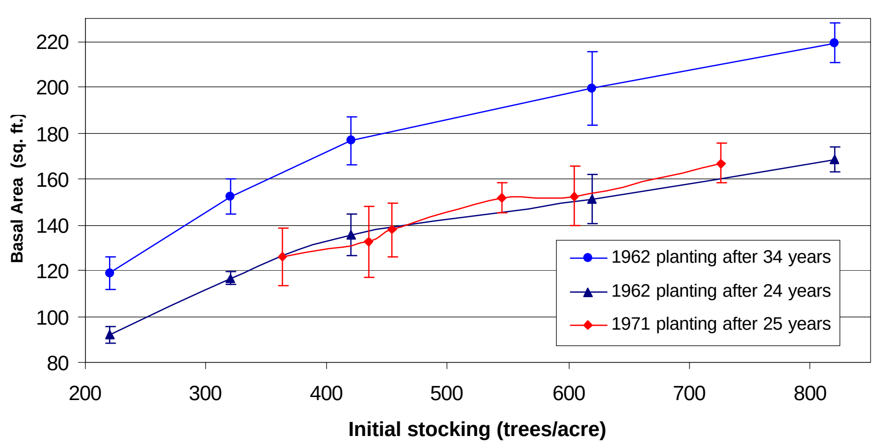

Figure 2. Basal area of unthinned red pine planted at various stockings in Michigan's eastern Upper Peninsula
(Error bars represent 2x Standard Error of the Mean)

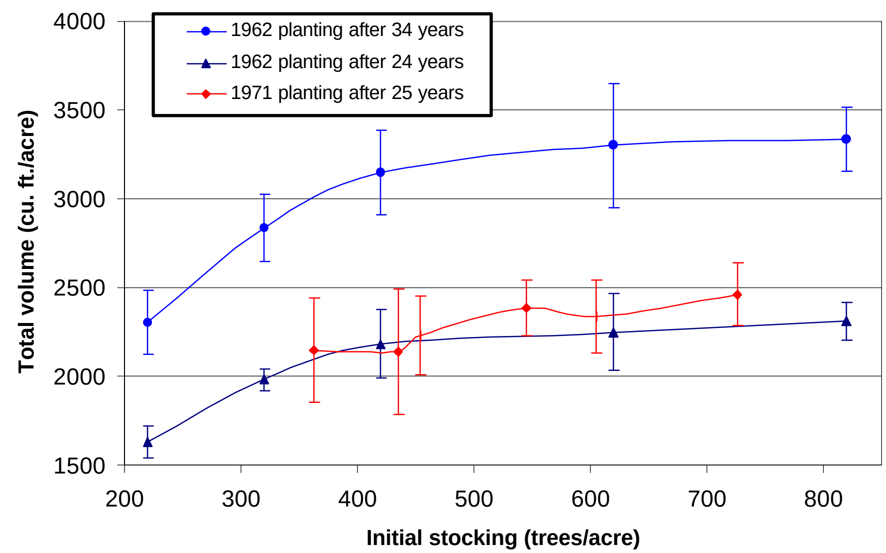

Figure 3. Merchantable volume produced in unthinned red pine planted at various stockings in Michigan's eastern Upper Peninsula
(Error bars represent 2x Standard Error of the Mean)

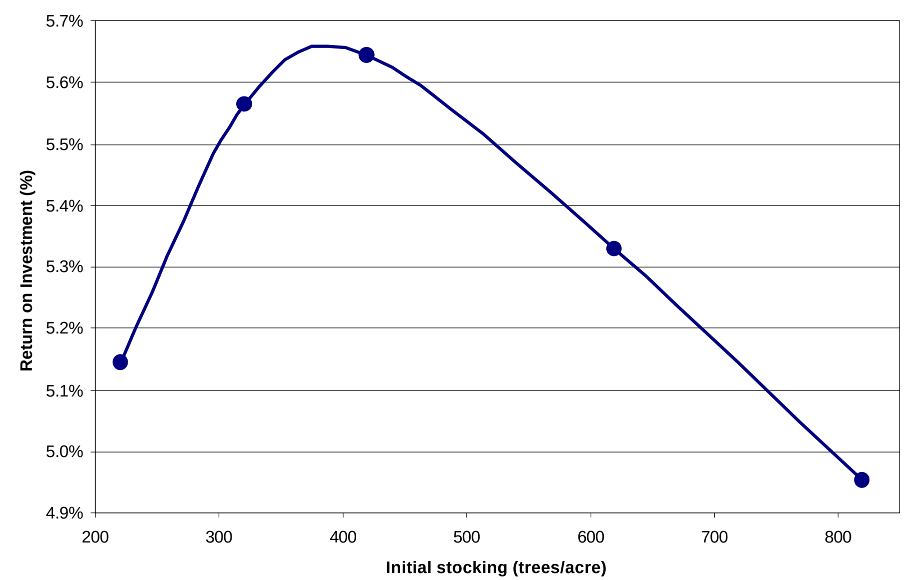

Figure 4. Return on investment over several initial stocking densities in an unthinned, red pine plantation in Upper Michigan after 34 years.