Management of Young Even-Aged Stands of Southern Pine: Technical Papers Presented at First Annual Symposium, School of Forestry, Louisiana State University, Baton Rouge, Louisiana, March 13-14, 1952

School of Forestry, Louisiana State University, Baton Rouge, Louisiana, USA

A. Bigler Crow

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PROCEEDINGS

YOUNG PINE MANAGEMENT

FIRST ANNUAL SYMPOSIUM

School of Forestry

Louisiana State University

Baton Rouge, Louisiana

March 13-14, 1952
"MANAGEMENT OF YOUNG EVEN-AGED STANDS OF SOUTHERN PINE"

Technical Papers Presented
At
First Annual Symposium
School of Forestry, Louisiana State University
Baton Rouge, Louisiana
March 13-14, 1952

A. B. Crow, Program Chairman

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Young, even-aged, loblolly pine stands are springing up on many thousands of acres in the South. With these stands have come new and pressing problems. Forest managers want to know when thinnings should be started, the type of trees to remove in thinnings, and the optimum growing stock to carry.

Unfortunately, it is impossible to prescribe a single set of rules for thinning. Thinning practices in any given stand are likely to differ sharply according to the kind of product the owner wants to grow and on his financial aims and needs. However, we do have considerable data to show how loblolly pine responds to various types and degrees of thinning. This paper summarizes the information collected on a 36-year-old study in central Louisiana.

The five plots I will describe comprise the Maxwell thinning study, conducted at Urania, Louisiana, by the Southern Forest Experiment Station and the Urania Lumber Company. They are some of the oldest loblolly thinning plots west of the Mississippi River. Although treatments in this study were not replicated, results from other thinning studies at Urania in comparable stands confirm the findings of the Maxwell study.

Site and Treatment

The stand now on the plots originated in 1907 on an old field. The average site index for loblolly pine is 93.

The plots represent four different thinning treatments plus an unthinned check. Two plots were established in 1915, when the stand was eight years old and well stocked. Plot U-3, the check plot, has never been thinned. Plot U-5 was first thinned at age eight and has been thinned lightly at 5- and 10-year intervals thereafter, whenever the stand closed in. The first two thinnings were pre-commercial—that is, the trees removed were too small to be used for pulpwood. In general, thinnings have been from below, although rough and deformed trees in the larger crown classes have also been cut.

The other three plots, U-54, U-55, and U-56, were installed and first thinned in 1925. At this time the trees were 18 years old and large enough for pulpwood. Plot U-54 was thinned very heavily, leaving only 100 of the largest and best dominant and co-dominant trees per acre. Additional thinnings were not needed in this stand until 1951. The purpose of this severe thinning was to compare diameter and volume growth from a very heavy thinning, leaving approximately the number of trees expected in the final crop of sawlog-size trees, with that from lighter thinnings made at relatively short, periodic intervals.
The original thinnings on plots U-55 and U-56 removed chiefly rough and deformed dominants plus smaller merchantable-size trees apt to die from suppression or the stands were thinned from above. Later thinnings removed mainly co-dominant and intermediate trees. The main difference between these two plots was that U-55 was consistently thinned more heavily than U-56.

Cordwood Growth

Up to 1940, when the stands were 33 years old, periodic annual cordwood growth was greater on the unthinned check plot than on any of the thinned plots. From 1915 to 1925, annual growth averaged 2.4 standard cords per acre on the check plot as against 2.3 cords on the early light thinning plot. Over the next 15 years, periodic annual growth was 2.4 standard cords per acre on the check plot, 2.2 on the early light-thinning from below, 2.0 on the deferred light thinning from above, 1.9 on the deferred heavy thinning from above, and 1.2 on the crop-tree thinning plot. After age 33, heavy mortality in the merchantable size classes sharply reduced cordwood growth on the check plot below that on all of the thinned plots.

Up to age 33, cordwood growth was greatest on plots with the heaviest residual basal areas. This relationship is clearly shown in the bar graph (Figure 1). Even the light thinnings reduced growth below that on the check plot, but not so much as did the heavy thinnings. The same relationship of growth being directly related to the amount of growing stock or basal area was found beyond age 33 on the thinned plots. It clearly indicates that when maximum volume growth is desired on a long rotation, thinnings should be very light, removing mainly trees that are likely to die in the next few years, and those that are defective or deformed. Moreover, these data indicate that stands that are unthinned, or thinned only enough to remove the trees certain to die in the next few years, will grow the most pulpwood on a short rotation.

Prior to 1940, nearly five cords of wood in merchantable-size trees were lost on the check plot through mortality. Even though cordwood growth on the check plot was superior to that on the thinned plots, some landowners may deem it advisable to salvage such material just before the trees die. However, the costs of marking and supervision, the reaction of contractors to cutting small trees almost exclusively, and the logging damage to the residual stand may make such salvage thinnings undesirable, particularly where heavy cuts per acre are required to make logging commercially feasible.

A practical objection to a policy of no thinning on a pulpwood rotation is that the seed trees left for restocking the area will have inadequate crowns for cone production. Of course, this may also be true for any short rotation, whether thinnings are made or not. Releasing selected seed trees several years in advance of the harvest cut is one possible solution. I think, however, that in the not too distant future the practice of many landowners will be to clear-cut and plant or direct-seed immediately.
Figure 1. - Relation of basal area and growth. Maxwell Thinning Plots, 1925-40.
It will seem more economical to do this than to leave seed trees and let the land lie idle and vulnerable to hardwood invasion until they can furnish natural reproduction.

Cordwood growth was greater on the early light thinning plot, which was given two pre-commercial thinnings, than on the deferred thinning plots. However, these differences are probably due to differences in stocking of the stand rather than to thinning treatment, since the early light thinning plot had the greatest basal area. Non-revenue thinnings are generally unnecessary in loblolly pine stands, for the trees usually express dominance early in life. Occasionally, loblolly pine on very poor sites becomes stagnated, and then a non-revenue thinning may be beneficial.

Diameter Growth

When the relative merits of different degrees of thinning are assayed, diameter growth must also be considered. Diameter growth, in contrast to volume growth, has been greatest where the thinnings were heaviest. (Incidentally, my remarks on diameter growth will refer to the 100 largest trees per acre, instead of all trees, to avoid distortions which might be brought about by mortality and cutting of small trees.) The heaviest thinnings tested in this study failed to give a consistent growth rate of three inches in 10 years (Table 1). This goal was most closely approached by the heavy deferred thinning, which gave an average growth rate of $2\frac{1}{2}$ inches per 10-year period over the last 26 years. Experience shows that very heavy periodic thinnings are required to obtain a growth rate close to six rings to the inch. Probably thinning back to about 70 square feet of basal area per acre is necessary for this rate of diameter growth.

The two early thinnings on plot U-5 did not stimulate diameter growth above that on the unthinned check plot. From 1915 to 1925, annual diameter growth averaged 0.51 inch on the check plot as against 0.48 inch on the early light thinning plot. This is another indication that pre-commercial thinnings are seldom needed or justified.

The check plot furnishes a good clue as to when the first thinning should be made if the objective of management is large products on a long rotation. From 1915 to 1925, diameter growth on the check plot exceeded that on the plot thinned lightly from below, and during 1925 to 1930 it equalled or exceeded the growth on all thinned plots except the crop-tree thinning. During the next five-year period, however, diameter growth was less on the check plot than on any of the thinned plots. This drop in diameter growth coincided with the beginning of heavy mortality of merchantable-size trees. Indications are that the first thinning should have been made about age 23, just before the period of heavy mortality and reduced diameter growth. The beginning of mortality of 4- and 5-inch trees from suppression should serve as a good signal to make the first thinning in most stands.
Table 1

Periodic annual diameter growth of the 100 largest trees per acre, by thinning treatment. 1915-51.

<table>
<thead>
<tr>
<th>Period</th>
<th>Un-thinned</th>
<th>Early light</th>
<th>Crop-tree</th>
<th>Deferred light</th>
<th>Deferred heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915-25</td>
<td>0.51</td>
<td>0.48</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1925-30</td>
<td>0.28</td>
<td>0.28</td>
<td>0.42</td>
<td>0.26</td>
<td>0.28</td>
</tr>
<tr>
<td>1930-35</td>
<td>0.20</td>
<td>0.22</td>
<td>0.32</td>
<td>0.24</td>
<td>0.26</td>
</tr>
<tr>
<td>1935-40</td>
<td>0.22</td>
<td>0.26</td>
<td>0.24</td>
<td>0.26</td>
<td>0.26</td>
</tr>
<tr>
<td>1940-46</td>
<td>0.17</td>
<td>0.23</td>
<td>0.18</td>
<td>0.25</td>
<td>0.27</td>
</tr>
<tr>
<td>1946-51</td>
<td>0.18</td>
<td>0.26</td>
<td>0.16</td>
<td>0.20</td>
<td>0.18</td>
</tr>
</tbody>
</table>
The crop-tree thinning was unprofitable in all respects. Not only was cordwood growth drastically reduced by the heavy thinning treatment, but the very fast diameter growth which followed the initial thinning steadily decreased. Starting in 1935, diameter growth was less than on any of the thinned plots, and in the last five years it was less than on the check plot. For the 26-year period from 1925 to 1951, average diameter growth on the crop-tree thinning plot was about the same as on the periodically thinned plots. While a second thinning in 1935 might have accelerated diameter growth, or at least staved off further decline, the basal area of 65 square feet per acre at that time suggests that a thinning was not needed. Moreover, if a thinning had been made in 1935, it probably would have reduced cordwood growth further.

Some Quality Considerations

Type of thinning has a greater influence on the quality of the products (and hence on net profits) than does degree of thinning. While the Maxwell plots are still too young to permit final evaluation of thinning from above as against thinning from below, the trends showing the superiority of thinning from above are readily apparent. These stands now average about 16,000 board feet per acre, International 1/4-inch scale. So far, none of the thinnings have produced any top-quality sawlogs. The light thinning from below has produced only 22 percent grade 2 logs, while the proportion of grade 2 logs has been 32 percent on the heavy thinning from above and 44 percent on the light thinning from above. Quality production has been poorest on the crop-tree plot, where only 12 percent of the logs are grade 2.

When thinning from above to increase quality, it is by no means necessary to remove all dominant trees. Some dominants will be very clean and well worth saving. Moreover, thinning primarily from above will be necessary only for the first two or three thinnings, or until the rough and deformed dominants have been entirely removed from the stand. After that, thinnings should be primarily from below, and should be designed to give ample growing space to the selected crop trees and to salvage anticipated mortality.

Other studies with older stands bear out the conclusion that initial thinning from above is preferable to thinning from below if quality is an important objective. Two or three thinnings from above, however, will result in a smaller average diameter and shorter trees than if thinning from below were practiced continuously.

Recommendations

In briefly reviewing how loblolly pine responds to different thinning treatments, I want to point out that any advantage or gain from a particular kind of thinning is usually accompanied by a loss. It is essential for the forest manager to weigh carefully all of these advantages and disadvantages when formulating his thinning policy.
For a pulpwood rotation up to about 35 years of age, unthinned loblolly pine stands have had the greatest cordwood growth. This means that early returns from intermediate thinnings are sacrificed for maximum production. Where early returns are needed, light thinnings that remove mainly suppressed trees are indicated, provided that logging damage or expense is not excessive. The important consideration is that reduced growing stock means reduced growth.

Landowners desiring maximum production of pulpwood and sawlogs per acre will probably favor light thinnings which keep the stand just open enough to forestall mortality from suppression and excessive shortening of live crowns. Light thinnings will result in slower diameter growth than heavy thinnings, thus deferring somewhat the time when products of a specified size can be harvested. Rotations can be shortened by making heavy thinnings to promote rapid diameter growth, but this will result in lower total yields.

Probably most landowners will prefer the middle course, where moderate thinnings are made to promote fairly fast diameter growth, though not without some reduction in total yield of the stand. Within reasonable limits, however, the dollar returns from all degrees of thinnings will be comparable over a rotation if it is assumed that all returns from thinnings are invested at three percent compound interest.
Gentlemen:

As a matter of general information I think it might be well to review briefly for you at this time some of the background of the forest plantation operations in Bogalusa by the Gaylord Container Corporation. In 1920-21 the first area was fenced for direct seeding of loblolly pine. At this time fire protection was being established and seed trees were left on a part of the longleaf land then being cut over. From this simple beginning has been carried on an ever expanding operation during the past 31 years, so that at the present time the land holdings under forest management for the company now amount to approximately 414,000 acres.

These lands all located within 100 miles of the mill at Bogalusa constitute the insurance policy carried on the permanent location of the paper mill. Their purpose might be summed up briefly as being the nucleus for the production of a never ending supply of raw material for the mill. The basic philosophy has always been the complete utilization of the site for maximum wood production, with major emphasis on pulpwood. However, a considerable quantity of poles and piling, pine sawtimber and hardwood products are sold annually but these are possible only as a result of the outside pulpwood supply which exists from year to year.

In order to expedite the putting back into production of large acreages of land on which natural reproduction had not occurred or where inadequate seed source existed a large planting program was conceived early in the history of the corporation. This program started in 1920-21 with the direct seeding of 800 acres of loblolly pine. It progressed through the use of wild stock and nursery stock until adequate information had been secured to point the way towards large scale planting. Much has been written concerning these early works and I am sure that the majority of you have visited our area viewing these pioneer activities. At the close of the planting season in 1950-51, 67,950 acres had been planted to slash and loblolly and longleaf pine. During the planting season of 1951-52 it is estimated that additional 7,400 acres of plantations have been completed. The ever changing future indicates that our anticipated planting program for next year will call for the planting of 13,500 acres, this figure to level off to approximately 10,000 acres per year for the five years following.
Earlier I mentioned the use of loblolly seed in the first planting. At that same time approximately four acres were sown to slash pine. Due to the excellent survival as a result of its adaptability to the sites being planted much of our work has been with slash pine (Pinus caribaea). However, it is well to note that both at the beginning and now during the later years of our planting history, longleaf (Pinus palustris), loblolly pine (Pinus taeda) and shortleaf pine (Pinus echinata) are also used. Inevitably among the first questions asked is one concerning why was this species used in preference to some other species. I think this might best be summed up in that the choice of species represents in any large scale operation the professional compromise between (1) site to be utilized, (2) product to be produced, (3) planting stock available, and (4) history of the area to be planted.

One thing which has been quite evident on several of the field trips which we have taken to surrounding properties has been the diversified spacing which is used and the complete confidence which each property manager has in the spacing which he has selected. This, I believe, is good because it very clearly indicates one cardinal principle, that there is no simple general answer to the problem of spacing, and that the choice between different spacing depends in the final analysis upon the specific needs and objectives of the owner himself. This in turn hinges on the values which he sets on the different kinds as well as sizes of the products to be produced. More careful analysis of the above usually brings to light a serious consideration of the size and volume of the first anticipated thinnings, the presence or absence of a market for that size product and the dollar value for material of that size class. At the Gaylord Container Corporation we have practically standardized all our plantations on a standard spacing of 6 x 8 feet. This means that the trees are 6 feet apart along the row and that rows lie 8 feet apart. This does several things: 1. It gives us approximately 1,000 seedlings to the acre in our plantation. 2. Competition between trees is maintained at a high level within the rows. 3. The 8 feet spacing gives considerable latitude for future operation between the rows.

Many of you are familiar with the data on the thinning plots established on the Gaylord holdings at Bogalusa by Dr. Albert Folweiler from Texas. Recently Professor Crow has released other information concerning later thinnings on these plots. I will therefore skip and leave any further discussion of the matter with him. Instead I would like to discuss the past, present, and future conditions on four experimental areas which were established in the 4,600 acre plantation planted in the winter of 1924-25. This plantation consisted of approximately 3,700 acres of loblolly and 900 acres of slash and it is within the slash plantations that this 80-acre experimental thinning was located.

The experimental area is sub-divided into four blocks of approximately 20 acres each, using natural boundaries then in existence as a means of separating the study. For example--Plots 6 and 7 are separated by a truck trail, Plots 7 and 8 by
a graded fire line and Plots 8 and 9 by a standard fire line. The original thinnings were marked in 1938 and cut in 1939. From Block 6, 15 percent was removed from the stand, from Block 7, 20 percent of the stand, from Block 8, 30 percent was removed and from Block 9, 40 percent of the stand was removed.
Gentlemen, you will note in this chart that we have presented a summation of the production on the four thinning areas in question. The percent of stems thinned is indicated in column two and noted in column four where changes were made.

The return from early thinnings is shown in column five. I think it is significant to note here what this material removed means to the property owner. These are the first two steps whereby he has received a return on his investment and the means with which to carry on a conservative program in the future without the need of outside financing.

The mortality has been high in the lighter thinned areas. This is traceable to two causes--heavy fusiform infection and the delay in 1944 and 1949 thinnings due to war effort. Future operations on a five-year cutting cycle should hold this to a minimum.

Behind the present base in cords per acre is shown the total production per acre in cords. To date the 20% thinnings are 2.9 cords ahead of the 30% thinnings. This stand also has the best indicated growth rate per year indicated by stand projection for each year of the 1950-54 period. Here again the 30% block is a close second.

The lowest mortality, base, growth, and total production has been in the 40% - 40% thinning. However the stand in question has certain spacing, crown size, diameter size and vigor which in conjunction with wood cut to date should bring interesting results in the next two periods.
In this chart has been presented a summary of the stand conditions as they exist on the plots at the present time. The basal area shows the spread now present and gives a good criteria of stocking. Note 128.2 square feet now present in the 20% plot after thinning.

The tree count follows just about as would be expected. Largest number of stems on area with lightest thinnings.

In average diameter there are two breaks in the continuity of figures. In both the 20% and 40% - 40% some above average, very vigorous trees had to be removed due to the size of the stem cankers of fusiform rust. Without this condition I believe the figures would have shown a smooth flow.

Growth per acre per year for 1950-55 period is shown. This is based on stand projection calculations. Rechecks are in the process in that each individual tree on the study plot is numbered. This will make possible growth and mortality figures by diameter classes.
Chart No. III

1924-25 SLASH PINE THINNING PLOTS
STAND TABLE

Percent Thinned
15% - 40% - 20%
20% - 40% - 40%
30% -
To complete the information on these study plots we have included a chart showing stand composition by individual diameter class for each of the five conditions. The more normal curve at present would seem to be the 20% thinning block.

The 40% - 40% block runs smoothly to nine inches and drops sharply where the spacing factor removed many larger trees to give space for crop trees. In our tentative plans we believe this block may serve as a seed orchard in that larger crowns are developing as a result of the open nature of the stand.

In summary Gentlemen, this is one of several approaches our company is using to determine thinning practices on our plantation areas. There are many types of applications, each working toward specific objectives. With this in mind we have charted for your consideration our tentative results to date. Each year will, we hope, find us closer to our solution. Should you be in the Bogalusa area we would be pleased to have you drop in and look over our setup.
The following pages describe a new and very convenient way of cruising timber. The method makes it unnecessary to measure or guess tree diameter, plot radius, or strip width, and it greatly simplifies office calculations. The cruiser merely stands at the center of the plot, looks through a simple hand-held angle-gauge, and counts all trees that appear larger than the angle laid out by the gauge.

Although based on a centuries-old concept, the use of an angle gauge to accept or reject sample trees is new, the inspiration of a European.1/ The first American exposition of the theory, published recently, adapted the method to American units of measure and developed several new applications.2/ Readers should consult it if they desire a more comprehensive account than can be given here.

For simplicity this paper assumes that the areas cruised do not slope more than 10 percent, but instrumental or computational corrections can be made to adapt the method to steeper country.

Instrument

Before starting any field work, the cruiser will need to make an angle-gauge for optically defining an angle of 104.18 minutes with its vertex at his eye.

His simplest course is to get a 33-inch stick and mount a peephole at one end with a line of sight bisecting a 1-inch metal crosspiece at the other end. The crosspiece, when viewed through the peephole, should exactly cover a 3-foot horizontal intercept at a distance of 99 feet from the eye. The distance between crosspiece and peephole should be adjusted till this occurs. Hypsometer and Biltmore graduations may be put on the stick if desired.

A 4- to 7-power monocular with two vertical reticule lines 30.3 mils apart constitutes a better instrument. Like the cross-arm device, it can be checked against a 3-foot intercept at 99 feet except that the vertex of the 104.18-minute angle will be 1 focal length in front of the objective lens instead of at the eye. Instruments adjusting for slope are feasible, but will not be discussed here.

Figure 1.—Plotless timber cruising. Shaded areas represent 104.18-minute angles optically established by the instrument described on the opposite page. Circles represent cross-sections (at breast height) of trees viewed from the sampling point. Cruiser merely stands at the sampling point (analogous to a plot center), counts every tree whose d.b.h. appears larger than the angle, and disregards every tree whose d.b.h. appears smaller. All trees visible from the sampling point must be counted or rejected. The count of trees, multiplied by 10, gives an estimate of basal area per acre. In the diagram, only two trees are counted, so the basal area estimate is 20 square feet per acre. Reliable estimates require more than one sample, of course.
Basal Area Estimates

Assured of an instrument, the cruiser should decide on the pattern of sampling points (analogous to plot centers) that he wishes to employ on the area to be cruised. He must then visit each sampling point (or at least an unbiased point in its vicinity), look in every direction through his instrument, and count the number of trees whose d.b.h.'s appear larger than the cross-piece. The principle is illustrated in figure 1. The eyepiece (or vertex) of the angle-gauge should pivot on the sampling point until the count is completed, except that it may be temporarily moved sideways perpendicular to the line of sight to clear nearby brush or trees likely to mask other qualifying trees. After a little practice, the cruiser will find he can gauge all but borderline trees by eye alone.

Suppose that the cruiser has tallied a total of 240 qualifying trees at 30 unbiased sampling points on an area.

Estimated basal area per acre
\[ = \frac{(10) \text{(Number of tallied trees)}}{(240)} \]
\[ = \frac{(10) (240)}{(30)} \]
\[ = 80 \text{ sq. ft.} \]

Pulpwood Estimates

Suppose, further, that the stand on the area is pine of pulpwood size in two even-aged groups. Qualifying trees would be counted in the same manner as above, but each age group should be tallied separately and the average total height of each group should be recorded. For example, 100 tallied trees might have had an average total height of 50 feet, while 140 tallied trees might have had an average total height of 80 feet, assuming the same 30 sampling points were used.

Estimated rough stacked volume per acre
\[ = \frac{\sum \text{(Number of tallied trees)}(\text{Av. ht. in ft.)}}{(20) \text{(Number of sampling points)}} \]
\[ = \frac{(100)(50) + (140)(80)}{(20)(30)} \]
\[ = \frac{16,200}{600} \]
\[ = 27 \text{ standard cords} \]
Local form, utilization, and stacking practice may justify the use of some divisor other than 20. Sampling stacked volume per square foot of basal area in various height classes will determine the divisor to use. It will usually be between 18 and 21.

Greater precision is possible where merchantable length of each qualifying tree can be predicted with some degree of confidence. The same 240 trees at 30 sampling points might have been tallied according to their expected merchantable lengths, thus:

- 50 trees with 30 lineal feet of pulpwood
- 50 trees with 40 lineal feet of pulpwood
- 50 trees with 50 lineal feet of pulpwood
- 50 trees with 60 lineal feet of pulpwood
- 40 trees with 70 lineal feet of pulpwood

Total: 240 trees tallied at 30 sampling points

Cubic volume per acre (including bark) could be estimated by multiplying the tally for each length class (shown in column 3 below) by the appropriate cubic volume factors (shown in column basal area 2 below). The sum of these products is used to obtain cubic feet as indicated below. Of course, local cubic volume factors for each merchantable length class would be best, but the ready-made factors will serve wherever great accuracy is unnecessary.

<table>
<thead>
<tr>
<th>Merch. length class (ft.)</th>
<th>Cu. vol. factor (incl. bark)</th>
<th>Tally</th>
<th>Example: Product of factor x tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>14</td>
<td>50</td>
<td>1,000</td>
</tr>
<tr>
<td>30</td>
<td>20</td>
<td>50</td>
<td>1,300</td>
</tr>
<tr>
<td>40</td>
<td>26</td>
<td>50</td>
<td>1,550</td>
</tr>
<tr>
<td>50</td>
<td>31</td>
<td>50</td>
<td>1,800</td>
</tr>
<tr>
<td>60</td>
<td>36</td>
<td>40</td>
<td>1,560</td>
</tr>
<tr>
<td>70</td>
<td>39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 240 trees; 7,210 = sum of products

Estimated cubic volume per acre (incl. bark) = \( (10) \left( \frac{\text{Sum of products}}{\text{Number of sampling points}} \right) \)

= \( (10) \left( \frac{7,210}{30} \right) \)

= 2,403 cubic feet
Cubic feet can be divided by a locally appropriate conversion divisor to give rough stacked cords per acre (26.7 cords if local divisor were 90 cubic feet per cord).

**Miscellaneous Estimates**

The number of trees tallied by the angle-gauge in any given class tends to be directly proportional to the total basal area per acre in that class. This fact allows estimating basal area distribution by species, quality, vigor, diameter, length, or any other desired criterion, by merely classifying tallied trees.

Basal area in each merchantable length class may be easily converted to various units of volume, because \( \frac{\text{volume}}{\text{basal area}} \) ratios within merchantable length classes are relatively stable, regardless of diameter. For simplicity, it will be assumed that 40 trees of the same species have been tallied at 5 sampling points and also classified as to their merchantable length in terms of 16-foot sawlogs, thus:

- 8 trees with zero logs
- 10 trees with one log
- 11 trees with two logs
- 7 trees with three logs
- 4 trees with four logs

Total: 40 trees tallied at 5 sampling points

It can be quickly estimated by earlier formulae that stand basal area per acre is \((10)\left(\frac{40}{5}\right) = 80\) square feet, of which 16 square feet is in zero-log trees, 20 is in one-log trees, 22 in two-log trees, 14 in three-log trees, and 8 in four-log trees.

<table>
<thead>
<tr>
<th>Merchantable length class</th>
<th>Volume factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Int. -inch</td>
</tr>
<tr>
<td>Zero-log</td>
<td>0</td>
</tr>
<tr>
<td>One-log</td>
<td>7</td>
</tr>
<tr>
<td>Two-log</td>
<td>13</td>
</tr>
<tr>
<td>Three-log</td>
<td>18</td>
</tr>
<tr>
<td>Four-log</td>
<td>23</td>
</tr>
<tr>
<td>Five-log</td>
<td>28</td>
</tr>
</tbody>
</table>
Volume per acre in terms of International rule (1/4-inch kerf), Scribner rule, Doyle rule, or peeled cubic feet (without bark) could be estimated by multiplying tally in each merchantable length class by appropriate factor tabled above, summing the products, and proceeding as indicated.

Example:

<table>
<thead>
<tr>
<th>Tally</th>
<th>Product of peeled cubic factor x tally</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>120</td>
</tr>
<tr>
<td>11</td>
<td>220</td>
</tr>
<tr>
<td>7</td>
<td>189</td>
</tr>
<tr>
<td>4</td>
<td>136</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total: 40 trees; 665 = sum of products</td>
<td></td>
</tr>
</tbody>
</table>

Estimated peeled cubic volume per acre = \( (10) \left( \frac{\text{Sum of products}}{\text{Number of sampling points}} \right) \)

= \( (10) \left( \frac{665}{5} \right) \)

= 1,330 cubic feet

Estimated board-foot volume per acre = \( (100) \left( \frac{\text{Sum of appropriate products}}{\text{Number of sampling points}} \right) \)

= \( 8,620 \) bd. ft. Int. 1/4-inch

= \( 7,460 \) bd. ft. Scribner

= \( 5,440 \) bd. ft. Doyle

The ready-made volume factors given above will satisfy the accuracy needs of many cruisers, but it is possible to attain any desired precision by merely sampling local \( \frac{\text{volume}}{\text{basal area}} \) ratios for each merchantable length class recognized (1/10 of that ratio has been used in case of board-foot factors).
Variable Plot Radius or Point-Sampling Concept

The 10 1/4-minute angle-gauge tallies all trees closer to the sampling point than 33 times tree d.b.h. Whatever the size of the tallied tree, the instrument guarantees that it is within a plot radius determined by that particular tree's d.b.h.

Thus, a tree with a d.b.h. of 1/2 foot (and a basal area of 1/5 square foot) would be tallied inside a plot with a radius of 16-1/2 feet (and an area of 1/50 acre). The basal area of each 6-inch tree must, then, be multiplied by 50 to place it on a per-acre basis. This means that such a tree would contribute

\[(50)\left(\frac{1}{5}\right) = 10\text{ square feet to the estimate of basal area per acre.}\]

However, a tree with a d.b.h. of 1 foot (and a basal area of 4/5 square foot) would be tallied inside a plot with a radius of 33 feet (and an area of 4/50 acre). This means that each 12-inch tree would contribute

\[(50)\left(\frac{4}{5}\right) = 10\text{ square feet to the estimate of basal area per acre.}\]

Tallied trees of different sizes would have different basal areas, different plot areas, and hence different blow-up factors, but the product of each tallied tree basal area times its appropriate blow-up factor would always be 10 square feet—the constant contribution of any tallied tree to the estimate of basal area per acre. This is why diameter of a tallied tree and its distance from the sampling point are immaterial.

Some people can conceive the idea more clearly by visualizing a sheet of paper with a known number of evenly spaced sample points plotted on it. On the sheet are placed 2 transparent disks of different size, each exhibiting on its face a small concentric circle with diameter 1/66 that of the disk, and with area \((\frac{1}{66})^2\) or \((\frac{1}{4356})\) that of the disk. Next, the number of disks sampled at each plotted point is counted (it will be 0, 1, or 2 in this simple example) and the counts at all points are summed. Those familiar with dot-counting know that

\[
\frac{\text{Sum of disk counts}}{\text{Number of sample points}}\]

estimates

\[
\frac{\text{Area of disks}}{\text{Area of sheet}}\quad \text{and} \quad \frac{\left(\frac{1}{4356}\right)}{\left(\frac{1}{66}\right)}\quad \text{estimates}\]

\[
\frac{\text{Area of small circles}}{\text{Area of sheet}}. \quad \text{Multiplying this last by 43,560 square feet (one acre) estimates the square feet of small circles per acre of sheet or (10) \left(\frac{\text{Sum of disk counts}}{\text{Number of sample points}}\right)},\]

which explains the reasoning behind computations on page 18.

In cruising, the sheet of paper becomes the land to be cruised, small circles become tree cross-sections, and disks become surrounding zones within which a sampling point must fall in order for the 10 1/4-minute angle-gauge to accept that particular tree for tally.
MANAGEMENT OF SECOND-GROWTH LONGLEAF STANDS ON THE
NATIONAL FORESTS IN SOUTH MISSISSIPPI

By

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As a foreword it might be well to state that this paper deals primarily with second growth longleaf stands in South Mississippi 40 years of age and less. As far as can be determined, second growth stands over 40 years of age are very limited in extent, therefore, no further reference will be made to them.

During the past 30 to 35 years, there have been startling changes in the longleaf forests of South Mississippi. It is still hard to visualize that the region now partially occupied by the DeSoto National Forests once supported magnificent stands of virgin longleaf averaging from 12 to 15 thousand board feet per acre, and seemingly limitless in extent. However, by the 1920's, practically all of the virgin stands had vanished. Left in their wake were hundreds of thousands of acres of logging slash, stumps, and grass. While the desolation appeared complete, a careful observer during the decade 1920-30 would have noted that new longleaf forests were in the making on scattered but extensive areas. Unknowingly, man had teamed with nature in the natural establishment of new forests, by a lucky combination of bumper seed crops, widespread logging activity, and uncontrolled fires. It is with the longleaf stands established during that period that we are now primarily concerned, since without them there would be very little management activity in second growth longleaf for at least another 5 to 10 years.

With this thought in mind let's look at the present condition of second growth longleaf stands on the national forests in South Mississippi.

Net commercial forest area of the DeSoto forests now totals 490,000 acres. Of this total, nearly 80% (or 382,000 acres) is properly classified as "Longleaf pine Type". What has been happening to this longleaf area since its purchase during the period 1935-37? For one thing, the natural seedling and sapling stands which existed at time of purchase have now moved into the pole and small sawtimber classes. Natural longleaf pole stands now occupy 41% (158,000 acres) of the original longleaf area, while natural sawtimber stands occupy 9% (36,000 acres). Of the remaining area, 15% (57,000 acres) is in longleaf pine plantations, which for the most part are still in the seedling and sapling classes. In addition, 10% (37,000 acres) has been planted to slash and loblolly pine; 21% (78,000 acres) is in scattered residuals still in process of restocking naturally; while the remaining 4% (16,000 acres) will have to be restocked artificially.

Now to direct our attention to the three stand classes which will be of the greatest importance to the local economy during the
next 8-year period. They are: 1) natural pole stands, 2) natural sawtimber stands, and 3) longleaf plantations established prior to 1940. Since our chief management effort will be aimed at these three groups, a somewhat detailed description of each seems appropriate:

**Natural Pole Stands**

These are the stands which contain less than 1500 board feet per acre in sawlog size trees, but are at least 10% stocked with trees 5" DBH and larger. On the national forests of South Mississippi, our pole stands are further divided into three sub-classes, based on degree of crown cover.

A - Over 70% crown cover - Dense (Pe3a)

B - 40-70% crown cover - Semi-dense (Pe3b)

C - 10-40% crown cover - Sparse (Pe3c)

A - In the dense stands, volumes generally range from 18 to 28 cord per acre, averaging 23. Basal area averages about 130 sq. ft. (including all stems 3" DBH and up). At age 30-35, uncut stands average 450 stems 5" DBH and up. (700 - 3" & up). Average annual growth approximates .6 of a cord, before cutting. Unfortunately, we have only a very few thousand acres of these dense stands. For that reason, and to simplify management, dense stand acreages have been combined with semi-dense in our management plans.

B - In the semi-dense pole stands, volumes usually range from 12 to 18 cords per acre, averaging 15. Basal area averages about 80 sq. ft. (including all stems 3" DBH & up). At age 25-30, uncut stands average 210 stems 5" DBH and up. (375-3" & up). Average annual growth approximates 1.1 cords before cutting.

C - In the sparse pole stands, volumes ordinarily range from 3 to 12 cords per acre, averaging 7. Basal area averages about 35 sq. ft. (including all stems 3" DBH & up). At age 20-25, uncut stands average 100 stems per acre 5" DBH and up. (135-3" & up). Average annual growth approximates .8 of a cord.

**Natural Sawtimber Stands**

These are stands which contain a minimum of 1500 bd. ft. (Scribner Dec. C) per acre in trees 11" DBH and larger. As in the case of pole stands, these also are divided into three sub-classes, based on degree of crown cover.

A - Over 70%

B - 40-70%

C - 10-40%

A - Dense sawtimber stands of second-growth longleaf are so rare that, as in the case of dense pole stands, they have been combined with the semi-dense classification. What fragmentary information we now have indicates that dense stands average
about 5,000 board feet per acre at age 35-40. Uncut stands average 55 stems 11" DBH and up per acre. (70-9" & up). Average annual growth approximates 400 board feet per acre.

B - Semi-dense sawtimber stands average about 2,500 bfa at age 35-40. Uncut stands average 16 stems 11" DBH and up per acre. (35-9" & up). Average annual growth approximates 300 board feet per acre.

C - Sparse sawtimber stands average about 1,900 bfa at age 35-40. Uncut stands average 12 stems 11" DBH and up per acre (25 - 9" & up). Average annual growth approximates 165 board feet per acre.

Longleaf Plantations Established Prior to 1940

We have a rather sorry tale to tell about the plantations established before 1940. In the first five or six years of growth, longleaf in South Mississippi is plagued by brownspot, and hogs and sheep. Field examinations of the 39,000 acres planted to longleaf during the period 1935-39 inclusive, have revealed that serious reduction in stocking has occurred on much of the area as a result of brownspot and hog and sheep damage. Use of prescribed burning to eliminate brownspot prior to 1940 was strictly on an experimental basis, and only negligible areas of these earlier plantations were so treated. Hogs also made heavy inroads on "grass" stage seedlings, despite extensive fencing programs. Furthermore, spacings in the longleaf plantations up to 1940 were usually 6' x 8' or 8' x 8', so that the original plantings averaged only 880 trees per acre. Because of this situation, it is estimated that only a third of these early plantings will have sufficient volume and basal area to be considered in our cutting plans during the next 8-year period. The oldest plantations are now 17 years old with an average basal area of 30 sq. ft., and an average of 90 stems 5" DBH and up per acre. (170-3" & up). Volume averages 5 cords per acre.

Characteristics of each of the three major groupings, natural pole stands, natural sawtimber stands, and plantations, have been discussed in some detail because of their importance in management, as stated previously. As most of you know, extensive management of second growth longleaf stands is still in its infancy. Therefore, the discussions of marking and cutting practice and other forms of stand improvement which follow, do not necessarily represent the ultimate in good longleaf management. We learn as we go along. Nevertheless, there are certain fundamentals which must be observed in any form of good management, longleaf or otherwise.

A very necessary action is to decide on the ultimate management objective. On the three working circles of the DeSoto National Forest the ultimate objective in longleaf stands is the production of high quality sawtimber, based on a tentative rotation of 80 years. The management of well-stocked stands of longleaf on a short rotation, primarily for the production of posts, pulpwood, and small poles, was never given serious consideration. Longleaf
is a "slow"-starter, and on a short rotation of 40 years or less could not hope to compete with such rapid starters as slash and loblolly, even on original longleaf sites. In well-stocked stands, the 80-year rotation envisions a series of perhaps 6 or 7 light intermediate cuttings beginning at age 20-25, followed by a regeneration cutting, and a harvest cutting near the rotation age.

Another important point is determination of the periodic management objectives which eventually will lead to attainment of the ultimate objective. In setting up these periodic objectives, there are at least three important items on which up-to-date information should be available: 1) Character, location, and extent of operable stands; 2) Location and diversity of markets, and market demand; 3) Cultural needs of inoperable stands. The management plans now in operation on the DeSoto units contain this information, and the stated objectives for the current 8-year period are based upon it. Certain of these objectives are concerned only with the portions of each working circle containing stands which are commercially operable now, or will be by the time cutting operations begin. They cover two broad phases of management: 1) The timber cutting program; 2) The timber stand improvement program.

Timber Cutting Program

Briefly stated, our cutting plans call for complete coverage of all longleaf stands operable for pulpwood, and all stands operable for sawtimber, in periods of 4 and 8 years respectively. In other words, control is by area, not volume. It is anticipated that pulpwood stands in the dense and semi-dense classifications can be subjected to a second cut within four to six years of the initial thinning, along with initial cuttings in additional areas which have become operable during that time. In operable sawtimber stands, naval stores operations will be permitted for a maximum period of three years prior to the sawtimber cut. Where feasible, combination pole, sawlog and pulpwood sales will be made.

At this point it might be well to define stand operability. Marking rules for the DeSoto units define an operable sawtimber stand as one which will sustain an average cut of at least 1,200 board feet per acre in trees 9" DBH and larger. An operable pulpwood stand is defined as one in which the cut will average at least 3 cords per acre. However, an exception to this rule is made in the case of highly accessible stands, where the average cut may drop to 2 cords per acre. With operability defined, let's review briefly the marking practice in the various stand classes:

Marking Practice in Natural Pole Stands

In the dense stands, the initial cutting is directed towards the removal of diseased, suppressed, poor form trees, plus sufficient thinners to relieve crown congestion between selected crop trees. The "leave" stand should be composed largely of well-space dominants and co-dominants of superior form. Basal area of "leave
stand should approximate 90 square feet per acre. Normally, this requires the removal of about 35% of the merchantable stand volume (8 to 10 cords). Stands should undergo a second thinning in from 4 to 6 years.

In semi-dense stands, a similar marking policy is followed, except that basal area of leave stand should approximate 70 square feet per acre. Normally, this requires the removal of about 25% of the merchantable stand volume (4 cords). Stand should undergo a second thinning in from 4 to 6 years.

Ordinarily, sparse stands are inoperable for pulpwood. However, there are two instances where such stands should be marked: 1) When they are scattered throughout an area in which dense or semi-dense stands predominate, more often the rule than the exception; and 2) when they are so heavily infected with cronartium that the minimum of 2 cores per acre can be salvaged. Marking in such stands should be confined to trees with cronartium on the merchantable portion of the bole and rough open-grown dominants. Basal area should be disregarded. Although primarily a salvage cutting, it should seldom be necessary to remove more than 25% of the merchantable volume (2 cords). No further cutting should take place in such stands until basal area has increased to 80-90 square feet per acre.

Plantations Established Prior to 1940

Unless heavy cronartium infection exists in longleaf plantations, extensive areas should not be entered for the initial pulpwood cut until age 20-25. Where cronartium is serious, a light sanitation cut may be made as early as age 18 in the better stocked areas, removing an average of from 1½ to 2 cords per acre. Normally, marking practice for the initial cut will be directed towards the removal of rough, poor-form dominants, and those trees which have serious cronartium infection on the merchantable portion of the bole.

Natural Sawtimber Stands

There are no longleaf stands of consequence in the dense sawtimber classification.

In semi-dense stands scattered residuals are present more often than not. The aim in such cases is to leave a well-balanced stand of the best-formed and most vigorous trees, whether second growth or residual. This is accomplished by 1) removal of diseased and poor form trees in the second growth, plus sufficient thinners to relieve crown congestion among dominants and co-dominants, 2) removal of all diseased, poor form, worked, and poor risk residuals. Such marking practice will result in the removal of about one-third of the total stand volume 9" DBH and up, including about 40% of the second growth sawtimber volume. Cut per acre averages 1,500 board feet. The trees will be worked for naval stores for 3 years prior to cutting.
Sparse stands are not considered operable unless scattered residuals are present. In such cases, marking procedure is similar to that followed in semi-dense stands, except that thinners rarely need to be marked. Ordinarily, about 40% of the total stand volume 9" DBH and up will be removed, including up to 50% of the second growth volume. Cut per acre averages 1,200 board feet. Trees will be worked for naval stores for 3 years prior to cutting.

So much for marking practice. Unfortunately, we have little or no information on growth response of well-stocked pole and sawtimber stands to the marking methods just outlined. However, some indication as to how longleaf responds to a heavy thinning was gained from a recent examination of a semi-dense pole stand on national forest land, which was cut-over six growing seasons ago by the International Paper Company. In 1945, average stand volume (in trees 5" DBH & up) was 12.6 cords per acre. Forty-two percent of this volume was removed, leaving 7.3 cords per acre. Six years later this same stand averaged 13.5 cords per acre (5" DBH & up), an average annual gain of about one cord per acre.

While this was excellent response, thinnings of this intensity should be the subject of further study before "all-out" recommendations for or against are made. There are other factors which influence degree of thinning besides silvicultural desirability. The first re-examination of some 400 permanent growth plots established in longleaf stands on the DeSoto units in 1949, should provide some badly needed information on growth response to different intensities of thinning in the several stand classifications.

**Timber Stand Improvement Program**

As we see it, the two major stand improvement activities in operable second growth stands are pruning and prescribed burning. Other cultural jobs such as pine release, planting, and fence construction and hog elimination, are of vital importance in our efforts to regenerate whole new stands, but these activities are outside the subject of this paper.

**Pruning**

This is an activity which, it must be admitted, has been too long shoved aside as low priority. True, in areas where the hardwood problem is serious, pine release work should take priority over pruning. But in the stands under discussion here, what few hardwood problem areas there are can be pretty well controlled by prescribed burning. In the absence of a real hardwood problem, therefore, pruning assumes primary importance. Large-scale pruning projects in second growth longleaf are just beginning to get underway on the DeSoto units. Time will not permit going into the details of the pruning operation but briefly, current pruning instructions call for: 1) No pruning of trees over 8" DBH; 2) Priority treatment to be given to understocked sapling and small pole stands; 3) Pruning to a maximum height of 17' 4"; 4) Selection of healthy, well-formed dominants and co-dominants for pruning.
with an occasional intermediate permitted; 5) Pruning a maximum of 90 trees per acre; 6) Spacing secondary to form. Numerous studies have proved that pruning, if done properly and early enough, can increase lumber values as much as 45%. Since the primary objective in the longleaf stands on the DeSoto units is to produce high quality sawtimber, it follows that pruning will help reach that goal all the more quickly.

Prescribed Burning

The second activity, prescribed burning, is also of great importance in the management and protection of second growth longleaf, if done properly. In order to prevent the accumulation of a rough which could raise havoc in case of wildfire, rough reduction is highly desirable at intervals of from 3 to 5 years. Prescribed burning in cut-over areas always should be postponed for at least a year after cutting is completed, and a 2-year wait is better. Additional benefits from prescribed burning include: control of undesirable species, brownspot elimination, and seed bed preparation. This is especially true in the sparse stands where many large openings commonly are found.

In concluding this paper, I should like to leave a final thought: Although a slow starter, longleaf pine in its natural range, on well-drained soils, and under proper management, is a tough customer to beat. For the loblolly-slash pine enthusiasts in the longleaf belt who may be managing on a sawtimber rotation and who may be tempted to write off longleaf, recommended reading is Aesop's fable of the "Tortoise and the Hare".
MARKING PRACTICE IN EVEN-AGED MANAGEMENT

By

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This discussion is concerned only with intermediate cuttings or thinnings in even-aged stands of loblolly and slash pine that have originated in old fields or in stands similar to them.

Prior to any marking or thinning in these, they should first be thoroughly examined and definite decisions made as to how they should be marked, if at all, to keep them in such an optimum condition that they will produce the greatest possible returns. In no case is any marking ever to be done just to be marking timber.

There are many methods of thinning and good reasons for using each method. One which we use and consider the best is that which assists and approaches most closely the natural thinning of a forest.

Pine trees early assert their dominance and this is true in most even-aged stands of timber. These dominant trees, generally speaking, are the most vigorous and valuable trees and the group which is adding by far the greatest increment. Therefore, it is to our benefit to aid them in every possible way in their progress towards a time of financial maturity, which time is determined by many variables such as the rate of growth, the main product the forest is to produce, stumps prices, availability for logging in wet weather, local labor supply, etc.

An even-aged stand of timber should be thinned as soon as it is evident that there is danger that the dominant trees will be adversely affected in growth either by themselves, the co-dominants, or the suppressed trees. These thinnings should take place as frequently as is required to maintain the best growth rate. It is important to thin stands often enough so that the more dominant fast growing trees never become suppressed but continue to grow at a rapid rate. The codominant and suppressed trees are following a natural downward trend and should be aided in their passage out of the stand in order that they adversely affect the best trees for as short a time as possible, and also in order that they be salvaged and value realized from them.

It may be desirable to delay the first thinning of a stand to enable the trees to naturally prune themselves. The large, limby, wolf trees even though dominant, are of course, removed along with weak, diseased, suppressed, and dying trees so that after each thinning the most desirable part of the stand, usually the upper canopy, is maintained in as vigorous a condition as is possible. This type of thinning generally produces poor monetary returns at first, as the cutting costs are high and
the stumpage values low, but with each succeeding cut, the returns will increase as the diameters are larger and the trees have better form.

Obviously, many of the best dominant trees are going to compete with each other, and of course, some will have to be removed in each thinning, but those left will still be the most valuable and the fastest growing.

Under conditions of extreme stagnation it may be desirable to thin the stand as soon as any of the trees are large enough to make fence posts or pulpwood. In which case most of the dominants would be removed. But only under these conditions would it be advisable, if then, to remove such a number of the dominant trees.

Thinnings should more or less be done from below. This will tend to improve or maintain an even growth rate without interruptions due to suppression and subsequent releasing. These interruptions always result in a loss of growth which is never made up. Also, the thinnings from below help to maintain an even, fairly closed canopy, but not closed to the extent of suppression or adverse competition. This type of canopy is unfavorable to the growth of understory hardwoods which, if they become established and of some size, can adversely affect the growth of the overstory pines and also later prevent the survival and hinder the growth of the reproduction. In Scott County, Mississippi, a half stocked overstory of loblolly and shortleaf pine whose diameters averaged approximately $1\frac{1}{4}$" DBH tripled its growth after the complete deadening of understory hardwoods. These hardwoods consisted of post oak, southern red oak, black jack, and hickory with diameters ranging from $1\frac{1}{4}$" to $12\frac{1}{4}$" DBH.

A fairly close canopy that is still not causing the trees to suppress each other will resist ice and wind damage much better than a canopy that has become too open due to thinnings from the top. This was vividly proven to us in Central Mississippi by a tornado in the spring of 1949 and again by the ice storm of last winter which broke down about 20 million feet of timber on our lands. Over-stocked, unthinned stands in many cases were totally undamaged by ice breakage. Those stands which have been heavily thinned from the top generally lost over 50% of their stems while those stands which we had thinned from the bottom in an attempt to emulate nature lost only about 10 to 15% of their stems.

Considerable work has been done in the past few years to determine the best density to which an even-aged stand should be kept during its rotation in order to obtain and retain maximum growth. These densities are generally either expressed by the average square feet of basal area of the trees per acre, or by methods of expressing tree spacing according to the average diameter. Both of these systems - basal area and tree spacing according to diameter - have disadvantages due to the fact that they cannot be expressed by simple figures remaining constant.
throughout the rotation of the stand. For example, basal area should increase during the intermediate stage of the stand and reach maximum a good while before the stand is mature. Also, basal area to the acre is a number which, in itself, conveys little notion as to its makeup in frequency of trees according to size. The various methods of tree spacing according to diameter give widely different answers for the same tree diameters and in small and large average diameters usually give either too heavy or too light a stocking.

There are several measures or expressions of densities which recently have been developed. One of these by Dr. L. H. Reineke is called "stand density index". It is of considerable value in maintaining an even-aged stand at a desired level of density throughout its life. It expresses stand density in terms of the number of trees per acre and average diameter, using a logarithmic formula.

Another is by Mr. G. A. Mulloy who has constructed a table or graph on double logarithmic paper which expresses the relationship between diameter, spacing basal area, and Dr. Reineke's stand density index. This table is especially useful as a guide in keeping even-aged stands at desired densities throughout their rotation. It shows the progression of basal area and demonstrates that rules of thumb can lead to inconsistencies unless they are changed to conform to the changing diameters.

A practical system of thinning even-aged loblolly and slash pine to predetermined or specified densities was devised by Mr. R. Stahelin. This uses as a standard the basal area of a fully stocked stand at a given average diameter based on the yield tables for second growth southern pine. The relative density of a stand is determined by computing its basal area and average diameter and comparing this with the standard. To thin to a given density or percentage of full stocking, it is only necessary to compute the basal area that corresponds to the desired density. Of course, the approximate average diameter of the reserve stand has to be estimated and the difference between the desired and the actual basal area per acre gives the cut. The tally sheets for the marking should contain the stand table and the trees marked are entered in the proper diameter classes along side of it. Tally sheets also should show cumulative basal areas and the marking continues until the desired basal area of the cut is reached. As the marking progresses estimates are made of the diameter of the reserve stand, and, if it differs from the original stands, adjustments are accordingly made in the basal area of the cut.

The above expression of densities and methods of using them are of value and will give accurate and desired answers in even-aged management. However, in order to use them, it is first necessary that an accurate estimate of each stand be available. It is doubtful that many landowners have such estimates. We do not have the necessary detailed information for portions of our lands and also for the lands of individuals for whom we are
supplying marking services. Because of this, it is thought best to use combinations of rules of thumb varying as the average diameters change in order to keep the stand nearest the basal area which will allow the greatest average growth.

It is assumed that a fully stocked stand of loblolly pine will have a basal area ranging upwards from 150 square feet (a marginally merchantable stand with diameters about 4" will be closer to 100 square feet). Also, it is assumed that for maximum growth under a cutting cycle of approximately 5 years, the basal area of the even-aged stand should be reduced to about 80 square feet at each thinning until the average diameter of about 11" is reached, at which time it should be allowed to grow until its basal area approaches 120 square feet. By the time it reaches that, the average diameter will be several inches larger than 11". If the basal area of 80 square feet is retained, the crowns of the trees will generally be too far apart and the forest space will not be fully utilized. Below are listed rules of thumb for proper spacing at certain average diameters:

4 to 5 inches DBH - DBH plus 3, expressed in feet
5 to 7 inches DBH - DBH plus 4, expressed in feet
7 to 9 inches DBH - DBH plus 6, expressed in feet
9 to 11 inches DBH - DBH plus 8, expressed in feet

After 11 inches average DBH of the stand is reached, a rule of thumb of DBH plus 6 expressed in feet will allow the basal area to approach 120 square feet.

It is known that a rule of thumb does not help select what trees should be cut or left, but it is an aid in visualizing how heavily to thin depending on the average diameter and the planned cutting cycle. The timber markers are guided by these rules and also by the natural thinning ideas expressed earlier in the paper, and it is hoped that they approach the right answers in a practical and efficient way in the absence of detailed timber estimates and stand tables.

Many, many thousands of acres of pine land in the south today are covered by dense, over-stocked, stagnated stands of unmerchantable size pine timber with diameters ranging from 4" DBH on down to seedlings. Sooner or later, and mostly later, some of these trees exert their dominance and finally the stand becomes of merchantable size and can be thinned profitably or without cost.

Mr. Fred Gragg, Division Forester of International Paper Company at Georgetown, South Carolina, built several machines for the purpose of thinning these unmerchantable stands of timber. They operate like a giant cotton stalk cutter and consist of a large steel drum on which are mounted grader blades or old veneer knives. This drum is filled with water to add weight and mounted in a steel frame. It is pulled by a D-4 size tractor which is protected on the front by a sturdy bumper and brush guard. The tractor knocks down the trees and the chopping machine cuts them into 18" lengths as it clears a swath about 8' wide.
Parallel rows are made through the woods and as thin a line of trees as is possible is left between them.

Last year in Central Mississippi the average cost of thinning an acre in this manner was $2.25. It is within the realm of possibility to shorten the rotation of a stand ten to fifteen years by the use of this non-commercial thinning machine and thereby greatly increase the returns from an even-aged forest.

Bibliography


DISEASE FACTORS IN THE MANAGEMENT OF YOUNG, EVEN-AGED SOUTHERN PINE

By

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So far as their pathology is concerned, young, even-aged stands of southern pine differ from plantations mainly in three ways: (1) In stands established by seeding, the root arrangement is usually normal, whereas in planted trees poor planting can result in adverse effects due to poor distribution of roots and root strangulation; (2) the seed source of planted stands is uniform and may not be of the most desirable source for the site; and (3) the age of a planted stand is uniform, leading to possible epidemics if conditions are right for a given disease when the trees reach a susceptible age.

Disease succession in young stands could be discussed by diseases or by tree species. From your standpoint I believe the latter is preferable, since any one operator is likely to be dealing with only one or two species in a limited area.

Longleaf Pine

The brown-spot disease may occur on longleaf seedlings anytime from the first year on, over most of the longleaf range. It is caused by the fungus Scirrhia acicola, which infects by two spore stages, conidia and ascospores, both produced on the killed needles.

Where needle killing involves more than a small percentage of the needle tissue, this disease can be a major factor in delaying initial height growth. This effect has been demonstrated by getting earlier height growth when longleaf is kept relatively free of brown-spot by spraying or by fire.

A single fire a year or two after stand establishment will often reduce infection sufficiently for the next 2 years to enable the trees to grow out of the grass stage. Some mortality may result from the fires, especially in the case of seedlings with many dead needles or other highly combustible material around them, but in general, prescribed fires are helpful in the case of brown-spot on longleaf.

The fusiform rust, caused by the fungus Cronartium fusiforme, can attack young longleaf, and in occasional cases may be severe. I saw a longleaf plantation near Columbia, S. C., with 80 percent of the trees bearing rust cankers. Usually, however, only a few percent are attacked, and the disease can generally be ignored in young longleaf stands. The fungus spends part of its life cycle on oak leaves, from whence come the spores that attack the
pine. The major discussion of this disease will be under slash and loblolly pine.

Pitch canker, caused by the fungus Fusarium lateritium f. pini, is common in some young longleaf stands in the south Atlantic States, and apparently to a lesser extent in the Gulf States. It kills leaders, producing cankers with little or no swelling, that bleed gum copiously, and the wood of which becomes heavily pitch-soaked. Branch killing also occurs. The disease seems to be of recent origin and is being watched to gauge its ultimate importance. The fungus causing pitch canker is the one that we have been experimenting with to prolong gum flow in trees being turpentined, and to induce pitch soak in living trees.

Other common diseases of young longleaf include needle casts and needle rusts. The needle casts cause the commonly noticed late winter browning, and seem to have little effect on longleaf. The needle rusts cause typical rust pustules on needles in the spring, and require an alternate herbaceous host to complete their cycle. They do little damage to longleaf. No important diseases bother older longleaf unless rots follow severe injuries, or in the case of older trees the redheart fungus enters large branch stubs and causes trunk curl.

Slash Pine

Brown-spot can often be found on slash pine but is usually not severe enough to cause important growth reduction or mortality. However, in restricted localities in south Mississippi it has been observed to almost completely defoliate young seedlings. Brown-spot control through the use of fire, in slash pine, cannot be recommended because of the disastrous effect of fire on young slash seedlings.

The fusiform rust is often a limiting factor in the success of even-aged natural stands and plantations of young slash pine in much of the Gulf Coast area, in many localities farther north, and also eastward to the Virginia coast. The spores formed on the oak leaves can apparently infect pines 1/2 mile or more away so that elimination of the alternate host, as practiced with the white pine blister rust, is not feasible.

Attacks are common during the first several years whenever weather conditions in the spring favor the spread of the rust. This was the case in 1938, in 1945, and again in 1949. Severity of attack is increased by wide spacing, fire, cultivation, and fertilization. These practices induce early shoot growth and prematurely expose the tender shoots and new needles to infection by spores from the oaks.

Where the rust is severe, spacings of 4 by 4 feet or 4 by 5 feet are recommended, and some trees that already have branch cankers can be saved from lethal trunk cankers by pruning off, cutting flush with the main stem, those branches bearing a canker within a few inches of the main stem. Removing cankered trees
has little or no value as a sanitation procedure.

The best guide to sites where excessive rust damage can occur is the degree of occurrence of cankers on the natural reproduction in an area under consideration for planting. Heavy abundance of trees of the black oak group is also an index of high rust hazard, particularly water, willow and laurel oak.

We hope, through current studies of rust susceptibility of geographic strains and individual tree resistance, to eventually be in a position to provide seed that will yield rust-resistant slash and loblolly nursery stock. We are cooperating with Wakeley's geographic seed source study with this in mind.

The pitch canker disease is killing leaders on slash pine in many areas. In parts of Florida it is common to find pitch cankers on 60 percent or more of the young slash pine in natural stands with most of these cankers resulting in death of the leader. Except in isolated cases, this disease would not yet be classified as generally serious, although some cankering on slash pine earlier attributed to the rust may well have been pitch canker. No control for this disease is known.

Needle rusts and needle cast occur on slash pine. The latter appears to be caused mostly by Hypoderma lethale. This fungus causes such complete browning of slash pine in late winter and early spring along the Atlantic Coast that we receive numerous reports almost every spring that large areas of slash appear to be dying. The effects of needle cast seem to be generally slight, and when the new growth appears, the browned trees usually appear healthy and growth is practically normal.

Butt and trunk rots become a factor in slash pine usually at an age far beyond current expected sawtimber rotations, except in stands injured by fire, ice, or excessive rust.

Loblolly Pine

Recent information indicates that brown-spot, which is usually regarded as a problem only on longleaf, can markedly check the growth of 1- to 5-year-old loblolly. This fungus also causes a striking fall and winter needle browning of loblolly in the sapling and sawtimber sizes along the Atlantic Coast and possibly elsewhere.

The most serious disease of young loblolly is the fusiform rust. On this species the typical spindle-shaped swellings are formed, in contrast to the flatter lesions on slash. The factors affecting the disease in loblolly are similar to those already given for slash. When the weather is warm in late winter, particularly March, followed by cool moist weather in April, serious outbreaks can be expected. The limbiness of some loblolly pines makes them good targets for the rust and may make the pruning of cankered branches on loblolly of particular value in keeping stem cankers to a minimum.
A major difference between the effect of the fusiform rust on loblolly and slash lies in the fact that loblolly, even when stem-cankered, will often live and produce a merchantable stem, whereas slash pines, when stem-cankered, usually die or break over at the canker.

Another stem rust, Cronartium cerebrum, occurs on loblolly and shortleaf. It also has the oaks as alternate hosts, and produces spherical galls on the pine. This gall rust does little damage.

The pitch canker has not been found on loblolly and inoculations on this species have failed.

Needle rusts, particularly Coleosporium solidaginis, with its alternate stage on goldenrod and aster, and C. vernoniae, with its alternate stage on ironweed, often become so abundant that when one walks through a stand in spring clouds of orange-colored spores rise and clothing becomes rust-colored. Even under these conditions it is doubtful that these needle rusts affect growth materially.

Spring needle-browning is also common in loblolly but we have not studied its significance.

A condition that might be called "black root rot", in which the roots of young loblolly on heavy soils rot and become blackened, followed by death of the trees, has been giving us concern in planted stands in North Carolina, South Carolina, and Tennessee. The cause, beyond adverse site conditions, is not known.

Loblolly beyond 20 years old is subject to littleleaf, although to a lesser degree than shortleaf. When this disease becomes very noticeable a stand should be harvested, since from then on mortality and growth reduction will usually exceed increment. This disease will be discussed further under shortleaf pine.

Shortleaf Pine

Shortleaf suffers from fewer of the juvenile diseases than the other species discussed. It is subject to pitch canker, rust cankers and galls, needle rusts and needle cast, but it is unusual to find any of these diseases as limiting factors in young shortleaf stands. Shortleaf is also the most resistant of the southern pines to damage by ice and snow.

In shortleaf pine, the most important disease called the littleleaf disease, seldom makes its appearance before an age of 20 years. Anytime from then on shortleaf growing on the soils of relatively poor internal drainage in the Piedmont region of the south Atlantic States and the upper Coastal Plain of Alabama, and in parts of Tennessee, are subject to littleleaf. This disease is characterized by short yellowish foliage, greatly reduced shoot and wood growth, and premature death. Littleleaf trees do not
Littleleaf has been found to result from a nitrogen deficiency of the tree, due to destruction of the fine root system, largely by the fungus *Phytophthora cinnamomi*. This fungus causes severe root disease in avocados in California and of pineapples in Hawaii. It caused a major root disease of American chestnut prior to the blight, and also affects several other hosts, including heather, rhododendron, and red pine seedlings.

In the case of shortleaf and loblolly pine, the fungus is generally distributed but as in the cases of the other hosts, becomes strongly aggressive primarily under conditions of poor subsoil drainage. The spores that attack the roots are motile and need water to swim to the root tips.

Our work is reaching the stage where we expect to be able to estimate the littleleaf potential of an area by measurement of certain soil variables, and so define areas where management for shortleaf pine is a poor risk. In cooperation with the U. S. Forest Service we are also carrying out soil amendment and species composition changes aimed at reducing littleleaf through rebuilding optimum forest floor conditions.

Our program of instruction in the salvage of littleleaf stands is resulting in the utilization of millions of feet of affected timber that would otherwise die and be lost.

We also have an active program involving the testing of geographic sources of shortleaf planting stock from over most of the range of the species to compare sources with respect to littleleaf resistance. Selected healthy residual trees on severe littleleaf areas are this year also being crossed with each other and also self-pollinated as the first step in determining whether littleleaf-resistant progeny can be produced.

Cutting guides have also been formulated, which call for light frequent cuts in areas with up to 25 percent of the trees showing clear symptoms of littleleaf, and virtual clearcutting, except for seed trees, in even-aged stands with more than 25 percent of the trees in advanced littleleaf.

Our pathologists will help you wherever they can. Those in the South, dealing with pine diseases, are located at Saucier, Miss.; Lake City, Fla.; Athens, Ga.; and Asheville, N. C.
THE EFFECT OF EARLY THINNING ON THE GROWTH AND YIELD
OF YOUNG SOUTHERN PINE PLANTATIONS

By
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The bulk of the forest plantations established at Auburn by the Alabama Polytechnic Institute were started in 1932. All of those to be discussed were established on recently abandoned fields of Chesterfield sandy loam to loamy sand soil types. The area is one of transition from Piedmont Plateau to Upper Coastal Plain. It is within the natural ranges of loblolly, longleaf and shortleaf pine; but is about 100 miles north of the natural range of slash pine.

Of the large variety of species and spacing combinations which are represented on the Auburn Forestry Plots, only slash and loblolly pines planted at 6 x 6 foot and 4 x 4 foot spacings were thinned more than a year ago. Therefore, it is for these two species and spacings only that response to early thinning has yet been studied.

For the 6 x 6 foot spacing, comparisons can be made among plots thinned to 600 and to 400 stems per acre at plantation age 12 and plots not thinned until plantation age 19. Plots thinned at age 12 received a second thinning at age 19. All thinnings were essentially from below, but consideration was given to uniformity of spacing and quality of trees left to grow.

Average stand characteristics of slash pine planted at the 6 x 6 foot spacing are shown in Figure 1 and Table 1. As would be expected, total basal area immediately before the age 19 thinning decreased and diameter of the average tree increased with increasing intensity of earlier thinning. In Figure 2 are shown the pulpwood yields of the 6 x 6 foot slash pine plantings. Total yields to each age are indicated by the total heights of the appropriate bars. Stands thinned at age 12 gave higher yields than those not thinned until age 19. This, however, must be explained by the unfortunate fact that there is a difference in the average site quality of the two sets of plots. The site variation is indicated by a difference in average tree height at age 19 of about 10 feet. Of the two degrees of early thinning, the lighter one gave an almost imperceptibly greater total yield of merchantable cordwood with bark included. Measured as solid wood exclusive of bark, however, the yield of the stands thinned to 400 stems per acre was slightly greater.

As shown in Table 2, the number of trees 10 inches d.b.h. or larger at age 19 and their sawlog volume increased with increasing intensity of early thinning.
A comparison of 4 x 4 foot plantings thinned non-commercially to an 8 x 8 foot spacing at plantation age 8 and commercially at plantation age 19 can be made with stands of the same original spacing left unthinned until plantation age 19. Stand characteristics and yields of the 4 x 4 foot slash pine plantings are shown in Table 3 and Figures 3 and 4. In spite of low diameter (the trees cut averaged only 5 inches d.b.h.) stands not given the pre-commercial thinning gave higher total pulpwood yields than those thinned at age 8. There were no saw timber trees in the 4 x 4 foot slash pine plantings at age 19.

Loblolly pine planted 6 x 6 feet (Table 5 and Figure 5) responded to early thinning in basal area and diameter growth in the same way as did slash pine of the same spacing. In total pulpwood yields to age 19 though, (Figure 6) the response was a steady decline with increasing intensity of early thinning.

Surprisingly enough, the plots not thinned at age 12 had the largest average number of saw timber trees left standing (Table 6) and the largest sawlog scale. In the stands thinned to 400 stems per acre at age 12, however, 6 saw timber trees per acre had been cut in the age 19 pulpwood thinning because of southern fusiform rust or other defect. The small number of 10 inch or larger trees on the plots which were given the lighter early thinning cannot be so easily explained.

Loblolly pine planted 4 x 4 feet (Figures 7 and 8 and Tables 7 and 8) apparently responded markedly to the pre-commercial thinning in increased basal area and diameter growth of the stand 4" d.b.h. and larger, as well as in greater total merchantable volume. This is in direct contrast to the reaction of slash pine planted at the 4 x 4 foot spacing, a decrease in merchantable growth on the plots thinned at age 8. It appears, then, that on sites similar to those at Auburn slash pine is capable of maintaining rapid growth in denser stands than is loblolly pine.
Figure 1. Basal Area Per Acre

<table>
<thead>
<tr>
<th>First thinned at age 19</th>
<th>Thinned to 600/acre at age 12</th>
<th>Thinned to 400/acre at age 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 12</td>
<td>Age 19</td>
<td>Age 12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Average diameter and heights

<table>
<thead>
<tr>
<th>Trees</th>
<th>First thinned at age 19</th>
<th>Thinned to 600/a at age 12</th>
<th>Thinned to 400/a at age 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d.b.h. : Height</td>
<td>d.b.h. : Height</td>
<td>d.b.h. : Height</td>
</tr>
<tr>
<td></td>
<td>inches : feet</td>
<td>inches : feet</td>
<td>inches : feet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut</td>
</tr>
<tr>
<td>--</td>
</tr>
<tr>
<td>Left</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut</td>
</tr>
<tr>
<td>Left</td>
</tr>
</tbody>
</table>
Figure 2. Pulpwood Yields Per Acre

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Left to grow</th>
<th>Cut at age 19</th>
<th>Cut at age 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>First thinned at age 19</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Thinned to 600/a. at age 12</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Thinned to 400/a. at age 12</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

Table 2. Saw timber per acre left standing at age 19.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>number</th>
<th>Board Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>First thinned at age 19</td>
<td>8</td>
<td>370</td>
</tr>
<tr>
<td>Thinned to 600/a. at age 12</td>
<td>13</td>
<td>750</td>
</tr>
<tr>
<td>Thinned to 400/a. at age 12</td>
<td>20</td>
<td>1,040</td>
</tr>
</tbody>
</table>
Table 3. Average diameters and heights

<table>
<thead>
<tr>
<th></th>
<th>First thinned at age 19</th>
<th>Thinned to 8' x 8' at age 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>d.b.h.</td>
<td>Height</td>
</tr>
<tr>
<td></td>
<td>inches</td>
<td>feet</td>
</tr>
<tr>
<td>Left Age 12</td>
<td>4.8</td>
<td>33</td>
</tr>
<tr>
<td>Cut Age 19</td>
<td>5.0</td>
<td>48</td>
</tr>
<tr>
<td>Left Age 19</td>
<td>6.3</td>
<td>50</td>
</tr>
</tbody>
</table>
There were no 10" or larger trees at age 19.
Loblolly Pine Planted 6' x 6'
Stand 4" d.b.h. and Larger

Figure 5. Basal Area Per Acre

Table 5. Average diameters and height

<table>
<thead>
<tr>
<th>Trees</th>
<th>First thinned at age 19</th>
<th>Thinned to 600/a. at age 12</th>
<th>Thinned to 400/a. at age 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>inches</td>
<td>inches</td>
<td>inches</td>
</tr>
<tr>
<td></td>
<td>feet</td>
<td>feet</td>
<td>feet</td>
</tr>
<tr>
<td>Age 12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut</td>
<td>--</td>
<td>5.1</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.7</td>
<td>30</td>
</tr>
<tr>
<td>Left</td>
<td>5.4</td>
<td>5.2</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>5.5</td>
<td>5.5</td>
<td>35</td>
</tr>
<tr>
<td>Age 19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut</td>
<td>6.1</td>
<td>5.6</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>6.4</td>
<td>6.4</td>
<td>41</td>
</tr>
<tr>
<td>Left</td>
<td>7.5</td>
<td>7.2</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>7.6</td>
<td>7.6</td>
<td>45</td>
</tr>
</tbody>
</table>
Figure 6. Pulpwood Yields Per Acre

Table 6. Saw timber per acre left standing at age 19.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Volume, International</th>
<th>number</th>
<th>Board feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>First thinned at age 19</td>
<td></td>
<td>20</td>
<td>960</td>
</tr>
<tr>
<td>Thinned to 600/a. at age 12</td>
<td></td>
<td>9</td>
<td>400</td>
</tr>
<tr>
<td>Thinned to 400/a. at age 12</td>
<td></td>
<td>18</td>
<td>880</td>
</tr>
</tbody>
</table>
Loblolly Pine Planted 4' x 4'
Stand 4" d.b.h and Larger

Figure 7. Basal Area Per Acre

Table 7. Average diameters and heights

<table>
<thead>
<tr>
<th>Trees</th>
<th>First thinned at age 19</th>
<th>Thinned to 8' x 8' at age 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d.b.h.</td>
<td>Height</td>
</tr>
<tr>
<td></td>
<td>inches</td>
<td>feet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age 12</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>4.6</td>
<td>33</td>
<td>4.9</td>
<td>34</td>
</tr>
<tr>
<td>Cut</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age 19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>5.9</td>
<td>40</td>
<td>6.8</td>
<td>45</td>
</tr>
</tbody>
</table>
Loblolly Pine Planted 4' x 4'

Figure 8. Pulpwood Yields Per Acre

First thinned at age 19

<table>
<thead>
<tr>
<th>Age</th>
<th>Cubic Feet peeled (hundreds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>15</td>
</tr>
</tbody>
</table>

Thinned to 8' x 8' at age 8

<table>
<thead>
<tr>
<th>Age</th>
<th>Cubic Feet peeled (hundreds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>19</td>
<td>15</td>
</tr>
</tbody>
</table>

Cut age 19

Table 8. Saw timber per acre left standing at age 8.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Trees 10&quot; d.b.h.</th>
<th>Volume, International or larger</th>
<th>In</th>
<th>board feet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
<td></td>
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THE PROBLEMS OF A FOREST MANAGER DURING THE EARLY STAGES
OF PLACING A PROPERTY UNDER MANAGEMENT

By

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Definitions:

Forest Manager — The executive in charge of operating the forest business.
Management — The act of organizing a forest business from wild lands.

Early stages in this paper will be the period of time elapsing from the organization of the enterprise through the first cutting cycle.

The growing of timber as a crop in the South has become commercially profitable because of the complete liquidation of original growth timber. This original growth was purchased at ridiculously low values, considering the age and quality of the timber. As long as this cheap, high quality timber was available, higher cost, inferior, second, third and fourth growth timber could not compete. The market for second-growth timber expanded as the old growth decreased. The expansion of the second-growth market created the demand for second growth and the business of growing timber came into being. The forest manager is the professionally trained forester acting in executive capacity in directing the forest business. The exhaustion of old growth timber is very recent, and it is probable that the majority of forest businesses or "tree farms" as they are beginning to be called are less than 20 years old. There is a comparative wealth of data on Forestry, but data on successful organizational techniques is largely in the formative stage.

Fortunately, foresters are a gregarious and curious lot. They get together in two's and three's at the slightest pretext, and exchange information on progress and techniques. Bound together by strong professional ties, the graduates of the various forest schools of the country have passed management knowledge along through meetings of the Society of American Foresters, the Journal of Forestry, the field trips, and the forest schools. The various companies that are manufacturing forest products, and who have subsidiaries forest business have, without exception, aided and assisted anyone interested in setting up his own forest business. To this informal exchange of information, I owe a deep debt of gratitude, since most of the techniques I have successfully used in the management of the various forest businesses I am connected with have come from other foresters working on the same problems. Men of the other professions express amazement and envy at the camaraderie that exists between all foresters, regardless of age, experience or employer. This meeting today is a perfect example of what I am talking about.
The growing of timber as a commercial venture is new, and many programs are being started without a clear idea of which direction the enterprise is headed. The very newness of the business makes this excusable, but the prudent manager will, at the earliest opportunity, define and chart the course of his enterprise as far in advance as possible, using the best information he has available, and obtaining that which he finds is lacking when he begins to chart his course ahead. I believe that each forest manager should have his detailed logging and planting plans charted one year ahead and his general plans at least 10 years or one cutting cycle ahead. Only by doing this, can future problems which will arise be recognized in time to do something about them.

To be effective an organization must have both a working plan and a goal toward which all activities are directed. Naturally, these will vary with the organization. Here is a list of the most prevalent goals.

1. Grow sawtimber only.
2. Grow sawtimber and pulpwood.
3. Grow pulpwood only.
4. Grow bulk cellulose only.
5. Grow products that will yield largest per acre income, regardless of final form.

Most forest managers have to start with cutover lands that have been stripped of most of the merchantable growth, and still contain all the culls of the original stand. His job is to plan the next crop of timber on these lands, and to arrange for a more or less continuous flow of either income of timber products from these lands.

First of all, the boundaries should be established, painted, posted, and permanent land records begun. I mention this because there are still projects that have been underway for many years that do not have their boundary lines painted and identified. The permanent land record is very important, because it contains all the information that succeeding forest managers will need to know in order to properly follow out the original plan of management, and to correctly interpret the results of various silvicultural treatments. I cannot emphasize the necessity of keeping a comprehensive land record book too strongly, because there are some foresters who feel that their job tenure is improved if they are the sole possessor of certain knowledge about a particular forest property.

This land record book should have large pages, be of the loose leaf type, and be kept in a fireproof vault whenever it is not actually in use. It should contain the following information, using one or two pages for each general land office sectional subdivision.

1. Space for recording deeds, abstracts, and numbers.
2. A space for recording the acreage owned, purchase price, and volume of timber products by whatever system is used to keep track of timber volumes. Also, on this same page,
should be a section for depletion so that a glance at the page will show the present status of the timber on the particular section involved. A type map of the largest scale possible should appear on one of the other sheets. This should be kept up-to-date and show the years in which planting, timber stand improvement, road construction, power lines, etc., were built. There should be space for mineral lease information, timber contract data, and for any other items which the forester in charge wishes to write about this particular section of land.

The purpose of this book is to concentrate in one place all of the information regarding the land. The book is a key to the location of the supporting data involved. For instance, a question is raised about a certain tract of land. If the land record book is properly kept, the section to which the contract applies will give the name of the contractor, the date of issuance of the contract, and the volume of timber removed during the calendar year. From this information, the original contract can be readily found in the file for that particular year. With a long term business enterprise such as managing a forest, the paper work of the business must be kept for a great many years longer than that of an ordinary business. It is customary for many businesses to throw away their records after three, five, or seven years. In actual practice, it is found that one cutting cycle (10 years) is about equal to one calendar year of an ordinary business. From this illustration, it is evident that the records that must be kept will be extremely cumbersome and hard to find, unless the pertinent information regarding each tract of land is concentrated in one book.

In accounting practice the keeping of records such as this is usually done by clerical help. I believe that because of the essential long range planning involved in management of a forest, this record should be kept by the forest manager. It is permissible to have someone well acquainted with timber accounting post the various figures in the records, but the land record book should receive a page by page detailed scrutiny by the forest manager at least once in every calendar year. Not only see that the contracts and timber cuttings are posted against the correct sections while this is still fresh in his memory, but it will also enable him to detect the trend of the business and will very likely suggest new subjects of investigation. A record of this type is invaluable in helping new employees get acquainted with the business.

The Type Map

I mentioned previously that this land record book should have in it a type map of as large a scale as was practical. In my own experience, operations under a ten-year cutting cycle were begun with the information that was obtained in an acquisition cruise. The type map obtained in this cruise merely indicated pine or hardwood sites. Since the first few years of operation were concerned with cutting of hardwoods on sites which obviously needed treatment, the need for a correct type map was postponed. Changes in personnel brought on by the war demonstrated very clearly the necessity of having a much more accurate type map. During the progress
took longer for us to see was that the composition of our stands was beginning to change. At first, this was not very noticeable, but after about three years of successful fire protection coupled with numerous trips to other holdings which had been under management longer than ours had, further reinforced our observations that some fundamental change had begun in these stands which we were helping to manage. Some folks have labeled the change "a hardwood invasion". Whatever is the term for it, it has posed questions which have caused many foresters, including myself, to go back and study again the fundamentals of plant and forest ecology. One of the first things that we learn in the study of forest ecology is that the forest composition is not stationary. It is dynamic and moves constantly back and forth in response to the treatment it receives from man, the climate, and from the interior microclimate within the forest itself. All of us are attempting to grow pine. A study of the ecology of the Southern States shows that the hardwoods and not the pines are the climax type for most of the regions. There are certain areas which because of an extremely sandy soil probably have longleaf pine as a climax type, but even on these soils, where the plant succession succeeds far enough in the absence of disturbing factors, scrub oak seems to take over and hold its ground against all comers. The rapid expansion of cultivation throughout the Southern States and its subsequent abandonment in later years has given rise to thousands of acres of old field pine stands. Some authorities report as much as 80% of the Piedmont has been under cultivation one time or another. I have studied photographs taken during the Civil War in order to see what the timber was like at that time and I noticed many stands of old field pine in those photographs which appeared to have been 30 and 40 years old even at that time.

To sum all of this up in a few words, the conclusion is: that when we stop fires, we remove the inhibiting force that has held the plant succession back and we allow it to proceed forward towards a climax type of oak and hickory. This conclusion is not original with us. It appears many places in the literature of forest management in the South. However, in our efforts to bring wildfire under control, we apparently did not have time to read these particular references and so we were left to rediscover this change in forest composition for ourselves.

This symposium today is studying the management of even-age stands of pine. There are certain fundamental physiological reasons why pine must be grown in even-age stands if it is to compete at all with hardwood vegetation. In the first place, hardwoods are able to grow and hold their own in a light intensity of only one-third that needed for pine. This means that a hardwood in an understory receiving one-third of the light of the dominant trees above it can grow and manufacture food. A pine seedling immediately alongside receiving the same light and having access to the same moisture and food in the soil cannot grow. Thus, under minimum light intensities, the hardwood has a considerable advance over pine in making understory growth. On the other hand, in full sunlight the pine possesses enough extra growth ability to outgrow the hardwoods and become dominant in the next stand. This light relationship is fundamental to the management of these
stands. It gives us a clue as to all of the treatment necessary wherever relationship between pine and hardwoods is to be changed. Daubenmire (Daubenmire—Plants and Environment) gives a poignant description of the problem: "If light-demanding species are the more valuable, as they usually are, most of the timber should be felled at once, and sometimes it is desirable to burn the area lightly in addition to remove all shade. The problem of perpetuating light-demanding trees is a difficult one, for by the time a forest of these trees matures, there is generally an understory of young shade-tolerant trees which, after the mature timber is harvested, tends to recover quickly from suppression and form a stand so dense that it completely prevents the reproduction of the desirable light-demanding species". W. G. Wahlenberg in his book on Longleaf says, "Fire holds down, tends to reduce, but by itself seldom completely eliminates understory vegetation. In the more open unburned stands and on moist sites enclosed stands, herbaceous ground cover often gives place to a heavy understory deciduous shrubs and trees. If fire continues to be excluded and hardwood seeds are available, a broadleaf understory invades more and more of the higher ground, developing a tall undergrowth and displacing nearly all herbaceous plants. Then, when drought occurs, the usual sources of moisture tend to dry up and can no longer supply both over and under stories. If the soil is too dry to a depth of three or four feet, the pines may be attacked by Ips Engraver beetles. In contrast, the moisture soil of frequently burned forests maintains the natural resistance of pine to insects. Thus, a sequence of related events may carry a pine stand through less fire, more brush, less moisture, more insects, and finally fewer pines. This cycle need not be repeated often to approach the natural, but undesirable, uplands (hammock) climax forest types. The succession can be checked by prescribing suitable burning treatment". (Dr. Frank Gates in his "Field Manual of Plant Ecology" states, "the relation of fire to succession can be nicely shown in the Southern States where the absence of fire for ten or more years is leading to the replacement of the pitch pines by hardwood species in many different areas".

"Weaver and Clements", "Plant Ecology", has this to say about the effect of light: "The most important effect of the reaction upon light as shown in the succession of dominance after one or more had secured the controlling position with respect to light. This is most clearly shown and is best understood in the case of trees, but it is true of shrubs and in some degree of grasses and herbs. To maintain itself a forest tree is confronted by the two-fold task of being able to grow in both sun and shade. If it is the first tree to invade, the crucial test comes when it has reacted upon the light in such a way as to make it necessary for its seedlings to seize in the shade. This is a test in which practically all pioneer forest trees fail. The species which invade the pioneer forest must grow in reduced light intensity for a long time until the individuals stretch above the original trees."

The change of the leafy top from shade to sun is an advantage however, and it marks the beginning of the disappearance of the trees of the first forests today. The reaction of closer growth,
denser crowns, or both, decreases the light still further, with the result that the seedlings now meet a severer test than did those of the preceding generation of the same species. In most cases they are able to establish themselves, but in smaller number and with reduced figure. They are placed at a disadvantage in competing with seedlings that endure deep shade. When these enter, they soon gain the upper hand, reach up into the dominant layer, and gradually replace the species already in occupation. In most, if not all, regions with a climax forest, this process may be repeated several times, one associates succeeding another, until the species of seedlings enduring the lowest light intensity are in final possession. Dr. Braun in her book, "The Deciduous Forest of Eastern North America" says of the oak-pine type, "However, except on poor soil and in dryer sites pines are more or less temporary and are ultimately replaced by deciduous species". Korstian and Coil, in writing of the Forests of the Piedmont have developed the following succession of communities: herbaceous, pine invasion, pino forests, hardwood invasion (establishing a deciduous understory) mixed pine oak, oak or oak-hickory climax.

I could cite a number of other references, all of which confirm the more or less transient condition of pine in the long range life of a forest. I have deliberately gone into detail on some of these references in order to furnish the basis for the discussion of this problem. H. H. Chapman in his article "How to Grow Loblolly Pine instead of Inferior Hardwoods" has this to say about the management phase of this problem. "The way for man to succeed in imposing his directed intelligence on the forces of nature is first to acquire a thorough understanding of these forces. If he lacks this understanding, they will inevitably defeat him".

Now that we have a brief outline of this problem, let us go back to the type map which we discussed a few minutes ago. Most of the tract of cutover lands that have been placed under management represent a hodge-podge of forest type and conditions, with types changing every few acres. In order to properly interpret what is going on, it is necessary to know what to look for when examining these stands. Dr. Braun in her book on "The Deciduous Forests of Eastern North America" says, "In a forest the perpetuation of the existing types is indicated by the essential accordance of canopy and understory layers". For this reason, statistical data on forest composition should separate the canopy layer from the second layer, whose individuals will gradually replace the trees of the canopy, as these die off as the result of old age or accident. The proportions in lower layers are less significant, as competition will eliminate many individuals and as different species respond differently to suppression. Lack of accordance of canopy and understory is always indicative of change, of development or succession. In other words, where a pine understory is present, it is safe to assume that there is accordance of canopy and understory layers. Where a hardwood understory appears there is a lack of accordance between canopy and understory layers and is indicative of a change. We all know that this is a change which we do not want to take place. We need to develop
our management plan so as to counteract this change. One of the primary requisites of this will be to know where the change is taking place, how fast it is taking place, and what relation this bears to the rest of the property. This is where the type map of the property is an absolute necessity. In making the type map, we went far beyond the usual type map which usually indicated pine or hardwood site only. We worked out a system whereby we could express for each type the relationship between the pine and the hardwood, not on the basis of size, but on the basis of density. The pine was given a rating of 1 through 4. Pine-1 being stands in need of cutting from a density standpoint without regard to size. Pine-2 represented merchantable stands, but not in need of cutting. Pine-3 were stands principally of sapling size, and Pine-4 were stands of pine reproduction size. The same system was used for the hardwoods, and combinations of these two for each type gave the relative position of the pine and the hardwood for each stand in the entire forest.

(Illustrate this by blackboard illustrations)

After the type map has been completed, the area of each type can be calculated and then plotted graphically for the entire property (make diagram on blackboard). Only when these areas are charted graphically can the relative importance of the various stands be detected. This chart of stands also helps the forest manager in determining what kind of work is most essential. Analysis of this chart will also indicate which of the necessary silvicultural treatments are commercial in character and which are non-commercial. For instance, mixed pine stands containing merchantable hardwoods can be treated by selling all of the merchantable hardwoods in order to release for additional growth of the pine. Areas occupied by unmerchantable hardwoods will have to be treated by company crews, either by girdling or by poisoning. The relative proportion of acreage in each of these conditions will also give the manager a guide as to the rate at which this work must progress in order to bring the forest to the desired condition at the end of the first cutting cycle.

From the management standpoint, it is also desirable to classify the stands on the basis of the soil type on which they are growing. In certain areas in the South, clay soils interfere with logging during wet weather. Forest managers in these areas should separate lands into areas capable of being worked in the dry season and the wet season. If these areas are out of balance, areas that can be logged during wet weather should be set aside in a special wet weather reserve and the growth allowed to accumulate in these stands in anticipation of a wet year when perhaps four or five years equivalent growth will have to be harvested during one rainy season. If the area of wet weather operations is small compared with the rest of the holdings, it would be extremely desirable to increase silvicultural treatments on these lands in order that they may have the most rapid growth rate of all portions of the property. If the owners of the land are dependent on a year-round supply of forest products, the winter cut lands should be covered by a separate management plan. If the
owners of the land are dependent on a year-round supply of forest products, the winter cut lands should be covered by a separate management plan. If the owners of the property are only interested in annual income regardless of what time during the year it is received, this is not of such a great necessity. However, from the standpoint of stumpage prices received from the sale of products, it would be well to withhold areas that can be logged during wet weather until such time as logging cannot proceed on the wetter and muddier locations.

In order that there can be continuity of operations over a period of as long as 10 years with an inevitable change in personnel and management, some form of management plan must be made. If the initial cutting cycle is to be 10 years, then the area should be divided into approximately 10 equal areas after eliminating the wet weather operation lands, if this is considered necessary. After the blocks have been laid out, the forester in charge should tentatively assign a relative cutting position to each of these blocks. The assignment of position to these blocks is one which calls for careful consideration of many facts. One of the most important and also one of the least recognized is the succession of age classes that may have been set up as a result of the liquidation of the original stand of timber. On the property which I manage, the previous owners began logging in the southeast corner and proceeded northwestward taking 20 years to remove the virgin timber, using railroad logging. For a period of four years at the close of the operation, the more advanced stands of second-growth were cut and logged by truck. In the main, however, this logging set up a series of age classes which was about in proportion to the schedule of removing the original timber. This arrangement of age classes did not leave much flexibility in the planning of the first cutting cycle. The oldest stands and the ones most in need of treatment occurred where the earliest cuttings of virgin timber had taken place. The stands that contained the least volume naturally occurred in those areas where the most recent cutting of the virgin timber had taken place. Scattered throughout the tract were holes and gaps left by the cutting of the advanced second growth. As a result of this consideration, the area was divided into 10 yearly cutting blocks, on the basis of the age classes that had been established by the logging of the virgin timber. On forests which have been assembled by the purchase of many units, reference to the arrangement of the types will provide a clue as to how best to make this arrangement of blocks.

Division into blocks is necessary for the intensive treatment that must be given these second-growth stands. By concentrating all of a year's operations within one block, a considerable economy in manpower and travel time is effected. Supervision can be extended to many more men operating within a close area than would be possible if operations were scattered all over the forest. The surveying of interior boundary lines, the marking of timber for sale, inspection of timber cutting, and timber stand improvement operations such as girdling and poisoning, will all be underway in one block in any given year. A forester may supervise three or more crews engaged in various types of activities, each within a short distance. Supervision of the logging is affected because of the close concentration of personnel in that area. It is highly improbable that all of the work needing to be done in a block can be done in one year. As the logging moves forward into the next block, a residue of uncompleted work in timber
stand improvement will undoubtedly be left behind. This residue will probably accumulate, since it has been the experience of most managers that the amount of timber stand improvement work needing to be done is far in excess of the labor available to do it. As a result, the type map will furnish the locations of those areas most urgently in need of timber stand work, and on which money spent will be of the greatest future benefit. By referring to the type map, any surplus labor which can be diverted from other projects can be sent back to continue timber stand improvement operations in blocks that have already been cut over.

The management plan must be flexible in order to take care of new markets as they arrive and the fluctuation of business conditions. In other words, the manager should have the authority to, and should not hesitate to begin logging operations in blocks that are scheduled for future operations if, in his judgment, the benefits from the sale of timber justify the change in the management plan. I refer specifically to the market for hardwood material which has fluctuated greatly within the past ten years. There have been times when there has been an exceptional market for hardwood cross-ties. The forest manager should not hesitate to harvest all of the hardwood cross-ties he possibly can without regard to his block operations which are concerned principally with pine. As markets for dogwood, hickory, and other products appear, they should be taken advantage of, regardless of the block in which the timber is cut. There will be certain operations in which it will be necessary to cut a limited amount of pine in order to give a sufficiently heavy cut per acre to interest a contractor in moving hardwood. Again, where cuttings of this type are possible, they should not be rigidly limited by a management plan.

Business conditions will also modify the management plan. I believe that it would be a sound practice to allow for a yearly income of twice the normal amount during any year of a ten-year cutting cycle. In other words, allow for the possibility of having double income in timber sales for one year out of the ten years for which you are planning. This has been found to be necessary because of the ups and downs in the business cycle. There will usually come a time within a ten-year period when business conditions will be such that extra income will be required from the forest in order to offset other unfavorable business conditions. It may be necessary to offset declining sales of other company products. It may be necessary to help finance an expansion in other company activities, or to finance expansion for the purchase of additional timberlands. If the manager can plan in advance for this increased demand for revenue from the forest, he will not be unduly distressed when he receives the request for it on short notice.

After a management plan has been set up covering the operations of one cutting cycle, it is necessary to begin to accumulate information which will be used to make the management plan for the second cutting cycle. It is my own personal opinion that a growth study at the beginning of the first cutting cycle on any property would largely be a waste of time. Stands which are just being brought under management are changing rapidly in their volume and
the extent of the change is governed in many cases by the rate at which timber stand improvement work can go forward. I believe that the first cutting cycle should be devoted to the cleaning up of each stand as it is reached in the course of the management plan without too serious consideration toward uniform yield or distribution of age classes. I realize, of course, that a certain revenue must be obtained from the forest each year in order that it may pay its own way, but I think that the needs of the stands for treatment of one kind and another offsets the restrictions which might be placed upon it by trying to stay within a figure determined by a growth study. In other words, a forester treating a second-growth stand in accordance with the silvicultural considerations which we are discussing here today will not exceed the rate of growth for the property as a whole. I do not believe that any attempt should be made to regulate the area of various age classes until the second cutting cycle. If we are going to do this in the second cutting cycle, however, information must be accumulated through the first cutting cycle on which to base the plans for the particular property involved.

Our forest is one of mixed pine and hardwoods. We do not yet understand the complete relationship between these two types of trees. In order to secure more specific data for our forest, we have established a one-acre square permanently marked plot in the northwest corner of our land holdings within each governmental section subdivision. This plot has been marked permanently and given a 100% cruise. No attention is paid to the plot when the timber is marked for cutting. Marking and logging proceed through them exactly as though they were not there. After logging is completed, a recheck is made on the plot and the depletion from logging is checked against the original plow and the cut per acre is obtained. This also shows the sizes of timber which were removed and the sizes of timber left. Periodic remeasurements at five-year intervals will show the change in both the composition of the stand and the volume per acre.

We have found that volume per acre is a very misleading figure to use in working out long range management plans. We think that the number of trees per acre is a more reliable guide than total volumes. A satisfactory volume per acre may be concentrated on a few large trees, with an understory completely lacking or made up of undesirable hardwoods. The figures as to the number of pine trees per acre and the number of hardwood trees per acre are much more indicative of the actual condition of the stand. It is assumed that if the pine tree is present on the ground, a forester has sufficient knowledge to grow this tree to maturity if he so desires, or to remove it at any step along the way for whatever product he chooses. In the final analysis when working toward adequate stocking to maintain the highest yield of timber products, we are of necessity talking in terms of number of trees per acre. When we begin to keep our records on this basis, then we have gone a long way toward the proper understanding of our problem.
The number of trees per acre is important for another reason. Most foresters would define a pulpwood tree as one between 6 and 10 inches d.b.h. Actually, the concept of pulpwood is not one of the size of an individual tree, but it is a concept of stem density. Eight inch pine trees growing 20 to 25 feet apart are not pulpwood trees. They are immature sawtimber trees. Although it is true that if these trees were cut down they could be sold as pulpwood, yet, to do this would destroy the pine component of the forest. Pulpwood is available as a marketable crop only if the stand is sufficiently dense on the ground to allow pulpwood to be removed at thinnings. This concept of pulpwood as being related to one of stem density is very important, since much of our forest management is being done by companies who consume pulpwood. For the proper relationship of our stands, we should turn again to the graphic representation of our type map and type analysis. (Illustrate on blackboard). I think you will be surprised at the small amount of pulpwood that is available from thinning in the usual second-growth pine-hardwood forest. Unless pine trees have the spacing of less than 15 feet, there will be no pulpwood available for thinning, if sawtimber is to be grown. The U. S. Forest Service estimates the average annual increment for an entire stand in Southwestern Arkansas at only .360 cords per acre and in Northwest Louisiana at .33 cords per acre. This reduction in yield from the possible yield of one cord per acre per year and more is directly due to the lack of enough pine stems per acre. Although the reproduction and establishment of a stand is not being considered at this meeting, it is obviously of the utmost importance for foresters managing pulp company lands to bend over backward to secure an adequate stocking of pine trees at the beginning of the rotation. Since yields of pulpwood can be doubled or tripled in this method without interfering with the growth of the sawtimber, this is also important for companies manufacturing lumber, since it increases the amount of pulpwood which can be sold to help offset the carrying costs of the lands.

Keeping Track of Our Progress

In all businesses progress is reflected in statistics - units sold, net profits, cost of production, cost of sales, etc. The forest business, likewise, requires records which will reflect the condition of the business. In the normal business world, the definitions of, and terms used, in accounting are universally known and universally used. The forest industry, however, suffers from a multitude of measurements which are, more or less accurate, and which may, or may not express the true condition of the stand. I wonder how many of you have had the experience of trying to explain to an outside auditor the difference between the measurement of a tree by the board foot of lumber tally, board feet according to the International One-Quarter Rule, board feet according to the Scribner Decimal "C", and board feet according to the Doyle Rule? The same problem came up under the ceiling price division of the late OPA. We had 128 cubic foot cords, long cords, double cords, 160 cubic foot units, 168 cubic foot units, and several other assorted measurements. We are selling products by the board foot, by the cord, by the piece, and by the ton.
Obviously, in order to keep track of production and sales of a business such as this, a better method of keeping records is clearly needed. Forest property growth records kept in terms of the Scribner Decimal "c" Rule or the International One-Quarter Rule will show much better progress than those being kept under the Doyle Rule. Timber which is recorded on the books as pulpwood is sometimes sold for sawtimber. Pulpwood trees grow into sawtimber size and in varying numbers leave the rank of pulpwood and move into the sizes of trees that must be measured in board feet. My experience with forest accounts has demonstrated that this can lead to a great deal of confusion. I believe, therefore, that it is going to be necessary to keep all forest accounts on the basis of cubic feet, regardless of the size or quality of the trees measured. The only accurate method of determining growth rate is in terms of cubic feet, and this can be most accurately applied to a growing stock whose total volume is also expressed in cubic feet. Trees out and sold for sawtimber can be converted to cubic feet and this amount depleted from the total account. Pulpwood, of course, is already sold according to the cubic foot basis. Poles and piling can be readily converted to cubic feet and deducted from the total account. Cross-ties and other miscellaneous products can be readily handled in this manner.

The accounting records of a forest business must be adjusted periodically to show increase due to growth. The Commissioner of Internal Revenue has suggested informally that this be done at least once every ten years. Although the Commissioner has not specified any particular method to be used, the periodic inventory seems to be the best method to use on stands which are developing and changing as fast as our second-growth stands are. Comparison of two successive inventories will give acceptable basis for correcting the account books for growth. Because it is a large scale sample, it will reflect true growth conditions far better than any growth survey or sample plot system could possibly do. It also provides the opportunity of going back over the lands again and of working up comparative stand tables.

Summary

It is the job of the forest manager to take a forest composed of a multitude of different, even-age stands of timber of every conceivable composition and to so arrange the cutting of them so as to produce a continuous yield of forest products. In order to properly do this, the condition of the stands must be known. The area they cover, the dominant understory species and their relationships must be known. A tentative rotation age must be established as well as the tentative length of cutting cycle. The condition of each of these types will govern what the forest manager must do before, during, and after logging in order to perpetuate the timber which he is managing.

The manager must realize that in order to increase the yield of the forest a larger number of trees per acre will have to be grown. The concept of volume per acre without any reference to
the number of trees on which this volume occurs can be very misleading. A high volume per acre may be concentrated on relatively few larger trees, with no understorey of the species which the manager is trying to grow. A forest in this condition cannot be cut until reproduction of the desired species has become established in sufficient amounts. Failure to get this reproduction established in advance of the time of cutting will result in large volumes of timber being unavailable for logging because adequate reproduction has not been established far enough in advance of the time the timber has been scheduled for cutting.

The pine component of the Southern forest is only temporary. This necessitates full scale continuous silvicultural treatment to hold the natural succession at the point that will secure maximum yield of pine, not only for this cutting cycle, but for all successive cutting cycles. This concept will greatly change the ideas concerning the amount of the work necessary to grow a crop of timber. It makes mandatory a much more intensive forest management than was dreamed of, even as recent as ten years ago.

Perhaps the most important work of the forest manager is not concerned with management of the forest, but with the education of his employers. Few foresters are fortunate enough to work for other foresters. Very few corporations owning forest lands are managed by executives having forestry training. Those of us who do work under this circumstance are fortunate indeed. The education of employers as to the long term nature of the program is absolutely necessary in order that they may understand the peculiar problems involved. There is the need of making personnel policy such as to secure the long tenure of foresters. It takes a forester at least a year to secure a working knowledge of his property and the people with whom he must work. It takes at least ten years in order to see the effects of his work, both desirable and undesirable. The most profitable forest enterprises I know are in charge of foresters who have worked with one property for many years. The continuous turnover of personnel has a very retarding effect on any forest management program. The highest type of management cannot be carried out by foresters who regard their jobs as only temporary.

The forester must be a teacher. Although he is working with trees, all of his work must be carried out through people. In order that he have a loyal organization, he must educate all the persons he comes in contact with as to the reasons why certain things must be done. The best management plan will gather dust on the shelf unless it is carried out in the field by the cooperative effort of many individuals, most of whom have an education which stopped at the eighth grade. Forest management must be interpreted in such a manner as to secure the complete cooperation of the several hundred or more logging contractors, woods laborers, neighbors, and other persons involved in doing the actual harvesting and cultural work on the forest.
THINNING METHODS IN PLANTED SLASH PINE

By

A. B. Crow

School of Forestry, Louisiana State University

The study I am going to describe was conceived, designed and established in 1937 by A. D. Folweiler, with the whole-hearted cooperation of Paul Garrison and the Gaylord Container Corporation, upon whose lands the plots lie. Mr. Garrison and his men have maintained the plots for more than 14 years and have made thinnings and measured the wood each time as required.

The study was established in one of the best of the Gaylord plantations when the trees - slash pine - had completed their 13th growing season. The objective was to test various kinds and grades of thinnings to discover which might best suit various objects of management and produce highest yields in volume and value.

Folweiler's approach was not the usual one, however. He elected to make deliberate application of the three standard thinning methods as practiced in Europe, instead of "just thinning" as most of us do. Furthermore, he proposed to keep applying the methods long enough to discover what stand structure and yields each would produce over a considerable period of time. The present speaker has continued this policy.

A brief description of the thinning methods follows. The first is a crown thinning of heavy intensity in which the main cutting is always concentrated in the overstory, principally in the codominants, and small stems are cut only when it is judged they are about to die. The second is a light crown thinning, of similar nature but with much less volume cut. The third is a low thinning in which the smaller, more crowded trees are removed each time before larger trees are cut. Thus, codominants are not touched until all the intermediates are gone and so on up, working always from below. The low thinning was applied with only moderate intensity. The fourth method is the selection or Borggreave method, to give it its European name. Here, large rough dominants are cut as well as suppressed trees, and the clean slender intermediates and codoms are left to grow in size and value. This thinning was applied in heavy intensity. The last method is no thinning, or control.

Each method was applied on two one-acre plots with a measured 1/4 acre in the center, so that there are 10 plots in all. The methods are hereafter referred to as Control, Heavy Crown, Selection, Low and Light Crown.

The Heavy Crown and Selection plots were first thinned at age 13 and the Low and Light Crown plots at age 14. It was planned to thin every five years, but the war prevented accomplishment of this aim. The Low and Light Crown plots were thinned
at age 24, ten years after the first thinning, while the Heavy Crown and Selection plots were not cut again until age 26 or thirteen years after the first thinning. Most of the results here presented are based on what happened in the ten years following the first thinnings at age 13 or 14. All data for each method are the averages of two plots.

Before thinning at age 13 the stand averaged about 625 trees per acre, 103 square feet of basal area, 5½ inches in diameter and 37 feet tall, and volume was about 17 cords. The Heavy Crown plots were cut back to about 60 square feet, the Selection plots to 44 square feet, the Low plots to 88 square feet and the Light Crown plots to 78 square feet. The following charts will show the response made to treatment in each case:

Chart 1 - Number of trees per acre at designated ages. Note that the Heavy Crown and Selection treatments greatly reduced density at an early age and that the Low and Light Crown treatments were conservative. Mortality in all but the Control plots has been small.

Chart 2 - Basal Area development. Severe cutting in the Heavy Crown and Selection plots at age 13 greatly reduced basal area. In these treatments recovery had not been made in five years and original basal area had not even been attained in ten years. These plots were not thinned again until age 26 or thirteen years after the first thinning. Then they were cut back to 70 square feet per acre.

The Low and Light Crown plots, however, recovered in five years and should have been thinned at that time. By ten years after first thinning they stood at 144 and 134 square feet per acre respectively and were badly in need of thinning, which was made at that time. The Low plots were thinned lightly to 110 square feet and the Light Crown plots to 100 square feet per acre.

Total basal area production is very revealing. It shows that regardless of treatment much the same production was reached. The Low plots look high, but were high to begin with and the margin of superiority has not increased. The Control has, up to age 24, held its own in basal area, due to high number of trees per acre.

Chart 3 - Average diameter at breast height. Starting at a similar figure of from 5.4 to 5.9 inches, average diameter shows a striking response to thinning method and intensity. At age 24 the differences, while not extreme, are exactly what would be expected in each case. Thus, the Control diameters are lowest, followed in order by moderate Low, Light Crown, Selection, and Heavy Crown. The latter has produced some pretty large trees, exactly as it is designed to do.

Chart 4 - Average total height. There is nothing unusual here, unless it be that thinning seems to have no particular effect on height growth on the same site. The old idea that close
Spacing stimulates height growth is not born out in these results.

Chart 5 - Average crown percent of total height. The effect of age and crowding is well shown here. At age 13 all plots had long deep crowns. At age 18 the Control, Low, and Light Crown plots were reaching the danger point of less than 1/3 crown. By age 23-24 these plots had lost crown vigor and growth was suffering. The severely thinned Heavy Crown and Selection plots still had fairly long crowns at this age.

Chart 6 - Cordwood production. With height growth little affected by treatment, it would be expected that volume would follow the same pattern as basal area and it does. The main points to note are: (1) the two heavily thinned plots have never caught up to the others in total volume production, although their diameters are larger as previously shown; (2) the moderately thinned Low and Light Crown plots are very productive; and (3) the Control, up to this young age at least, has done about as well as any of the thinned plots. This is the usual response in this case. Its significance will be discussed later.

Chart 7 - Periodic annual increment. All the plots are highly productive at this, the weak period of growth. Note that the Heavy Crown and Selection plots lagged far behind after the first five years but are rapidly catching up. Note also that growth has not fallen off much, if any, in the other two plots, which should have been thinned at the end of five years but were not. Finally, note the good growth shown by the Control plot, which is a matter of heavy stocking and not fast growth in individual trees.

Chart 8 - Mortality expressed in cords. Mortality was naturally light the first 5-year period and increased during the second period when the needed thinning was not applied, especially in the Low and Light Crown plots. Much of the mortality was due to fusiform rust, a factor which tends markedly to disrupt experiments like this one. The Control plots show very definitely the inevitable losses that will occur after age 18 in unthinned stands of southern pines. But don't forget the high volume and growth levels attained by these same plots up to age 24.

Chart 9 - Number of sawlog-size trees per acre. This chart shows better than any of the others the effect of method and intensity of treatment. Again, all treatments produced exactly the expected results. The superiority of the Heavy Crown method in producing large timber in a hurry is clearly demonstrated. Note also that the Light Crown treatment is doing the same thing on a moderate scale. The moderate Low and the Control plots naturally are far behind the others in producing large-size trees.

Analysis of Results

Time will not permit lengthy discussion of the many interesting points brought out by the experiment. Let me call attention briefly to the significant facts as I see them.
1. Up to age 24 at least, no thinning at all will result in as much wood volume as can be attained by any thinning method. Nearly all such studies show similar results. Your speaker is convinced that slash pine on good sites like this one can produce about 50 cords of wood in 30 years with no treatment, and suggests that pulpwood companies might well consider such a practice. The joker, of course, is that planting costs cannot be written off at an early age when no thinning is done and, hence, no intermediate revenue is obtained.

2. Your speaker cannot go along with those who claim that European silviculture has no place in America. The results here shown completely refute that idea. In this case three classical thinning methods were applied as the book said they should and the results were exactly as predicted. The Europeans know their business when it comes to thinning. If you want to grow just wood on a short rotation, don't thin at all. If you want to get high yield and retain lots of stems for future selection, use a moderate low thinning. If you want to get pretty good size and also high yield at a young age, thin lightly among the codoms. If you want superior quality and at the same time high present returns, cut out the big timber every time and free codoms and intermediates for future promotion to larger sizes. Finally, if you want big timber in a hurry, thin very heavily from above and you will get it. The book says this will happen and it did.

3. It is perfectly obvious to everyone that thinning method and intensity should be based on the objects of the owner. Let me briefly point out where each of these methods might find application in southern forestry today:

I have already suggested that pulpwood companies might well consider a policy of short rotations and no thinning. I leave it to friend Bercaw and others to figure out a way to get around the matter of initial establishment cost and compound interest.

The low thinning method as here applied has produced astonishing yield and good quality. I recommend it for the naturally conservative owner who likes to take out the little ones and leave the big ones, since most anybody can do it and the stand is never harmed. Slowed-down growth will come later, but lots of poles will be available for high returns and sawtimber is building up all the time.

The light crown method has produced the best all-around results in this study. In my opinion this is the one for the intelligent owner who wants to make the most money out of integrated production. All products will be available in abundance and yield and value should be high. Our plots show that sawtimber sizes are being attained in a reasonable time and plenty of poles will be ready for sale in a few years. Pulpwood yield has also been good. The method, if applied early and often, will prevent stagnation, save mortality, produce high volumes, and yield a good profit to its practitioners.
The heavy crown method is strictly for the sawtimber people. Our results show that at age 24 the 100 largest trees have a diameter of 9½ inches. If this growth rate can be maintained, the forester's dream of 100 18-inch trees at about age 50 may be realized. On that basis yield at harvest cutting time might approach 30,000 board feet per acre. Quality is, of course, sacrificed to yield, but will still be satisfactory to most operators.

Finally, let's consider the farmer for a moment. Oddly enough, the selection or Borggreave thinning method fits his needs pretty well. When he wants timber for his own use he wants big trees, not little ones. In this method he cuts them once in a while as needed and promotes the smaller but cleaner codoms and intermediates in their place. If practices skillfully, the method yields, at fairly long intervals, a supply of large timber with quality getting better all the time. Also, and this is a point often overlooked but well demonstrated on our plots, a good growth of grass for grazing is available as a result of the large holes made in the forest canopy. Whether we like it or not, most farmers are going to graze their woods and this method gives their woods-run cows a better break than any of the others.

Summing up, these results are too early and fragmentary to be conclusive, but they do indicate some interesting possibilities. As time goes on it is expected that the study will yield more and more useful information, which we shall be glad to pass on to you as it becomes available.
CHART 1 - Number of Trees Per Acre

CHART 1 - Number of Trees Per Acre

C - Control
HC - Heavy Crown
S - Selection
L - Low
LC - Light Crown

Before Thinning
After Thinning
After 5 Years
After 10 Years
CHART 2 - Basal Area Production

- **C** - Control
- **HC** - Heavy Crown
- **S** - Selection
- **L** - Low
- **LC** - Light Crown

<table>
<thead>
<tr>
<th>Age 13 Before Thinning</th>
<th>Age 13 After Thinning</th>
<th>Age 18 - 19 After 5 Years</th>
<th>Age 23 - 24 After 10 Years</th>
<th>Total Production Age 24</th>
</tr>
</thead>
</table>
| Basal Area Per Acre - Square Feet
| 180                    | 160                   | 140                       | 120                       | 100                    |
CHART 3 - Average Breast High Diameter

C - Control
HC - Heavy Crown
S - Selection
L - Low
LC - Light Crown

Average Diameter at Breast Height - Inches

Before Thinning
Age 13

After Thinning
Age 13

After 5 Years
Age 18 - 19

After 10 - 11 Years
Age 24
Chart 4 - Average Total Height

C - Control
HC - Heavy Crown
S - Selection
L - Low Crown
LC - Light Crown

Average Total Height - Feet

Before Thinning
Age 13

After Thinning
Age 13

After 5 Years
Age 18 - 19

After 10 Years
Age 23 - 24

60 50 40 30 20 10 0
Average Crown Percent of Total Height

Before Thinning

- Age 13

After Thinning

- Age 13

- After 5 Years

- After 10 Years

- Age 18 - 19

- Age 23 - 24

CHART 5 - Crown Percent of Total Height

C - Control
H - Heavy Crown
S - Selection
L - Low
L C - Light Crown
C H - Crown Height
CHART 6 - Volume Production

C - Control
HG - Heavy Crown
S - Selection
L - Low
LC - Light Crown

Before Thinning
Age 13

After Thinning
Age 13

After 5 Years
Age 18 - 19

After 10 Years
Age 23 - 24

Total Production
Age 24
CHART 7 - Periodic Annual Increment

Cords Per Acre

1st 5-Year Period
Age 13-14 to Age 18-19

2nd 5-Year Period
Age 18-19 to Age 23-24
CHART 8 - Mortality

Mortality - Rough Cords Per Acre

1st 5-Year Period
Age 13 to 18-19

2nd 5-Year Period
Age 18-19 to 23-24

C H S L C

C H S L C

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
CHART 9 - Number of Sawlog-Size Trees Per Acre
at age 24

Number of Trees

0 10 20 30 40 50 60

0 10 20 30 40 50 60

Control Crown Heavy Selection Low Light Crown
The purpose of thinning is to furnish each tree with room to grow, but with no growing space to waste. Skillful liquidation of the poorer trees and concentration of increment on the better trees increases net income. Net returns are maximized when the growing stock is regulated and held to the smallest amount of timber capital that will produce maximum yields within the capacity of the site and species. With too much volume of growing stock the net return per acre may be high, but the rate of return on the large investment unsatisfactory. With too little growing stock, the rate of return on the small investment is likely to be high, but the net return per acre unsatisfactory.

Economics Supplements Silviculture

The yardstick for measuring what volume of growing stock should be carried and what trees should be cut at each periodic thinning is the dollars-and-cents net return. Economics, however, cannot control the capacity of site to produce pine timber, or the capacity of a pine tree to grow on that site and to respond to silvicultural treatment. Silviculturists, not economists, must determine these fundamental facts. But with these facts available, economics can be applied in determining when, what, and how much to thin. Then these economic answers can be translated into marking rules for use as guides in thinning.

Silvicultural information covering behavior of even-aged stands following various degrees and kinds of thinning is limited and incomplete. Until plantations have been managed for at least one rotation, essential data will be lacking. Accordingly, no attempt will be made here to determine optimum stocking, possible net income for various products or for integrated utilization, or economic answers to numerous other management problems applying to even-aged stands. This paper will be limited to the problem of using financial maturity as a guide in selecting the individual trees to cut in thinning young even-aged stands.

The Financial Maturity Concept

Maximum net returns per acre will be realized if at the time of each thinning only financially mature trees are cut. A tree which will not increase in value during the next cutting cycle at a rate equal to that which could be obtained by taking the money out of that tree and investing it elsewhere at equal risk is financially mature.
The rate against which a tree’s rate of value increase is judged—sometimes called the alternative rate of return—is a thing peculiar to each forest owner, whether individual or corporate. The rates of return demanded from investments vary with the degree of risk involved, being higher for those of higher risks. Likewise, in managing timber the owner expects to earn at a higher rate where risks are higher. With young timber, for example, where risk of fire damage is great, the owner logically should expect higher rates of return than for older timber with less risk.

Using Financial Maturity in Thinning

How can the financial maturity concept be used as a guide in thinning young even-aged stands? Let us use a slash pine plantation with spacing of 6 x 8 feet as an illustration. By age 20, if survival has been reasonably good, the crowns and roots have developed until most of the available sunlight and soil is being utilized. Because of this competition, the rate of diameter and volume growth has decelerated. The trees have cleaned themselves for at least 16 feet. Silvicultural studies indicate that a thinning to salvage diseased, limby and marketable suppressed trees and to stimulate growth of reserved trees is needed. Five years after this thinning the stand would contain about 320 trees per acre with an average diameter of about 8 inches at breast height. Because the crown canopy has closed again, growth has once more decelerated in some trees. Another thinning is needed. Now, let us use this stand to illustrate our case.

Since there is considerable chance of loss from fire, ice storms, and other natural calamities, the owner feels that his risks are fairly high and that he could find another investment of equal risk which would pay 6 percent. He is offered $3 per cord stumpage for pulpwood. Should he mark and sell some of his trees? Evidently it will not pay to hold any trees for further growth unless they will increase in value at a rate equal to that which the money invested after sale of stumpage would earn. He therefore decides to cut not only the diseased and very limby trees, but also other trees that during the next 5 years will not increase in value at a rate of 6 percent compounded annually.

If the value of pulpwood is $3 per cord regardless of tree size, then the rate of value increase of a tree is identical with that of volume increase. If an 8-inch pine tree increases annually in volume at 6 percent at the end of 5 years it will have increased from 0.037 to 0.116 cords. The diameter at the end of this period is 8.9 inches. For all practical purposes any pine tree in the stand that will not during the next 5 years grow at least an inch in diameter is financially mature.

Good judgment, however, must be used before all trees, which apparently are mature, are cut. For example, two trees competing with each other are both growing less than an inch in 5 years.
If one is cut then the other should develop a larger crown and grow more than an inch during the next 5 years. Cutting both would leave an area devoid of trees. In these cases the experienced forester decides which of the two will respond best to release and then marks the other for cutting. In a typical 25-year old slash pine stand with 320 trees per acre, about 20 percent would be removed because they are financially mature. The remaining four-fifths of the trees with more room to grow would be expected to grow at a satisfactory rate of more than an inch in diameter in the next 5 years.

Next let us consider another thinning in this slash pine plantation when it has grown to small sawlog timber. In considering values of saw timber different owners might use different kinds of value, as stumpage, delivered sawlogs, conversion surplus, or realization value. Because most forest owners would use stumpage prices we shall use those values in the example. Furthermore, we shall assume that the stumpage value per M is the same for trees at beginning and end of the 5-year period. It follows that the increase in value is identical to the increase in volume.

Our hypothetical saw-timber stand is well-stocked with 110 trees per acre, averaging 14 inches d.b.h. and 164 board feet (Int. 1/4 inch rule) apiece. Since the stand has previously been thinned several times, there is not much range in diameters, but another thinning is badly needed. Which trees are financially mature? This stand is safer from fire and other natural hazards than the pulpwood stand and the owner considers that the alternative rate of return should be 5 percent. Accordingly, any tree that will not during the next 5 years increase in volume at the rate of 5 percent compounded annually apparently is financially mature. If the tree increases annually in volume and value at 5.0 percent compounded the volume would be 209 bd. ft. and diameter about 15.1 inches at the end of 5 years. All trees that will not increase in diameter more than 1 inch in the next 5 years therefore are apparently financially mature. Here, however, as in the pulpwood timber an experienced forester must make decisions as to leaving and cutting competing trees. Usually a cut, which removes only a fifth of the total number of trees will leave the stand growing at a satisfactory rate.

Now let us go back and consider that point in thinning this pine plantation at which trees grow from that size at which they are usually harvested for pulpwood to a size at which they would be harvested for sawlogs. As an example, a 10-inch tree with a volume of 0.158 cords and a value of $0.47 at $3 per cord stumpage may grow to 11 inches in 5 years. If then harvested for sawlogs it would have a volume of 72 bd. ft. (Int. 1/4 inch) and a stumpage value of 30.72 at $10 per M bd. ft. It would have increased in value annually at 8.9 percent compounded, a satisfactory rate. If harvested for pulpwood, however, it would have a value of $0.61 and would have increased in value annually at only 5.3 percent. As pulpwood, using an alternative rate of 6 percent, the tree is financially mature, but in changing from a pulpwood to a saw-timber
tree it is still increasing in value at a satisfactory rate. No
doubt some trees while increasing in value at 6 percent would com­
pete severely with other trees and not grow in volume at a satis­
factory rate. Thus we may reason that trees, which are of such
a size that they may become a higher valued product within the
period of the next cutting cycle, should be left—provided that
competition with others will not reduce the volume growth below
the alternative rate. A corollary to this is that insofar as
possible the timing of intermediate cuts should be arranged to
allow the greatest number of trees, consistent with the expected
rate of growth, to become the size of the higher valued product
at the end of the cutting cycle.

Application of Financial Maturity Concept in the Woods

To maximize net income in even-aged stands, each forest manager
must know at time of each thinning which trees are financially
mature and which will increase in value at a satisfactory rate if
left to grow. He can use the method developed in this paper to
determine financial maturity for his own conditions. But before
he can put his technical findings to use in the woods, he must draw
up simplified marking rules to guide his timber marker. Can a
marker be trained to recognize financially mature trees?

Foresters now train men to mark trees for thinning of even-
aged stands. They have set up marking rules to guide the markers.
These rules are planned so as to keep a canopy of even-aged trees
and to discourage regeneration. Often "growing space" in terms
of diameters as 3/4D or a designated number of trees or basal area
per acre is set up as a guide. Instructions are given to mark
bark-beetle infested, diseased, excessively suppressed, very limby,
and injured trees first and then other healthy trees if required
to reduce the stand to a desired level of growing stock. It is
especially in deciding which of healthy trees to take that the
financial maturity concept is useful. It gives a sound basis for
judging the economic advantage or disadvantage in cutting question­
able marginal trees.

The only problem in marking added by the new concept is that
of recognizing financially mature trees. In trees of a single age
class this is not difficult. The restricted crowns and distinctive
bark—flatter, less rough, and with narrower fissures—of the slow
growers stand out prominently. After some experience, and with
the aid of an increment hammer or borer, an observing marker can
learn to pick those trees that are growing at an unsatisfactory
rate. He must also be able to predict whether released trees,
reserved for further growth, will grow and increase in value at
a satisfactory rate.

Marking Guides for Thinning Even-aged Slash Pine Stands

The following illustrate simplified marking rules for slash
pine. The rules should also serve for other southern pine species
if the spacing and growth rate suggested are suitably modified.
1. General rules
   a. Maintain a crown canopy over all the area since regeneration is not desired.
   b. Do not remove poor trees if no better trees of this age class are present to occupy the area.
   c. Work for growing space of $3/4D$ (d.b.h.) from stem to edge of crown for each tree.

2. Mark trees in the following priority until desired growing stock level is reached.
   a. Bark beetle infested.
   b. Fusiform rust infected $1/3$ or more around trunk.
   c. Suppressed that will not recover.
   d. Excessively limby.
   e. Leaning.
   f. Very crooked.
   g. Slow growers--less than 1-inch growth in 5 years except where two or more are competing, take one that will release others for accelerated growth; take the poorer and leave the better where practicable.

Conclusion

In conclusion I would like to make two points clear. The first is that economic calculations and formulae cannot replace the judgment and skill of well-trained and experienced foresters in marking timber in the woods. I think my illustrations of marking for thinning in slash pine plantations show how important it is that well-qualified men make the correct decisions on each acre. Bad judgment and mistakes can be very costly.

For the second point, I want to emphasize the fact that the financial maturity concept is not offered as a substitute for good silviculture. It is offered as a method of using economics to determine what is good silviculture. Without sound silvicultural facts it is impossible to apply this or any other economic principle. With sound silviculture however, economics can be applied in arriving at decisions which will result in more profitable management.
A PULPWOOD COMPANY'S VIEWS OF EVEN-AGED MANAGEMENT

By

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International Paper Company
Natchitoches, Louisiana

The major premises on which this paper is based are as follows:

1. The Company owns a great deal of forest land.
2. The forest on this land is considered as a backlog for the mill.
3. Pulpwood has a minimum diameter of 4" inside bark at the small end, but for all practical purposes there is no maximum diameter.
4. The forest is to be managed for maximum returns by fully utilizing the growing capacity of the soil.
5. It is not an objective of management to have sufficient land and timber to supply 100% of the mills' requirements.

An even-aged management system for the Southern Pines on large ownership is dictated by the silvical characteristics of the species involved and by the economic factors involved in growing pine timber in the Southern United States.

The Southern Pines are intolerant trees, requiring a maximum of freedom from the suppressing forces of shade, space, and heavy competition for water. Characteristically they regenerate themselves abundantly; grow rapidly in diameter when spaced out so they do not crowd one another for growing space; grow rapidly in height when not overtopped by other trees, either pine or hardwood; shed their lower limbs satisfactorily at an early age when properly spaced to leave a minimum core of knotty material in the first and second logs; bear seed at an early age when maintained in an uncrowded condition; disperse a heavy crop of seed every few years over relatively wide areas, and generally germinate in large numbers.

It is therefore felt that for a paper company owning large acreage, the even-aged management of the Southern Pines is dictated for the following reasons:

1. It is efficient and economical.
2. It makes for more orderly and systematic management.
3. It yields at least as much timber volume as other systems and should yield more merchantable volume because of full utilization of the soil.
4. The strain of the species is being constantly improved by retaining the thriftiest and best formed individual trees at each successive cut and finally leaving the most choice trees as those to regenerate themselves.
5. It makes for cheaper logging.
6. The items of hardwood, volume and quality control are more readily handled than under other systems.

On a small ownership it is possible that the owner or supervisor can see each tree in the forest once a year and can practice forestry by an intimate knowledge of each acre, impossible of achievement on large ownerships. On large ownership as compared to small, the operating area or stand is similar to the individual tree on the smaller sized forest. Roads and other natural boundaries thus become very important as the boundary lines of the stands with which work is to be done. From an economical standpoint, it would be ideal if stands of pine were grown in an even-aged condition bounded by roads, each age class making up its proper proportion of the forest acreage, and distributed in stands of such size that during each operation it could be handled as a unit. To expect this in a present-day forest is to expect a miracle and to try to place a present-day forest in such a condition through the operations of one cutting cycle is suicide. To be efficient it is necessary to operate the forest on some form of schedule, but it is necessary also to work with what is on hand, coddling it in such a fashion that after four or five cuts it is possible to have the even-aged condition that is required.

Starting with the regeneration of a stand, we feel that the area should have removed from it or destroyed everything except about four seed trees per acre. By removing everything but the seed trees there is usually sufficient disturbance of the underbrush, litter and soil to have prepared a good seed-bed on which the seed can germinate readily. Four seed trees of good form and showing some history of past seed bearing possibilities, will produce on an average sufficient seed to allow for a full stand to be started on the area within a short time.

With some combinations of site and species it is not always possible that there will be a sufficient expression of dominance by individual trees to make it possible for the stand to develop properly. Oftentimes it is possible that even though the dominance is expressed, the sheer numbers of stems makes it obligatory that something be done. In times past, non-commercial thinning in stands such as these was done by means of axes, machetes or knives, wielded by forest laborers. During the past few years non-commercial thinning has been done by the company on the East Coast by means of a giant-size stalk cutter pulled by a tractor and using road-grader blades or veneer knives for cutting down the undesired stems. Thus, at an early age it is possible to achieve desired spacing on the even-aged stands produced by the aforementioned seed trees. By arriving at this initial good spacing at an early age, only those trees which will grow to merchantable size are left to utilize the full growing capacity of the soil, and the period between incomes from the acreage is shortened to a minimum. Of course there is always the period between germinating seed and first cut when there is no income, but there is no reason why this should be a long, drawn out period
leading to higher production costs during the rotation when non-commercial thinning is possible. The forest as a whole will still be represented by stands of various ages from seedlings to financial maturity, making annual incomes possible while waiting for the regenerated areas to come into production.

By starting the new crop off with proper spacing, it is possible to maintain full stands of unmerchantable size that will quickly grow to merchantable size. Further, by having the new crop in blocks of sizable acreage it is much cheaper to manage the entire forest. When the stands are of merchantable size some of the better aspects of even-aged management come to the fore. A full stand with a 1.0 density is maintained at all times except immediately after thinning, and by maintaining the full canopy and a basal area of 100 to 120 square feet per acre, each stem in the stand is growing and putting on increment both in volume and in dollars. No pine trees are remaining in the understory to suffer from the effects of an overwood, and all existing hardwood trees are being given the best treatment possible to hold them in a suppressed condition.

With each successive thinning after the trees have reached merchantable size, the poorest trees are removed and the best-formed, thriftiest trees are left to continue to utilize all the growing powers of the soil. There will not be enough of anything left over to support an understory worthy of consideration. Thus, the trees composing the stand become fewer in number as the stand grows older, but the basal area is maintained; the quality of the trees remaining grows better with each cut, and the increment being put on by the trees is of excellent quality. Should it be desirable to meet long-term trends in market demands, it is much easier with even-aged stands to control the quality of the material produced by maintaining heavier stocking or lighter stocking as the case may be, with a relatively quicker response to treatment.

When the regeneration cut is to be made, there is a great concentration of timber to be moved. This makes for cheaper logging, which is always dear to a sawlog man's heart, and it is possible for him to get on one area the timber that under other systems of management would require him to cover eight or ten times as much acreage.

It is intended by even-aged management, to have excellent quality trees as seed trees; to establish proper spacing at an early age in the stand and maintain it thereafter; to maintain a basal area of 100 to 120 square feet; and to maintain a full canopy; that the pulpwood company will be able to grow its pine timber on a rotation of about 50 years and obtain the highest return from its land.

In summing up we feel that under the even-aged system it is possible to grow pine timber more economically because our stands and, thus, our products are in operating units, not scattered in small openings throughout the forest, making it necessary to
operate on small, scattered stands for all classes of products continually; that we can manage to control undesirable hardwoods more thoroughly by maintaining complete canopies, thus causing them to be either progressively less of a problem or at least not allowed to be given as much chance as they are when the competition around them is reduced; at all times our soil is being utilized to the fullest extent and there is only a one-storied forest in which there is not one story thriving at the expense of the other story; logging is cheaper in even-aged than in all-aged because the logging is concentrated, a heavier cut can be made per acre, and less acreage needs to be covered to get the required volume; the trees are grown in a condition that affords them a maximum of growing space from an early age, the quality being controlled by carrying heavier or lighter stands as is desired; contrary to the concept that even-aged management cannot produce high-quality timber, it can be arranged to produce just as high quality timber, if not a higher quality, than the all-aged system because of the possibility of much more rigid controls; by cutting from below, leaving successively the best-formed, most vigorous trees each time, the strain of the species is improved and the very best trees left to regenerate themselves; lastly, it is interesting to note that experience in Northern Europe started some thirty years ago using the single tree selection system has proven itself to be unsatisfactory. This practice was started in the pine and spruce forests, where it undoubtedly had its best chance of success. However, the results are starting to show up poorly and the practice is being abandoned there as well as in other parts of Europe.
The degree of success a forester may attain in producing near-maximum volume and high quality of wood depends in large measure upon his understanding of what constitutes optimum stock- ing of trees in his forest. In terms of even-aged stands, he must start with a number and distribution of seedlings that results in overstocking and the opportunity for a commercial thinning when the trees attain smallest commercial size and then hold the growing stock at proper density by periodic thinnings until the mature stand is finally harvested. The all-aged southern pine forest is composed of even-aged groups, so the same principles of even-aged management apply.

The D-plus principle of stand structure provides a scientific basis for evaluating overstocking or understocking and for accurately prescribing the amount of growing stock the manager wants left in the woods to meet his particular objectives.

Dominant southern pine trees of equal diameter require the same minimum growing space regardless of species, age or site quality. The D-plus principle recognizes that the definite space requirement of the individual tree relates to stem diameter and can be described with practical accuracy by squaring the figure obtained by adding 4 as a constant to stem diameter in inches at breast height. For example, an 8 inch southern pine requires \((8 + 4)^2\) or 144 square feet of growing space to remain dominant; and a 16 inch pine requires \((16 + 4)^2\) or 400 square feet of growing space to remain dominant. \(D / X\) is merely a convenient, conversational way of saying \((D / X)^2\), although it does express the average distance between adjacent dominants in a normal stand.

Discovery of the D-plus principle of stand structure came about in this way: Some 12 years ago there developed an urgent need among Soil Conservation Service technicians for a simpler approach to problem of thinning young stands than that of trying to teach it in terms of crown classes, crown-stem ratio, or distance between crowns. In hopes that it might be possible to express desirable spacing after thinning in terms of distance between trees for stands of various average diameters, all data presented in USDA Miscellaneous Publication No. 50(1) showing stand diameter and numbers of trees per acre by age and site classes for pine stands 2 inches and over in diameter were retabulated in adjacent columns. In a third column was listed a figure intended to give a general idea of the average distance between trees, assuming square spacing. This figure was calculated by
the formula \[ S = \sqrt{\frac{43560}{N}} \]. This was done for shortleaf, loblolly and slash pine which were the three we were mostly concerned with in dealing with farm woodlands.

By inspection, it was observed that the calculated average spacing figures differed from the corresponding average diameter figures by approximately two, being two greater. Hence the origin of the expression "\( D / 2 \)" as the spacing in fully stocked stands of southern pine. The average of all differences, in the case of loblolly pine, was 1.971 or only 0.029 less than two. Thus, the formula \( (D / 2)^2 \) describing the minimum space requirements in square feet for loblolly pine cannot be far wrong by practical standards. For those of you who are statistically-minded, the cumulative error in using the round number 2 amounts to the equivalent of one 15 inch tree in 294, or one tree to nearly two acres.

The \( D / 2 \) description of spacing in the fully stocked stand is of interest and has some uses in problems of practical silviculture but, for the most part, foresters are more concerned with the characteristics of the dominant fraction of fully stocked stands. After the first thinning, good practice will never again permit the stand to attain \( D / 2 \) spacing. Dominant trees are the ones that comprise our growing stock, hence we need to know all we can about them.

In general, a maximum number of dominant trees represent the stand condition that should exist at the end of a cutting cycle when thinning is needed again. Any less than the maximum number of dominants means understocking which costs both in quantity and quality of production. Any greater number means that some trees are being forced into subdominance and that all trees are losing proper crown development needed for quick recovery after thinning and for optimum board foot growth. Thus, a workable understanding of dominant stand structure is a vital key to the proper control of growing stock.

An analysis of the numbers of trees per acre and average stand diameters for the dominant fraction of southern pine stands was made in the same manner as was previously described for the total stand. The analysis disclosed that the calculated spacing figures differed from the corresponding diameter figures by approximately four. To verify this point, a curve based upon the formula \( N = \frac{43560}{(D/4)^2} \) was superimposed over all data from Miscellaneous 50 showing number of trees per acre by average diameter and site class for each of the four principal southern pines. The curve seemed to fit the data well enough to suit a practitioner. (Charts for the four principal southern pines were exhibited, but only the loblolly pine curve is included herewith).

In the case of loblolly pine, the calculated spacing figures actually varied from the corresponding diameter figures by 4.081 rather than the round four. The error in using 4 for convenience amounts to less than an inch in the average linear distance.
between trees or, if cumulative on an acre basis, would equal about one 15 inch tree in 117 or about one such tree per acre. So the formula \( D / 4 \) seems to provide a practically accurate basis for determining either the total number of dominant trees per acre, or the minimum growing space that a southern pine will tolerate and still remain dominant. The latter is the really significant figure.

Recognition of the definite space requirements of the individual tree is not new although a method for applying the information to the practical problems of forest regulation was not devised prior to discovery of the \( (D / X)^2 \) definition. Thirty years and more ago, Professor Filibert Roth told us students at the University of Michigan that ideal stocking was "room to grow and none to waste". Roth must have been thinking of trees as such rather than of acres of trees.

Later, Professor D. M. Matthews\(^2\) came a little closer to segregating the individual tree as the unit for forest regulation when he observed that "there are certain maximum and minimum limits of spacing of trees in a forest, as:

"a. All the space a tree can use...thus a tree in the open will use space up to the limit of its ability to spread and then can use no more.

"b. Just space enough to keep alive and make some growth. Between these limits the forester works for good growth in volume, high quality, and the maximum safety of the stand."

Neither Roth nor Matthews, however, found a way to describe the space requirements of the individual tree in terms that could be used effectively in regulatory problems and both had to continue the concept of volume or basal area on an acre basis.

That trees of given species and diameter do have definite space requirements has been demonstrated repeatedly and for a variety of species. I will mention briefly three of these demonstrations.

In 1933, L. H. Reineke \(^3\), working with data for 14 species, including the four principal southern pines, found that the number of trees per fully stocked acre varied with the average diameter of the stand and concluded, in effect, that age and site quality have no significant effect upon the number of trees per acre at a given average diameter. His curve for the number of trees per acre over average diameter was described by the formula \( \log N = -1.605 \log D / K \), wherein \( N \) is the number of trees per acre, \( D \) is their average diameter, and \( K \) is a constant varying with the species. (I suspect that it might have been more accurate to have said that the constant varies with ecological type rather than species.) He observed that the curve for 12 of his 14 species followed the same slope though at different altitudes. The exceptions were shortleaf and slash pine and it can be observed that even these curves for diameters exceeding 6 inches conform
to the same slope closely enough to satisfy any practical application that might be made of the information.

Then in 1935 A. L. MacKinney and L. E. Chaiken (4) developed a specific curve for loblolly pine that varies little in slope from Reineke's curve. They confirmed the principle that the number of trees per acre in fully stocked stands relates to average diameter rather than to site quality or age. They defined the curve for number of trees per acre over average diameter for fully stocked loblolly pine stands as \[ \log N = -1.707 \log D / 4.1588, \]
wherein \( N \) and \( D \) have the same meaning as stated before.

H. H. Chisman and F. X. Schumacher (5) carried the principle a step further in 1940 with the conclusion that single loblolly pine trees of given diameter require a definite allocation of space in the stand. They described the space requirement for the individual tree as \[ Y = 0.0480 / 0.0668 D + 0.267 D^2, \]
wherein \( Y \) is in milacres and \( D \) is tree diameter in inches. Here is one of the most significant concepts ever developed but, so far as I know, the Chisman-Schumacher formula has not been used by forestry practitioners in the solution of forestry problems.

It is possible that the reason for non-use of the valuable diameter-space relationship expressed by these three formulas is that their very form has tended to disguise their real meaning and caused them to be classified as academic curiosities rather than as the useful tools of silvicultural management that they are. Expressing the space requirements of a tree in relation to its diameter in terms of \( D \)-plus apparently overcomes this handicap and such expression appears to be about as accurate as the others. (Exhibit chart)

Now to the application of the \( D \)-plus principle to the management of young stands of southern pine.

The most obvious application of the spacing principle is in thinning, or controlling the growing stock as to areal distribution and, in part, as to quantity. I have shown that the extreme limit of close spacing, except in stagnated stands, is described by \( D / 2 \) spacing. I have also shown that the minimum spacing a southern pine will tolerate and still remain dominant is described by \( D / 4 \) spacing. The profession has learned through the years that to reduce a stand from \( D / 2 \) to \( D / 4 \) spacing by merely taking out the suppressed and intermediate trees is not a thinning. The \( D / 4 \) stand is still too dense to permit satisfactory growth. To make a thinning, then, it is necessary to increase the growing space available to each leave tree to something over \( (D / 4)^2 \) square feet. How much over? There is where your skill as a forester, guided by the objectives of management, enter the picture. I have noticed that Gaylord, in thinning its plantations, has stayed very close to the \( D / 4 \) figure - in other words, it has made extremely light thinnings. On the other hand, certain very wide experimental thinnings have resulted in less volume growth than have other, more conservative thinnings. In the Western Gulf Region of the Soil Conservation Service, \( D / 6 \)
Spacing after thinning has been recommended and practiced in the belief that such spacing will result in production of the largest volume of high quality wood in the shortest time, considering the practical aspects of pulpwood and log cutting. While I believe that D / 6 spacing after thinning is an entirely satisfactory specification, I do not say that it is necessarily the best under all circumstances. I do say, however, that whatever your notion may be as to the best spacing of a stand after thinning, it can best be expressed in terms of D-plus. D-plus provides a positive, accurate method for making thinning specifications that are wholly consistent with natural stand structure.

So we have thinned our stand. When do we come back to thin it again? We have had only vague information on this point. It is recognized that cutting cycle cannot be too long without seriously impairing growth both as to quality and volume. On the other hand, it is impractical to cut over the same area every one or two. For the first time, application of the D-plus principle gives us a direct reading on what the cutting cycle should be on the various sites. If our thinning specification is D / 6, and we already know that thinning will be needed again when diameter growth brings the stand back to D / 4 spacing again, then the time it takes to do that is the natural cutting cycle for a given site. Site quality, of course, affects rate of growth, so it takes longer for a tree to increase two inches in diameter on a poor site than on an excellent one. By counting the number of rings in the last radial inch on trees that now have exactly (D / 4)^2 square feet of growing space, we have estimated that it takes from 4 years on site quality 120 to 12 years on site quality 40 for trees to grow back to D / 4 spacing after having been thinned to D / 6. Accurate cutting cycle determination is almost as important in the intensive management of young stands as is the thinning specification itself and I prophesy that before very long it will have a prominent place in management planning.

Another place for application of the D-plus spacing principle is to the problem of plantation spacing. The best plantation spacing, as I see it, must be related to the smallest sized tree that can be utilized at the time of the first thinning. Depending upon local markets, the smallest southern pine products that usually can be marketed in volume are fence posts at about 4 inches and pulpwood at 5 inches d.b.h. It is desirable to have the planted trees grow to these sizes as rapidly as possible and in maximum quantity. The formula \( \frac{43560}{(D / 2)^2} \) defines the maximum number of trees that will reach a given diameter. If more are planted, no more will reach the given diameter and it will take longer for the surplus number to eliminate by suppression. For fence posts and pulpwood, the problem of how many trees to plant figures like this:

- **4" posts**, \((4 / 2)^2\) or 36 sq. ft. per tree = 1210 per ac., -
  20% = 968 or D / 2.7 spacing.
- **6" pulp**, \((6 / 2)^2\) or 64 sq. ft. per tree = 680 per ac., -
  20% = 544 or D / 3 spacing.
In each case, with expected mortality of 20 percent, there would be more than full stocking of dominants at the time of minimum utilization.

Spacing requirements in terms of square feet per tree at the time of minimum utilization is known, and any reasonable combination of row spacing and spacing of trees in the row that provides that square footage cannot be far wrong. Initial plantation spacing is of no concern beyond the first commercial thinning.

One of the most important applications of the D-plus principle is that it provides an orderly procedure for converting the even-aged forest into a series of even-aged groups to attain a distribution of size classes that permits sustained yield cutting. Such conversion may not pertain directly to our subject in this discussion, so I will pass it by with mere mention.

In conclusion, I would point out that for nearly ten years the Soil Conservation Service in Arkansas, Louisiana, Oklahoma and Texas has used the D-plus principle as the basis for regulatory aspects of forestry practices recommended to many thousands of farmers and other small forest owners; our own management plans for some 130,000 acres of public forest embody D-plus regulation; and similar plans are being followed by operators of several large forests. This experience has convinced me that the known space requirement of the individual tree can be used with facility and accuracy, both in planning and application, in the regulation of forest growing stock. In my opinion, the individual tree space requirement, described as \( (D / X)^2 \) square feet, is a natural, biological basis for understanding and manipulating stand structure.

To those of you who are concerned with extending the practice of forestry on private land, I would again call your attention to the fact that discovery of the D-plus principle came about because of the need to devise some means for teaching a workable concept of sound forestry practice to large numbers of people. The system has been an outstanding success in this.

Bibliography

(1) USDA Miscellaneous Publication No. 50. "Volume, Yield and Stand Tables for Second Growth Southern Pine".


First, I want to express some convictions on this symposium. The wonderful setting on L.S.U. campus; the tireless efforts of Professor Crow and others; the unusually solid program of contributing foresters; the inimitable chairmanship of Charlie Connaughton—all these are elements in the success of the Young Pine Management Symposium. I am glad to see it now termed the "first annual" symposium.

Second, I want to orient our thinning of pine plantations in this program. The subject plantations are "baby-sized" compared with the extent of the pinery of the Deep South. We are dealing with less than 1 percent of 14 million acres of forest in the Tennessee Valley—which, as Mr. Nelson pointed out, is and will continue to be dominantly hardwood. Our study, beginning in 1945, is a baby in duration compared with those reported by Messrs. Mann, Bercaw, Livingston, and Crow. Quite logically, we are dealing with pine in the baby stage.

To start with, we were not working with pulpwood thinnings—which had been dealt with by Hank Bull and other investigators and several pulpwood companies. We felt that new simpler methods of fence post preservation could make possible the economic thinning of pine plantations before the pulpwood stage. Our Utilization Section, headed by Bill Darwin, an L.S.U. graduate, investigated problems of peeling and preservation. With fine cooperation by Experiment Stations at Land Grant Colleges in the Tennessee Valley Region, the Forest Products Laboratory, and chemical industries, Darwin's efforts show significant progress in just a few years. Concurrently, our Management Section investigated postwood thinning. We now have a simple method—the subject of our Technical Note No. 9. We have experimental results on the cost of post production and response of the plantation to first thinning. These are not on a test-tube scale. The progress of this utilization-management project can be measured by (1) establishment of some 30 new small treating plants in the Tennessee Valley, (2) interest by pressure treating plants in commercial post procurement areas, and (3) inquiries on peeling and preservation that we receive on the average of 50 per month.

Our data have the following bases: Resources from TVA records by counties; stand conditions from sampling 300 young pine stands; thinning yield and response from 22 experiments, covering 35 acres. These thinnings produced 33,000 posts, 80 cords of wood for pulp and fuel, 41 small poles and 900 light rails.
The 11 charts are used for illustration as follows:

1. Young pine (planted and native) in Tennessee Valley--available for postwood thinnings 1951-1956. The map shows concentration for estimated thinning of 60 million posts in a 6-year period.

"High" - 39 counties (average 1,230,000 posts) could support commercial production of pine posts

"Adequate" - 49 counties (average 220,000 posts) could supply local-use pine posts for farm fencing

"Low" - 37 counties (average 32,000 posts) have established sources of native durable posts of black locust and redcedar.

2. Pine products. Thin plantations from below to use the smallest diameter (inches). Table (given in our Technical Note No. 9) shows minimum specification for products and corresponding DBH of merchantable tree, and of operable stand--the step-ups average one inch.

3. Logging, trucking, peeling, and treating give hourly production costs that are representative for a good operator. They are summarized in the following:

4. Total costs (at $1 per hour for labor) Item - Cumulative

| Produce 100 posts from thinning 1/10 acre | $3.60 |
| Fell, limb, bunch (bow saw) | $3.60 |
| Skid 190 feet (horse) | $1.31 |
| Buck (bow saw) | $1.25 |
| Load and unload (1 1/2 T. truck) | $0.42 |
| Haul 10 miles (return empty) | $0.52 |

Rough posts, total $7.10

Peel in spring of year (drum peeler) $2.90

Treat, cold soak (copper napthenate) $21.00

Treated posts, total $31.00

Treat 10 crop trees per 1/10 acre, selected from the best leave trees. (This follow-up right after thinning is essential for loblolly plantations and desirable for shortleaf.)

Prune to half total tree height to clear one 16-foot log $0.85

Fertilize with high-nitrogen mix (1/2 pound spread in 5-foot radius circle about tree) $0.15

Crop trees treated, total $1.00
6. Drying posts thinned from one acre. This shows peeled and stacked posts ready for treating. The typical distribution, for the average yield of 1,000 posts 6-feet long by diameters:

<table>
<thead>
<tr>
<th>Diameter (inches)</th>
<th>Average Diameter of Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2-inch average DIB at middle of post</td>
</tr>
<tr>
<td>3</td>
<td>3-inch average DIB at middle of post</td>
</tr>
<tr>
<td>4</td>
<td>4-inch average DIB at middle of post</td>
</tr>
<tr>
<td>5</td>
<td>5-inch average DIB at middle of post</td>
</tr>
</tbody>
</table>

In volume the 3-inch bulk up the greatest, the 4-inch next. The 2-inch posts have the least volume, and were produced by too-close utilization of tops.

9. DBH growth varied with average "D plus" stocking in young pine stands sampled by increment borings before thinning. This relationship was independent of average stand DBH in the range from 3 to 7 inches. A graph shows averages for loblolly and shortleaf plantations of fair to good site from which we read:

<table>
<thead>
<tr>
<th>&quot;D plus&quot; of stand (average spacing minus DBH)</th>
<th>Dominants:</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rings per inch</td>
<td>Average stand: Years for 1 inch DBH growth</td>
</tr>
<tr>
<td>6</td>
<td>3.7</td>
<td>2.8</td>
</tr>
<tr>
<td>5</td>
<td>3.6</td>
<td>2.7</td>
</tr>
<tr>
<td>4</td>
<td>4.0</td>
<td>3.0</td>
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<tr>
<td>3</td>
<td>4.9</td>
<td>3.7</td>
</tr>
<tr>
<td>2</td>
<td>6.6</td>
<td>5.0</td>
</tr>
<tr>
<td>1</td>
<td>7.8</td>
<td>5.9</td>
</tr>
</tbody>
</table>

This shows a slowing-up of the rapid growth rate when the stocking of the plantation gets heavier than D plus 4—a guide for thinning. With similar trends the average growth showed superiority of loblolly over shortleaf, good over poor site, and planted over natural stands.

10. Response after thinning in average loblolly pine plantation by (a) selected trees in stand, (b) treatment of crop trees in thinned stand, and (c) treatment of entire stand.

Bar diagrams show 2-year DBH growth ranging from 0.2 inches for "not thinned but marked to cut" to 0.6 inches for "thinned crop trees." When these thinned crop trees were pruned the growth decreased slightly, fertilizing with nitrogen corrected this to give better growth than for not-pruned crop trees. The stand "not thinned" with basal area of 124 square feet per acre increased 15 percent in 2 years. In the thinned stand the crop trees (pruned and fertilized) had 32 square feet that increased 25 percent, and the remaining non-crop trees with 29
square feet increased 19 percent in the 2-year period. We expect the growth in the "not-thinned" stand to slow up with crowding, and growth of the thinned stand to be sustained until next thinning.

11. Loblolly pine plantation--one acre on good site. Estimates are tabulated for producing high-value clear sawlogs from this stand. In this plantation on a 110-foot site DBH growth since first thinning at 13 years has averaged nearly a half-inch annually, and 0.6 inch for crop trees. The initial stand of 850 trees averaged 5.5 inch DBH, with dominants 37 feet in height and form class 67 percent. It is projected to harvest of 100 crop trees averaging 17.8 inch DBH, with dominants 87 feet in height and form class 75 percent. Yields projected through 4 thinnings to harvest total 1,430 posts valued at $143; 16.4 cords of pulpwood, $196; and 37,000 board feet of sawlogs, $2,730. The total in cubic feet is 7,335 valued at $3,069. The thinning interval of 2-inch growth in four years is followed by thinnings at 3-inch intervals. These would be at 6-year intervals if the rapid growth could be maintained, making the harvest at 35 years. Even with some slowing of diameter and height growth, and harvest at 41 years, the yield would show rapid production of sawlogs. Butt logs would have wide but uniform growth rings, cutting out a high percentage of clear lumber from pruned crop trees.
GUIDE FOR FIRST THINNING OF
PLANTATIONS OF LOBLOLLY AND SHORTLEAF PINE

TECHNICAL NOTE NO. 9 - MARCH 1952
Norris, Tennessee
Keith D. Lange*

* Formerly with TVA. Mr. Lange conducted the basic studies for this guide. W. H. Cummings and the late L. V. Kline planned the investigations; Frank E. Blow rendered valuable assistance in the field, and Sara M. Potts on statistical work.
The healthy young plantation of loblolly or shortleaf pine is a promising even-aged stand. It can yield high-value returns in a relatively short rotation. These would come from high-quality butt sawlogs and intermediate thinning products. The real opportunity lies in prolonging the typically rapid diameter growth. To thin as soon as feasible for yield of products is the key.

This guide points the pine plantation toward intensive even-age management. It calls for the following:

1. Thinning the plantation from below in 2 steps.
2. A cut that will yield products that make the treatment economically feasible.
3. Converting plantations of varied condition to a standard of stocking that prolongs rapid DBH growth.
4. Leaving stands with room-to-grow, in contrast to the crowded conditions of "fully stocked" stands.

The stand we are dealing with consists only of those trees over the minimum DBH that yields usable products, such as posts. In the first step we aim to:

1. Thin trees yielding products that pay for treatment.
2. Select to leave the best trees, well-distributed, and from them pick crop trees to produce high-quality butt logs.
3. Reduce competition by cutting some of the large undesirable trees that are merchantable.
4. Bring through for future utilization some of the small non-merchantable trees by providing more growing space.
5. Set up the stand for the second thinning.

When the average DBH of the merchantable stand has increased 2 inches it is ready for rethinning. The second thinning has these aims:

1. To yield some profit from the cutting.
2. To favor superior crop trees for sawlogs.
3. To eliminate all undesirable competition in the stand.
4. To utilize all small merchantable trees that are poor risks for the future.
5. To set up a managed even-aged stand.

The above objectives are reflected in the thinning guide that we present.

Since 1945, a total of 22 thinning experiments yielding 30,000 posts have provided evidence for this guide. Sampling of 300 young pine stands in the Tennessee Valley revealed a wide range of plantation conditions: loblolly, shortleaf, and some Virginia pine planted for erosion control or sawtimber; spacing from 4 by 5 to 8 by 8 feet, that means 2,150 to 681 trees per acre; age, 5 to 20 years; site, fair to excellent; height, 15 to 60 feet; DBH growth of 1 inch in 2 to 6 years; average DBH,
3 to 9 inches; survival, 56 to 100 percent, that gives 380 to 1,610 trees per acre; basal area from 20 to 200 square feet per acre; and potential thinning yields from a few to over 2,000 posts per acre. On the basis of tests, we consider the thinning guide applicable through the above range of conditions.

**Basis for Guide**

This guide has three essential features that are basic to the thinning chart. (1) We will consider only merchantable trees in the stand; (2) the planting square1/ (or foursome of planting spots) is the marking unit; (3) the thinning from below leaves a standard stocking of trees. The following paragraphs enlarge on these points.

1. To consider only trees above minimum merchantability focuses attention on the usable part of the stand. Here are suggested minimum diameters for several usable products from thinning pine plantations from below.

<table>
<thead>
<tr>
<th>Product Kind and length</th>
<th>Specification</th>
<th>Merchantable Tree DBH(o.b.)</th>
<th>Operable Stand, av. DBH of merch. trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post, local use, 6-foot</td>
<td>2.0 inches</td>
<td>3.0 inches</td>
<td>4.0 inches</td>
</tr>
<tr>
<td>Post, commercial, 7-foot</td>
<td>3.0 inches</td>
<td>4.0 inches</td>
<td>5.0 inches</td>
</tr>
<tr>
<td>Pulpwood stick, 5-foot</td>
<td>4.0 inches</td>
<td>5.0 inches</td>
<td>6.0 inches</td>
</tr>
<tr>
<td>Pole (No. 10), 16-foot</td>
<td>3.8 inches</td>
<td>6.0 inches</td>
<td>7.0 inches</td>
</tr>
<tr>
<td>Sawlog, small 16-foot</td>
<td>5.0 inches</td>
<td>7.0 inches</td>
<td>8.0 inches</td>
</tr>
</tbody>
</table>

Our experimental thinnings have concentrated on producing local-use posts, but they have yielded small quantities of the other products listed. The chart has proved reliable for stands of trees with minimum merchantable DBH of 2.0, 3.0, 4.0, and 5.0 inches—the last in limited tests.

2. The rule for marking by planting squares has this basis: When merchantable trees occur on 65 percent of the planting spots, we expect out of 100 planting squares 2 with no merchantable trees, 11 with 1 only, 31 with 2, 36 with 3, and 18 with 4 trees.2/ This gives leave trees in terms of initial merchantable trees as follows:

1/ This consists of four planting spots with two in one row and two opposite in an adjacent row-making a rough square that may have a variable number of trees.

2/ Based on the binomial expansion \((0.35 + 0.65)^4\).
<table>
<thead>
<tr>
<th>Initial Stand</th>
<th>Number of leave trees when initial number per planting square is--</th>
<th>Average leave stand (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>(Very heavy)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Heavy</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Medium</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Light</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(Very light)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The first line, with one tree per planting square, applies to the "best, biggest" tree. Very heavy stands can be marked this way. However, there is a risk of too drastic opening up. The marking in the last line can be used to thin very light stands. However, the cut may not be enough to make them operable for thinning. The "heavy," "medium" and "light" values are the basis for the thinning chart. Thus, the leave percentages apply to the middle of the respective bands on the chart. Thinning from below increases the average DBH of the stand. The chart gives a "leave stand" DBH that is ½ inch greater than the initial stand DBH. After thinning, the stand should fall in the band for "leave stand" on the chart. Our results from marking by planting squares have proved satisfactory for stands with minimum DBH from 2.0 to 5.0 inches, and merchantable trees on 56 to nearly 100 percent of the planting spots. The method is simple. It provides for maximum selection of trees consistent with good distribution.

3. The leave stand after first thinning has the following standard of stocking merchantable trees per acre:

<table>
<thead>
<tr>
<th>DBH av. inc.</th>
<th>Trees no.</th>
<th>Basal area sq.ft.</th>
<th>Spacing average &quot;D plus&quot; ft. (Spacing minus DBH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>681</td>
<td>59</td>
<td>8.0</td>
</tr>
<tr>
<td>5</td>
<td>509</td>
<td>69</td>
<td>9.2</td>
</tr>
<tr>
<td>6</td>
<td>395</td>
<td>77</td>
<td>10.5</td>
</tr>
<tr>
<td>7</td>
<td>316</td>
<td>84</td>
<td>11.8</td>
</tr>
<tr>
<td>8</td>
<td>258</td>
<td>90</td>
<td>13.0</td>
</tr>
</tbody>
</table>

These values determine the center of the band for "leave stand" in the chart. First thinning of the plantation to this standard should prolong rapid growth until DBH has increased 2 inches for the second thinning. Thus we avoid the slow DBH growth and high mortality of the fully-stocked natural stand. However, the stocking outlined in the table is only a little less than
that for the dominant stand of natural loblolly pine made up of the more thrifty trees.\(^3\) By the useful rule-of-thumb described by Mitchell\(^4\), stocking approximates D plus 4.5. This provides a progressive reduction in number of trees, but an increase in basal area per acre. Our standard represents the maximum stocking that gave response to experimental first thinnings in pine plantations. The basis for diameters beyond 6 inches is meager. However, first thinnings should be completed before the plantation reaches this stage.

**Chart**

We have reduced to a simple chart the basic recommendations for young plantations of loblolly and shortleaf pine in the Tennessee Valley. It shows when the first thinning is needed, how to thin, how much will be cut and left, and when the second thinning will be needed. Use of the chart is restricted to normal plantations that have been set out in rows and have not been either replanted or previously thinned. Of course, the chart should not be used on stands where thinning might incur losses. Examples of this are high risk of loss by disease or likelihood of erosion due to burning or grazing.

Here are directions for use of the chart in making a thinning.

1. Set the minimum DBH for merchantable trees that will yield a usable product.
2. Sample the plantation to get the average DBH and number of merchantable trees per tenth acre. (We found 5 percent sampling adequate for plantations up to 5 acres.)
3. Plot these values for merchantable trees on the chart in order to decide on need for thinning and select the marking rule.
4. Mark the plantation by the selected rule. Walk between 2 adjacent rows. Look at the area of one planting square (foursome of planting spots) at a time. Judge only merchantable trees. After reserving the best tree, mark the number of cut trees prescribed by the rule (a paint gun is handy for this purpose). Proceed to the next square. Rapid progress of marking may be interrupted by irregularity due to closer spacing in one row. Correct this by marking a triangle of 3 planting spots to square up the next planting square. In marking next to gaps, avoid cutting trees that will enlarge an opening too much.

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An example:

1. A minimum merchantable DBH is set at 4.0 inches for commercial pine posts.

2. A loblolly pine plantation has merchantable trees averaging 5.3 inch DBH and 80 per tenth acre. These values plot on the chart to show--
   a. need for thinning.
   b. marking rule. If there are 4 trees, cut two; if there are 2 trees, cut one; if there are 3, cut one and two trees in alternate squares.
   c. estimated leave stand is 42 trees, averaging 5.8 inch DBH.
   d. estimated cut stand is 38 per tenth acre (80 minus 42).
   e. expected average DBH for rethinning is 7.6 inches (for 42 trees).

The thinning operation should include essential sanitation cutting and release. Eliminate diseased trees that are a risk to the stand. Eliminate undesirable competing trees larger than the minimum merchantable size of pine. (Poisoning is recommended for hardwoods.) After cutting, size up the leave stand for the second-step thinning, and select crop trees. Pick from 100 to 200 per acre of the larger "best trees", well-distributed—no closer than 12 feet apart. We consider treatment essential for loblolly and optional for shortleaf. Crop trees should be treated in the spring before growth begins. Prune to half the height, cutting branches off flush to clear a 16-foot butt log. Fertilize to offset pruning shock. Spread high nitrogen complete fertilizer (equivalent to ½ pound of 24-12-4) about tree in a 5-foot radius circle. This treatment costs about $0.5 cents for pruning and $1.5 cents for fertilizing, or 10 cents per crop tree.
VARIABILITY IN WOOD OF SOUTHERN PINES AS
INFLUENCED BY SILVICULTURAL PRACTICES

By

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Introduction

It has been said that "no two pieces of wood are exactly alike." The southern pines, which furnish excellent lumber and pulpwood, are no exception. Their wood is, within limits, variable in weight, in strength, in shrinkage, and in practically all properties and characteristics.

Causes of variation in wood are many. Individually or in combination, each of the factors of growth and environment plays a part. Sometimes these factors act in the same direction; sometimes in opposition to each other in their tendencies to modify the structure and properties of wood.

Some of the more obvious factors affecting variability of wood have been studied in the past and certain conclusions drawn from the studies. Probably some of the conclusions are wrong; some of them may be right, or at least partly right. Often conclusions concern only one predominant factor which, in its effect, has obscured the action of other factors. Under natural forest conditions, it is very difficult to distinguish between environmental and hereditary factors. This paper shall adhere primarily to a consideration of environmental factors and of some wood characteristics influenced by them to a greater or less degree.

Site Quality

Among environmental factors influencing variability of wood, site quality will be first considered. Site quality influences height growth of trees, taper, knottiness, and specific gravity of the wood.

1 Prepared for presentation at symposium on management of young, even-aged stands of southern yellow pine, sponsored by Louisiana State University at Baton Rouge, La., March 13, 14, 1952.

2 Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
Since site quality, expressed as a site index, is determined by the amount of growth of trees in height over a given period of time, it follows that poor sites have relatively short trees and good sites relatively tall trees. Short trees usually have greater taper throughout their merchantable length than tall ones of the same age; and since, in many species, whorls of branches occur at the end of the terminal growth each year, the shorter the height growth the closer together are the whorls of branches and the greater is the number of knots per given length of tree bole. Since in the southern yellow pines branches are developed not only at the annual terminus of the leading shoot, but also at intermediate points, site alone is not the controlling influence upon number of branches per unit length of the bole.

Soil Type and Soil Moisture

Soil type, principally through its capacity to retain moisture, has an important influence upon the growth and structure of wood. Soil moisture is reflected in the continued growth of a tree, especially in diameter, throughout the warm season. It is true that many trees actually stop growing in diameter during seasons of dry weather. This could happen on any kind of soil, but it is more likely to happen on sandy or gravelly soils, and on impermeable soils and steep slopes from which most of the precipitation flows away on the surface and is unavailable to the roots of the trees. Trees on such dry sites are likely to be deficient in summerwood, the part of the growth ring that normally develops during the summer months. Lack of water also may become apparent rather quickly in very closely crowded stands due to absorption by roots.

Information available at this time indicates that the layer of humus and leaf mulch in the forest is primarily important from the standpoint of conserving moisture and also of adding fertility to the soil in the process of its disintegration. In addition, it helps maintain the soil in the physical condition necessary to promote biotic and biochemical activity. There are sites, however, where the supply of moisture and the fertility of the soil are sufficient for forest growth even if the leaf mulch is not present.

A comparison of the specific-gravity values of longleaf pine from two soil types in South Carolina showed that during the same 20 years the wood produced in trees from a shallow soil that frequently became dry in summer, was much lower in specific gravity than that of trees growing on a deep, moist soil in the same vicinity. In another comparison, the specific gravity of the wood from trees growing on steep slopes and ridges of the Ouachita Mountains was 12 percent less than that of trees from more level land lying just below the steep slopes.

Low production of summerwood is commonly the result of lack of water during the growing season. Years of prolonged drought are reflected in narrow summerwood bands of the growth rings, except in naturally moist situations. In some cases it was found
that fall rains brought about renewed growth activity that resulted in wood intermediate in appearance between typical springwood and typical summerwood.

An experiment several years ago in Choctawhatchee National Forest determined the effect of irrigation upon summerwood production during the growing season. Old-growth longleaf pine trees, growing on deep sand, when kept continuously supplied with water from March to December, increased not only total ring width, but summerwood increased more than springwood. The results of those investigations justify the conclusion that a fairly close correlation exists between the current soil-moisture supply and the formation of summerwood.

**Silvicultural Considerations**

**Growing Space**

Silvicultural practices that influence variability of wood in one way or another afford the most useful means available to the forester for controlling wood quality. One condition under which wide variation in the density of wood occurs is that of uneven distribution of young trees over an area. Young trees with a large amount of growing space, especially in restocked old fields, grow rapidly in diameter with a high proportion of springwood comprising the annual-growth ring. Trees growing from the start in densely stocked areas have narrower growth rings and proportionately much less springwood.

In natural stands the initial degree of stocking may be the result of chance. Where stocking is very dense, the early growth of the individual trees may be very slow. It can be accelerated by thinning. Thinnings, perhaps, are the simplest form of growth and quality control. Where wide spacing of trees occurs in sparsely stocked natural stands or in plantations, silvicultural control of wood quality is more difficult of application. Recent experiments in regulating the size of crowns, however, appears to offer a possibility of control in such trees. Removal of up to three-fourths of the crowns of trees in understocked stands had an important effect on the quality of wood currently produced by reduction in width of the springwood portion of the growth rings. This phase of control is yet in the experimental stage.

Several comparisons of the wood of second-growth southern yellow pine trees, mostly 20 to 30 years of age, grown continually in the open, with that of similarly aged trees of the same species in adjoining densely stocked stands, showed early differentiation in the density of the wood of the openly grown and of the closely grown trees. The trees in the fully stocked stands increased more rapidly in specific gravity from the pith toward the bark, with average values 8 to 15 percent higher than in the open stands.
Recent writers on development of plantations in Africa have reported an increase in specific gravity with successive growth rings in young plantation trees and have attached considerable importance to a so-called specific gravity - age relationship. It has been our experience that this relationship often is subject to modification by environmental factors acting independently of age. These factors may include density of stocking, soil moisture supply, acceleration of growth by partial cutting in a stand, or slowing of growth by severe pruning of the green crown.

It appears that wood of uniformly heavy weight can be attained most quickly in the southern pines if, under good forest conditions, the trees are spaced so closely when young that a full-crown canopy is established as soon as possible and the living crown moves upward so that it occupies no more than one-third of the tree length. Afterward, thinnings should follow at sufficiently frequent intervals to maintain the desired width of growth rings uniformly through the tree section.

**Pruning**

Pruning in itself may be considered a valuable practice in second-growth southern pine stands. If pruning is started very early, when trees are no more than 1 to 2 inches in diameter and 10 to 12 feet high, and continued at frequent intervals, lumber from the lower 16-foot log of a pruned tree will be almost entirely in the select grades. This butt log may contain nearly half of the lumber in a 50-year-old tree.

A study of knots showed that the species of southern yellow pines differed markedly in the time that branches remained alive in the lower 20 feet of the stem. In loblolly and longleaf pine, lateral branches remained alive for an average of 7 years, in shortleaf pine 8 years, and in slash pine 9 years.

Two to four branches usually occurred at each node. The percentage of nodes having more than five branches was negligible. The number of knots in different stands of the same species appeared to be influenced by stand conditions. Where loblolly and shortleaf pines were growing in mixture with hardwoods, the reduction in the number of knots in the first 20 feet ranged from 15 to 25 percent. In longleaf pine the denser stands also contained fewer knots.

**Mixed Stands**

Second-growth southern pine stands containing a substantial mixture of second-growth hardwoods of about the same age as the pine have been found to produce a higher percentage of the lumber in the better grades than pine stands that contained relatively few or no hardwoods in mixture.

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Studies made in loblolly pine forests showed the highest lumber values were derived from stands in which 20 to 25 percent of the timber consisted of second-growth hardwoods well-distributed among the pines. The hardwoods, though of the same age as the pine trees, were not as tall as the pines, and this fact gave the upper portions of the pine crowns abundant room for development. At the same time the broadleaved hardwoods shaded the lower portions of the pine trunks and assisted in the removal of their lateral branches.

Other advantages also accrue as the result of mixed hardwood and pine stands. Hardwood leaves decay more readily than resinous pine needles and thereby more quickly restore plant foods to the soil. Also, by absorbing and holding moisture, the hardwood leaves assist in the disintegration of the pine needles and the formation of humus. Thus, in mixed stands, it is not only possible to produce better grades of lumber but also to maintain the forest soil in a more productive condition.

The benefits of hardwoods in mixture were found to be offset by a lower yield of softwoods when the basal area of hardwoods amounted to more than 20 to 25 percent of the basal area of the stand. When hardwoods are equal in value to the pine, the presence of more of them should not be objectionable. In stands of mixed species of pines and hardwoods, the pines must be allowed to maintain a predominant position to prevent their suppression by hardwoods.

Wood Characteristics

Variations in growth conditions influence many characteristics of the wood. Its appearance is affected by width of growth rings and by proportions of springwood and summerwood and of sapwood and heartwood. The relative proportions of springwood and summerwood influence density, which in turn is an index of many strength properties. Density has an influence on the amount of shrinkage, since, normally, the heavier pieces shrink more during drying than the lighter ones. The proportion of heartwood influences durability, because heartwood is less subject to decay than sapwood. On the other hand, sapwood is more easily penetrated by wood preservatives than heartwood.

Width of Rings

When other conditions are equal, moist sites produce wider growth rings than dry sites. Even on dry areas rings may be fairly wide for the first few years if the trees are widely spaced and have large crowns. Usually, such wide rings are largely of springwood. Generally, wide-ringed growth is not maintained for very long since, as the trees increase in size, they compete with each other. Even the competition of herbaceous vegetation may affect the width of growth rings. On good sites, variation in the width of rings may range from as few as 2 or 3 rings per inch to as many as 20 or more within a period of only 20 to 30 years. This type of growth is characteristic of stands that have
originated with little competition during the first few years, particularly on old fields. Similar results may occur in plantations.

A comparison of second-growth longleaf pines of approximately the same age in open and in crowded situations on the same site, showed that the wood of the trees growing in the dense stand, although having a rapid initial growth, became heavier as growth in diameter slowed down, while in the freely growing trees, the initial rapid growth had continued up to the time of cutting and the weight of the wood throughout the cross section was uniformly lower.

In a study of loblolly and slash pines, it was found that wood of rapid growth near the center of trees was not only low in density but also lower in strength for its weight than is usually the case.

Ring width in itself is not a reliable criterion of the strength of southern pine lumber. A combination of ring width and proportion of summerwood, however, is made use of in application of the well-known density rule used for segregation of dense southern yellow pine for structural uses. A specific-gravity determination, however, is a better criterion of strength than judgment based on visible features of ring width and summerwood.

Variation of Density in Springwood and Summerwood

Summerwood, having a larger proportion of cell-wall substance per unit of volume than the springwood portion of a growth ring, imparts density to the timber and influences its properties. However, the summerwood or springwood may vary independently in density.

Variations in density and width of springwood and summerwood bands have a direct bearing upon the strength, hardness, workability, and shrinkage of wood, upon its ability to hold paint, and upon the quality and yield of pulp obtained from it.

In wide growth rings the transition from springwood to summerwood frequently is so gradual that no clear line of demarcation between the zones is discernible. The transition from springwood to summerwood is more abrupt in wood of narrow rings.

Heartwood and Sapwood

Formation of heartwood is a natural consequence of increasing age and size of trees. In the southern yellow pines, heartwood may begin formation at about 15 to 20 years of age or a little later, depending upon the site and such other factors as crown size and growing space. In fully stocked stands heartwood may begin to form in suppressed trees a little earlier than in dominant trees. In one analysis of young stems, heartwood was evident at a height of 8 to 16 feet above the stump before becoming
clearly evident at the stump itself. Among older trees, those with large crowns that maintained rapid growth in diameter had wider sapwood layers than trees in the same stand with small crowns and of slower growth. The crown size may be used as an index of the sapwood thickness among even-aged second-growth trees on a given site or in a given stand. Crowding of pole-sized stands may reduce sapwood thickness. This may be desirable from a wood-preservation standpoint.

Shrinkage

The transverse shrinkage of a piece of lumber is related to its density. The heavier pieces shrink more radially and tangentially than the lighter ones. In the case of longitudinal shrinkage, however, the lighter pieces, especially when of wide-ringed material that originated near the pith of the tree, shrink longitudinally more than narrow-ringed wood further out toward the bark. Severe crooking during drying occurred in pieces containing both wide- and narrow-ringed material. Such behavior is explained by the tendency of low-density wood to shrink more longitudinally than high-density wood, and by the fact that the wide rings near the center of the trees have a high proportion of low-density springwood. While the usual longitudinal shrinkage of lumber is only 0.1 to 0.2 percent from the green to the oven-dry condition, shrinkage as high as 1.9 percent has been found in wood of southern yellow pines having less than four rings per inch. Shrinkage of this magnitude would equal 3.6 inches for a board 16 feet long. Such high shrinkage probably would not take place in ordinary lumber uses, because wood, even though installed when green, would not become completely dried out without application of heat.

From an investigation of 75 trees it appears that wide growth rings with their accompanying abnormal longitudinal shrinkage are more prevalent in the lower than in the higher part of a tree, but in practically all cases the shrinkage of wide rings near the pith was abnormally high in all parts of the tree. There is no reason to believe that the pronounced longitudinal-shrinkage characteristic of this type of wood will change with advancing age of the trees, since the cellular structure of wood after once being formed remains constant.

The unsuitability for many purposes of rapidly grown coniferous wood has long been recognized in Europe. Foresters there strive to restrict the initial width of growth rings of young pine trees to about 10 to the inch.

Compression Wood

Compression wood is a peculiar type of wood that occurs to a greater or less degree in all coniferous tree species. It occurs commonly on the under side of leaning trees and of branches.

The most outstanding characteristic of compression wood is a tendency to shrink along the grain to a much greater extent.
than normal wood does. This tendency often causes considerable bowing, splitting, and twisting, and occasional breaking across the grain. Compression wood sometimes shrinks 10 times as much as normal wood. If a board is composed of both compression wood and normal wood, the shrinkage of the compression wood will be more or less retarded by the lower shrinkage of the normal wood attached to it, but the shrinkage will still be sufficient to cause the lumber to bow, crook, or twist considerably.

Compression wood is usually easily identified by its appearance. The annual-growth rings in compression wood are often relatively wide, with an apparent preponderance of summerwood and without a clear line of demarcation between springwood and summerwood. The eccentricity of annual-growth layers, together with the darker color of compression wood, are distinguishing marks on the ends of logs.

When compression wood is difficult to distinguish from normal wood, the use of transmitted light is particularly helpful in its identification. In cross sections of wood, about 1/8 to 3/16 inch along the grain, that are held against a bright light, the compression wood appears practically opaque. Normal types of wood are translucent when held against light in the same manner. Microscopic examination of compression wood shows the fibrils of the secondary tracheid walls to lie at a greater angle than those of normal fibers. In addition to the oblique spiral structure of the summerwood tracheids, countless spiral cracks are apparent in the cell walls. It is this discontinuous structure in the secondary cell walls of the summerwood tracheids that, by dissipating the light, causes the greater opacity of the summerwood of compression wood.

Compression wood differs markedly from normal wood not only in physical properties but in chemical composition, especially in an excessive lignin and a low alpha-cellulose content, and in pulping properties. Its presence adversely affects the yield, chemical purity, and bleaching requirement of pulp. Strength properties of pulp are also adversely affected by the minute checking in fiber walls of compression wood that accelerates fragmentation during processing.

To hold occurrence of compression wood to a minimum, crooked and leaning trees should be removed when making thinnings or improvement cuttings.

**Specific Gravity and Strength**

The general relationship of specific gravity to strength in southern pines may be illustrated in two second-growth stands of shortleaf pine -- one in New Jersey and one in North Carolina. The New Jersey stand averaged only 0.40 in specific gravity while the North Carolina stand averaged 0.46. Comparative values for bending strength were 6,110 and 7,420 pounds per square inch, respectively. Similar comparisons may be found in the data for the other species.
Some Anatomical Features

One anatomical feature of wood structure noted in compression wood has been found lately to be associated with other types of wood having high shrinkage along the grain, for example, in the wide-ringed wood near the center of young trees. This feature is the large angle of fibril with respect to the long axis of the wood fiber. The angle of the fibril has been found to decrease quite regularly from near the pith until, with decreasing ring width, the slope of fibril becomes normal. In extreme cases, the fibril angle may be as much as 45 degrees, normally it may be as low as 5 to 10 degrees.

Preliminary studies indicate that the fibril angle not only decreases in successive annual rings from the pith outward -- but that the change takes place more quickly in trees of slow growth in diameter. Another interesting feature found was that when ring width was reduced after heavy pruning for crown control, there was a sudden decrease in fibril angle accompanying the change in ring width. This is further indication of benefits of initial close stocking and early elimination of side branches to promote long, clear boles. The best-quality wood then will be produced along the entire length of the clear bole.

Summary

1. Site quality affects size and external characteristics of trees more than the intrinsic quality of the wood. Extreme conditions with respect to one or more factors of site may, however, influence wood characteristics to a marked degree.

2. Availability of soil moisture to trees, or lack of it, particularly during the period of summerwood development, influences the amount of summerwood in the growth ring.

3. Growing space, as it influences relative sizes of tree crowns, influences wood quality. Trees with large crowns extending along a considerable proportion of the bole tend to produce proportionally more springwood than trees with small crowns restricted to the upper portion of the bole.

4. Pruning of green branches may be expected to influence wood quality in the same way as growing space. Early removal of dead or living side branches improves the grade of lumber obtainable.

5. Hardwoods in mixture with pines improve quality and grade by restricting the green crown and facilitating natural pruning.

6. Relative proportions of springwood and summerwood are the main wood characteristics affecting density in southern yellow pines.

7. Certain growth-ring patterns are an indication of variation in wood density; however, width of rings alone is not a reliable criterion of wood quality.
8. Both springwood and summerwood may be variable in specific gravity.

9. Trees with large crowns that are growing rapidly in diameter usually have thicker sapwood zones than trees that are growing very slowly.

10. Wood of wide growth rings near the center of trees has a tendency to shrink excessively along the grain, thus causing warping and consequent degrade in lumber.

11. Compression wood forms on the under side of leaning trees. It affects usefulness of lumber adversely. Leaning trees should be removed in silvicultural practice.

12. Variations in specific gravity of wood are reflected in strength and most other mechanical properties.

13. Large fibril angles with respect to the long axis of the wood fiber are associated with excessive longitudinal shrinkage of wide-ringed wood near the pith. In closely grown trees the fibril angles are smaller than in openly grown trees.