AN ECONOMIC APPROACH TO THINNING IN LOBLOLLY PINE PLANTATIONS

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Abstract. --Economically optimal thinning regime and rotation age are determined for loblolly pine plantations thinned from above and below. Yield equations derived from an individual tree growth simulation are used with dynamic programming to determine the management regime yielding the maximum net present value for the stand. Results show timing of thinnings, number of thinnings, thinning removal and rotation age for selected economic and physical conditions. Tentative results of thinning from above and below are compared.

Although loblolly pine (Pinus taeda) is the most important commercial southern timber type, little is known about the economics of alternative thinning regimes for the species. This paper reviews and compares preliminary economic results of thinning from above and below, using dynamic programming to evaluate thousands of alternatives.

Selection of a thinning regime entails the choice of thinning intensity, timing of thinning, number of thinnings, type of thinning and original planting spacing. Here we consider two thinning types: thinning from below (low thinning), and thinning from above (high thinning). Figure 1 shows an example of thinning from below which removes trees of smaller diameter and less value than thinning from above (Fig. 2). Economic comparison between the the two types of thinning implies weighing the relative benefit of receiving a higher early income when thinning from above versus higher income from the final harvest when thinning from below. The economically optimal regime will maximize the rotation-start present value, given certain economic assumptions.

Gingrich (1983) suggested that high thinning in southern forests might sometimes be economically preferable to low thinning. Unfortunately, limited data is available for high thinning in loblolly pine. On even-aged second-growth loblolly-shortleaf pine stands in Arkansas and Louisiana, little difference was found in cubic foot wood production between stands thinned from below and stands thinned from above (Bassett 1966, Burton 1968, Burton 1979). However, sawtimber production at age

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FIGURE 1. THINNING FROM BELOW ON 15 YEAR OLD LOBLOLLY PINE PLANTATION.

FIGURE 2. THINNING FROM ABOVE ON 15 YEAR OLD LOBLOLLY PINE PLANTATION.
35 years was much higher for the stands thinned from below. Burton (1979) showed the diameter distributions for various high and low thinning regimes. By age 45 years, the percent of trees in the sawtimber class was less for stands thinned from above. In planted stands on abandoned fields in Georgia's Piedmont, Belanger and Brender (1968) found higher annual growth rates in stands thinned from below than in stands thinned from above. Their results are questionable because of glaze storms that more severely damaged the stands thinned from above. Mann (1952) found that old-field stands thinned from above had slower annual growth rates in cords than stands thinned from below, but produced the best sawlog grade yields. We have found no economic comparisons of the thinning types in loblolly pine.

THE GROWTH MODEL

In order to model many potential thinning regimes, we used a revised version of the old-field loblolly pine growth simulator PTAEDA (Daniels and Burkhart 1975). Since the new model, PTAEDA2 (unpublished), is based on more data and deals with cutover sites, it provides more realistic volume projections for typical plantations.

For simulating effects of thinning, the PTAEDA models are especially useful because they use competition between trees as a variable in determining tree growth and mortality. Preliminary tests indicate that responses of PTAEDA2 to thinning from above and below fall within the range of results from the limited field studies available (Mann 1952, Bassett 1966, Belanger and Brender 1968, Burton 1968, Burton 1979).

Two adjustments were made to the PTAEDA2 model for this study. A new thinning routine was added to apply thinning from above. It removes trees with the highest relative competition, centered on the desired diameter. A forester-controlled thinning is approximated by this technique of removal. Additionally, a new routine was added to give pulpwood, sawtimber and peeler volumes.

Since the PTAEDA2 model is stochastic, it was necessary to create deterministic equations from it. A sampling scheme was devised to create whole stand equations using PTAEDA2 as a data generator. These whole stand equations give quick predictions of growth and yield while providing consistency in predictions necessary in the optimization technique.

ECONOMIC OPTIMIZATION PROCEDURE

For low and high thinnings separately, the optimum thinning regime and rotation age combination was that which maximized rotation-start present value per acre, or "soil expectation value" (SEV) at a given interest rate. Dynamic programming was used to search through the thinning options and seek the regime
with the highest SEV for each rotation age.

The program FORTE\(^2\) (Arthaud 1986) was developed to utilize the whole stand equations generated from PTAEDA2. FORTE has 2 segments: a menu driven input segment and a dynamic programming run segment. The program is written in BASIC and runs in one minute to one hour on an IBM-PC, depending on the size of the problem and resolution required. FORTE uses forward recursion optimization which moves from planting date to rotation age, examining options at selected intervals. At each interval, the stand with the highest present value for a given stand description is used for future growth, and the other stands are discarded. Stands are defined by age, basal area, trees/acre, and whether the stand has been thinned. Stand descriptions are stored through "neighborhood storage" (Brodie and Kao 1979) at the nearest 5 sq. ft./acre basal area and 5 trees/acre.

To restrict problem size, the following variables can be set: minimum basal area and number of trees remaining after thinning, minimum thinning removal, time between thins, thinning removal increments, and minimum thinning age. For this analysis we constrained the problem to leave a minimum of 50 sq. ft./acre basal area and 100 trees/acre. Thinning increment was varied, with time between thinnings ranging from 1 to 10 years. Thinning was not permitted in stands less than 10 years old, and was performed in increments of 5 sq. ft./acre basal area with a minimum removal of 20% of volume or 300 cubic feet.

**Preliminary Results**

Base case assumptions are shown in Table 1. Product values are translated into stumpage value per cubic foot as an increasing linear function of average stand diameter.

The preliminary optimum regime for site 60 (base age 25), given the base case assumptions, was planting at 440 trees per acre (about 10'x10' spacing), one low thinning at age 20 years removing 23% of the basal area and a final harvest (clear-cut) at 36 years. As shown in Figure 3, low thinning yielded a higher SEV value than high thinning or no thinning. Low thinning peaked with an SEV of $210 per acre at rotation age 36 years with the stated optimal regime (optimal for the discrete amount tested). High thinning peaked at $201 per acre by removing 30% of basal area at 24 years with a 38 year rotation age. For the base case, eliminating thinning produced a peak SEV of $196 at age 31 years. For pulpwood only, no thinning was optimal, with a rotation age of 24 years on site index 60 land.

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2 FORTE program is available from: Management/Economics Section, Department of Forestry, Virginia Tech, Blacksburg, VA 24061. To help defer costs, make $30 check payable to Department of Forestry, VPI & SU.
Table 1. Base Case Assumptions

6% real interest  
Pulpwood price, $11/cord  
Sawtimber price, $100/MBF  
Peeler price, $137/MBF  
Thinning stumpage price = 80% of clearcut price  
Fixed thinning cost = $20/acre  
Site preparation cost = $75/acre  
Planting cost = $.06/tree  
All costs and revenues before tax  
Constant real costs and revenues  
Site index 60 (base 25) stand

FIGURE 3. Present Values for Thinning Options

Δ = POINT OF MAXIMUM PRESENT VALUE  
PLANT AT 10' X 10'  
SITE INDEX 60  
6% REAL INTEREST
Figure 3 shows that present value was not highly sensitive to rotation age. SEV for the low thinning was roughly $210 for rotation ages from 34 to 38 years. The high thinning SEV remained at about $200 from 35 to 40 years.

A planting density of 440 trees/acre provided an SEV that was 5 percent higher than 680 trees/acre (about 8'x10' spacing) (Figure 4). Apparently, the lower cost and increased diameter growth of the wider spacing more than offset the higher site utilization of the narrower spacing. Considering hardwood competition costs may reduce the optimal spacing (Klemperer et al., 1986).

For the thinned stands, an increase in site index gave shorter optimal rotation ages. Using the low thinning and base case assumptions, except for adjusting the site index, Figure 5 shows that site index 70 yielded an SEV of $330 per acre at a rotation of 34 years. When site index (SI) dropped to 50, rotation age increased to 38 years with an SEV of $134. At SI 50 it was not economically sound to thin under the base case assumptions. For SI 50 without thinning, the SEV maximum was $135 with a rotation age of 33 years.

There also seems to be a wide variety of thinning and timing-intensity combinations that provide near optimal SEV's. In some cases age of thinning could vary 6 years without decreasing SEV more than $.01. As thinning age increased for these similar SEV's, optimal thinning intensity tended to increase. SEV was more sensitive to changes in thinning age and intensity when either one was held constant.

Overall, these preliminary results suggest that high thinning is not an economically correct practice, given our input assumptions. Future testing will determine if changes in site index, planting density, interest rate, product values, or taxation could create cases where high thinning would generate greater present values than low thinning. We must stress that our results can only be tentative until more extensive field trials of thinning from above and below are made in loblolly pine.
FIGURE 4. Effect of Planting Spacing on Present Value

\[ \Delta = \text{Point of maximum present value} \]

Low thinning
Site index 60
6% real interest

Plant 10' x 10'
Plant 8' x 10'

Rotation, years

FIGURE 5. Effect of Site Quality on Present Value and Rotation Age

\[ \Delta = \text{Low thinning} \]

Site index 70
Plant 10' x 10'
6% real interest

Site index 60

Site index 50

Rotation, years
Literature Cited


