THE ROLE OF THINNING IN MANAGEMENT OF SOUTHERN BOTTOMLAND HARDWOOD FORESTS

JAMES S. MEADOWS\textsuperscript{1}, USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research, PO Box 227, Stoneville, MS 38776
J. C. G. GOELZ, USDA Forest Service, Southern Research Station, Alexandria Forestry Center, 2500 Shreveport Highway, Pineville, LA 71360

Abstract: Thinnings, improvement cuttings, and other partial cuttings are important tools to manage existing southern bottomland hardwood forests. These techniques are designed to enhance growth and development of species favored for management objectives. Hardwood tree classes and stocking guides are tools used to plan and implement partial cuttings in hardwood forests. However, there are disadvantages associated with any partial cutting in hardwood stands. These include logging damage to boles and/or exposed lateral roots and possible production of epicormic branches on the boles of residual trees. General guidelines for thinning in mixed-species stands of bottomland hardwoods, as well as guidelines to reduce the risk of epicormic branching, are presented. Plans to develop a growth and yield model for managed stands of southern bottomland hardwoods also are described. Our long-term goal is to develop practical recommendations for a planned program of intermediate operations over the course of one rotation in even-aged stands of southern bottomland hardwoods.

Key words: epicormic branches, growth and yield, guidelines, hardwood tree classes, logging damage, modeling, partial cutting, Quercus, red oaks, southern bottomland hardwoods, stocking, thinning.

A silvicultural system is a comprehensive, planned program of silvicultural treatments conducted in logical sequence during the entire life of a stand (Smith 1962). Although greater emphasis is generally placed on silvicultural treatments imposed during the regeneration period, a properly designed silvicultural system also should include a planned program of intermediate operations designed to attain the objectives of management. These intermediate operations include, but are not limited to, improvement cutting, thinning, and other partial cuttings. Although the focus of this paper is on production of high-quality sawtimber in southern bottomland hardwood forests, many of the principles discussed also are applicable to achieve other objectives, such as wildlife management.

Production of high-quality sawtimber in hardwood stands requires not only maintenance of satisfactory rates of growth, but also development of high-quality boles. Various types of partial cuttings can be used to increase growth and enhance or improve bole quality of residual trees. If used improperly, however, partial cuttings may actually reduce or degrade bole quality.

Partial cuttings in southern bottomland hardwood forests are generally separated into 3 categories. Improvement cuttings are usually applied to previously unmanaged stands to remove low-value, overmature, damaged, diseased, or cull trees, as well as trees of undesirable species. Thinnings, in a classical sense, are used to regulate stand density and to maintain or increase growth of residual trees. Other partial cuttings include crop-tree release, in which a relatively small number of pre-selected crop trees are released from competing vegetation. In practice, a combination of improvement cutting and thinning is used in most mixed-species stands of southern bottomland hardwoods to achieve 3 general objectives: (1) to maintain or enhance growth and development of trees of desirable species, (2) to improve species composition of the stand, and (3) to maintain or improve bole quality of residual trees (Meadows 1996). Characterization of desirable trees and desirable species is defined by management objectives. A secondary objective of intermediate silvicultural operations, particularly those conducted late in the rotation, should be to create environmental conditions favorable for establishment and development of advance reproduction of desirable species (Meadows and Stanturf 1997).

HARDWOOD TREE CLASSES

The first step in planning partial cuttings in southern bottomland hardwood forests is to identify the types of trees to be left to form the residual stand
and types of trees to be cut. Hardwood tree classification is an excellent tool available to the resource manager to accomplish this initial task. Four hardwood tree classes were developed many years ago as a basis for planning partial cuttings and for developing marking rules (Putnam et al. 1960). These tree classes, with some modifications (Meadows 1996), are still used today. The 4 tree classes are described below with timber production as the primary goal of management, but the definitions could easily be revised to apply to other management objectives.

**Preferred growing stock**, originally called "leave" trees, includes trees that: (1) are in good condition; (2) are of a desirable species for the site and for management objectives; (3) have dominant or codominant crowns; (4) can be left indefinitely if in good condition; and (5) currently meet or have the potential to eventually meet minimum log grade specifications, which may vary by management and product objectives. Preferred growing stock trees are the most desirable and most valuable trees in the stand and may be thought of as final crop trees. They are expected to increase in value at a satisfactory rate if left in the stand after some form of partial cutting.

**Reserve growing stock**, originally called "storage" trees, includes trees that are also in good condition but do not meet all requirements for preferred growing stock. Reserve growing stock trees are good trees (but not the best) that can be safely stored on the stump with little risk of mortality or degrade in merchantability if left in the stand for 10 years or more. They are not expected to increase in value at a satisfactory rate, but also are not expected to decrease in value, if left in the stand after partial cutting.

**Cutting stock**, originally called "cut" trees, includes trees that should be cut during the next harvest operation. Cutting stock trees may be in poor condition, may pose a significant risk of mortality or degrade in merchantability, or may be of a species that is unsuitable for the site or for management objectives. This class includes trees that are overmature, damaged, diseased, poorly formed, or otherwise undesirable. They are likely to die or to suffer significant decay or degrade in the near future and are, therefore, expected to decrease in value if left after partial cutting.

**Cull stock** includes trees that are incapable of meeting desired product goals. Two types of cull trees are recognized: (1) sound culls, which will never produce sawtimber but do contain usable fiber for pulpwood, and (2) unsound culls, which do not contain enough merchantable fiber to be marketed for timber products. Cull trees may provide habitat for wildlife and may be valuable for other non-timber management objectives. In fact, a tree classified as cull stock strictly for the objective of timber management may actually be very desirable for the objective of wildlife management. For example, a large, hollow red oak (*Quercus* spp.) may have no value for timber, but may produce large quantities of hard mast as well as provide den habitat. Strictly from a wildlife management viewpoint, this tree could be classified as preferred growing stock rather than as cull stock.

The four hardwood tree classes, as defined above, are designed for situations in which sawtimber production is the primary goal of management. However, the concept of tree classification in bottomland hardwood forests can be applied to any non-timber management objective. The resource manager can easily redefine tree classes to reflect any objective he chooses. By doing so, he can create a set of tree classes that delineate characteristics of trees that are desirable, acceptable, undesirable, or unacceptable for his specific management objective. For example, if the landowner's primary objective is wildlife management, the resource manager can define preferred growing stock as trees that exhibit the most desirable characteristics for wildlife habitat, reserve growing stock as trees that, although not the most desirable, do exhibit characteristics acceptable for wildlife habitat, and so on. The manager simply lists those characteristics he deems critical for each tree class. In this way, the concept of hardwood tree classification can be applied to any specific management objective or combination of objectives.

Hardwood tree classes can then be used to establish a cutting priority when marking a stand for partial cutting. The classes identify which trees should be left and which trees should be cut. In most instances, all preferred growing stock trees should be left and all cutting stock trees should be cut. None, some, or all of the reserve growing stock trees may be cut, depending upon the planned intensity of the partial cutting. Reserve growing stock trees are not expected to significantly contribute or significantly detract from the future value of the stand. They may be harvested to meet residual density goals or may be left with little risk of mortality or degrade in merchantability. In this way, **reserve growing**
stock trees are used to regulate the intensity of the partial cutting operation. Cull stock trees may be removed, deadened, or left depending upon management objectives.

STOCKING GUIDES

The next step in planning partial cuttings in southern bottomland hardwood forests is to determine the intensity of the cut. Stocking guides should be used to determine not only when a stand needs thinning, but also the desired residual stocking, thus setting the intensity of the cut (Goelz and Meadows 1997). In general, stocking is a qualitative expression that compares the existing density of a stand to the density desired for optimum growth (Avery 1975). Consequently, stands can be understocked, fully stocked (the theoretical ideal), or overstocked. As used in Goelz (1995), stocking is an accurate indicator of stand density because it incorporates more than one measure of density into a single quantitative variable. Other estimates of stand density, such as basal area and number of trees per unit area, rely solely on a single measure of density. It is also recommended that partial cuttings be designed to shape the stand to some desired level of residual stocking, rather than to harvest some level of density. In this way, the focus of the partial cutting operation is on the portion of the stand to be retained for management rather than on the portion of the stand to be harvested.

Goelz (1995) presented a stocking guide developed specifically for southern bottomland hardwood forests (Fig. 1). It is based on hypothetical stocking levels for managed, even-aged, southern bottomland hardwood stands before and after thinning, as recommended by Putnam et al. (1960). Specifically, Putnam et al. (1960) presented stand density values (average basal area per acre and average number of trees per acre), before and after thinning, for a hypothetical stand at various stages of stand development. Density values of the hypothetical stand before thinning represent 100% stocking. Any stand in which stocking is estimated to be over 100% is considered to be overstocked and a partial cutting is warranted (Goelz 1995). Putnam's recommended residual density of the hypothetical stand after thinning represents B-line stocking, generally considered to be the minimum stocking required for full site utilization. The B-line represents the density to which stands of southern bottomland hardwoods should be thinned. The B-line created by Goelz (1995), based on hypothetical data from Putnam et al. (1960), is not a constant level of stocking, but ranges from about 50-55% stocking in small-sawtimber stands (quadratic mean diameter of 9 inches) to about 80-85% stocking in large-sawtimber stands (quadratic mean diameter of 30 inches).

As presented by Goelz (1995), stocking can be estimated from any 2 of the following stand-level variables: (1) number of trees per acre, (2) basal area per acre, or (3) quadratic mean diameter (Fig. 1). Stocking also can be calculated directly from an equation developed by Goelz (1995):

\[
\text{Stocking} = 0.01373 \times \text{TDA} + 0.00960 \times \text{TDA} \times \text{QMD} + 0.00378 \times \text{TDA} \times \text{QMD}^2
\]

where

- \( \text{TDA} \) = number of trees per acre
- \( \text{QMD} \) = quadratic mean diameter, in inches

To set the intensity of the partial cutting, the resource manager may choose Putnam's B-line to represent optimum residual stocking or may choose some constant level of stocking, such as 70%. However, neither Putnam's recommendations nor any other level of residual stocking have been validated experimentally to represent optimum residual stocking in southern bottomland hardwood forests. Consequently, definitive guidelines on
optimum residual stocking levels cannot be presented at this time. However, a series of thinning studies was recently initiated in red oak-sweetgum (*Liquidambar styraciflua*) stands across the South to test the effects of various residual stocking levels, including Putnam's B-line, on both stand- and tree-level growth and value. Preliminary results from one of the studies in this series indicate that heavy thinning to 50-55% residual stocking may produce the best combination of stand-level growth and individual-tree diameter growth (Meadows and Goelz 2002).

**USE OF TREE CLASSES AND STOCKING AS MANAGEMENT TOOLS**

The hardwood tree classes as outlined above and the stocking guide developed by Goelz (1995) can be used as tools to assist the resource manager in making numerous important management decisions in existing stands of southern bottomland hardwoods: (1) to determine if an existing stand should be managed or regenerated, (2) to determine if a stand needs to be thinned, (3) to determine the desired residual stocking and thus to set the intensity of thinning, and (4) to develop marking rules that identify trees to be cut and trees to be left in the residual stand.

Before these or any other decisions can be made, however, the resource manager must obtain accurate, up-to-date information on the stand in question. This information can be gathered easily and quickly through a well-designed “management cruise” of the stand. At minimum, information to be collected on each tree during the management cruise should include (1) species class, (2) diameter class, (3) tree class, and (4) estimated volume. These data can be summarized in a number of different ways to provide a clear picture of species composition, structure, quality, and relative value of the stand.

In most cases, particularly in previously unmanaged stands, the first decision to be made by the resource manager is whether to manage the existing stand or to regenerate it. The basic question is “Are there enough desirable or at least acceptable trees in the existing stand to accomplish the goals of management?” If so, the stand should be managed; if not, the stand should be regenerated. The resource manager can use information gathered in the management cruise to address this question. Cruise data can be summarized to calculate the basal area per acre, number of trees per acre, and the quadratic mean diameter for each of the 4 tree classes. From Fig. 1 or from Equation 1, the resource manager can then estimate stocking for each tree class and produce a tree class distribution, based on stocking, for the entire stand. By definition, cutting stock and cull stock trees, collectively referred to as overburden, are undesirable components of the stand and should be removed during the next harvest operation. If not removed, they are expected to reduce the future value of the stand. As a general rule, if stocking of the overburden is greater than about 40-50% of stocking of the entire stand, the resource manager should consider regeneration as the best management decision for that stand. The existing stand does not contain enough preferred growing stock or reserve growing stock trees, collectively referred to simply as growing stock, to warrant continued management. A partial cutting to remove the overburden would create an understocked stand that would be incapable of fully utilizing the site for many years to come. However, if the overburden component is less than 40%, the existing stand contains sufficient growing stock to meet the goals of management and the decision should be to manage that stand.

For those stands that will be managed, the next step is to determine if the stand needs to be thinned. The resource manager should estimate stocking of the entire stand from either Fig. 1 or Equation 1, using data collected in the management cruise. If total stocking is greater than 100%, a partial cutting is warranted. If stocking is less than 100%, a partial cutting is not necessary and the stand can be allowed to grow. However, if stocking is near 100% and the next entry into the stand is not scheduled for a number of years, the resource manager should consider conducting a partial cutting now, especially if the overburden component is relatively high.

For those stands that need to be thinned, the resource manager must next determine desired stocking of the residual stand. This decision thus sets the intensity of the planned thinning. As mentioned previously, no definitive guidelines on optimum residual stocking levels are available at this time. Neither recommendations by Putnam et al. (1960) nor any other levels of residual stocking have been validated experimentally to represent optimum residual stocking in southern bottomland hardwood stands. Preliminary results from our research to test various residual stocking levels indicate that heavy thinning to 50-55% residual stocking may produce the best combination of stand-level and tree-
level growth (Meadows and Goelz 2002). However, these results are based on only 4 years of response to thinning, whereas recommendations from Putnam et al. (1960) used to produce the B-line in Fig. 1 were based on many years of observation and experience. Consequently, the most reasonable guideline available to the resource manager at this time is to thin the stand either to the B-line level of residual stocking or to a level just slightly below the B-line.

The final step in this process is to develop marking rules that identify trees to be cut and trees to be left in the residual stand. It also is necessary to develop a strategy that will enable the timber marker to accurately mark the stand to the desired residual stocking level. As one walks through the stand, the timber marker should use the 4 hardwood tree classes to help identify those trees to be cut and those trees to be left. The timber marker must have the ability and skill to consistently classify trees according to this classification system. In general, all preferred growing stock trees should be left and all cutting stock trees should be cut. Cull stock trees may be cut or left, depending on management objectives. The timber marker must then select enough reserve growing stock trees to cut in order to reach the predetermined target residual stocking. Based on the original tree class distribution of the stand derived from data collected in the management cruise, the timber marker should know the approximate proportion of reserve growing stock trees needed to be removed in order to reach the target stocking level. Because stocking percent is a difficult stand characteristic to visualize, the timber maker may use Fig. 1 to convert the target stocking to a target basal area, an attribute that is much more easily visualized. The timber maker may then use the target basal area for that particular stand as a visual check when walking through and marking the stand for thinning.

**A PRACTICAL EXAMPLE**

Data from one of our thinning studies in Alabama (Meadows and Goelz 2002) can be used as an example to illustrate the use of tree classes and stocking as management tools in stands of southern bottomland hardwoods. Stand-level attributes prior to thinning are indicative of information gathered during the management cruise (Table 1).

<table>
<thead>
<tr>
<th>Tree class</th>
<th>Number of trees -No./ac-</th>
<th>Basal area -Sq ft/ac-</th>
<th>Quadratic mean diameter -Inches-</th>
<th>Stocking -%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred growing stock</td>
<td>10</td>
<td>21</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Reserve growing stock</td>
<td>94</td>
<td>70</td>
<td>12</td>
<td>61</td>
</tr>
<tr>
<td>Growing stock</td>
<td>104</td>
<td>91</td>
<td>13</td>
<td>78</td>
</tr>
<tr>
<td>Cutting stock</td>
<td>43</td>
<td>20</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Cull stock</td>
<td>5</td>
<td>6</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Overburden</td>
<td>48</td>
<td>26</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
<td>All trees</td>
<td>152</td>
<td>117</td>
<td>12</td>
<td>101</td>
</tr>
</tbody>
</table>

The first decision to be made is whether to manage the existing stand or to regenerate the stand. In this example, the overburden accounts for about 23% of total stocking of the stand (Table 1). Because the overburden component is less than 40%, the existing stand contains sufficient growing stock to meet the goals of management. **The decision is made to manage the stand.**

The next step in the process is to determine if the stand needs to be thinned. In our example, stocking of the entire stand is 101% (Table 1). Because total stocking is greater than 100%, **the decision is made to thin the stand.**

The resource manager must next determine desired stocking of the residual stand. The best guideline available today is to thin the stand either to the B-line level of residual stocking or to a level just slightly below the B-line. In our example, the quadratic mean diameter of the stand is about 12 inches (Table 1). From Fig. 1, the B-line for a stand with a quadratic mean diameter of 12 inches would be approximately equivalent to 65% residual stocking. However, most of the trees to be cut in this stand are smaller in diameter than most of the trees that will be left. Consequently, the quadratic mean diameter of the residual stand after thinning is very likely to be greater than the quadratic mean diameter of the stand prior to thinning. In this example, quadratic mean diameter of the residual stand is estimated to be 13-14 inches. From Fig. 1, the B-line for a stand with a quadratic mean diameter of 13-14 inches is approximately equivalent to 65-
70% residual stocking. The decision is thus made to thin the stand to a target residual stocking of 60-65%, a level just below the B-line for the stand in this example.

The final step is to develop marking rules that identify trees to be cut and trees to be left in the residual stand. In our example, removal of the overburden alone will reduce stocking of the residual stand to 78% (Table 1). Because the target residual stocking is 60-65%, some of the reserve growing stock trees also will have to be removed. If approximately 25% of reserve growing stock is marked to be cut, residual stocking would be reduced to about 63%, well within the range of the target residual stocking for the stand in this example. The decision is made to remove the overburden and approximately 25% of reserve growing stock. Attributes of the residual stand after thinning are presented in Table 2.

**PROBLEMS ASSOCIATED WITH PARTIAL CUTTING**

Potential problems associated with any partial cutting in hardwood stands are (1) excessive logging damage to boles and/or exposed lateral roots of residual trees and (2) possible production of epicormic branches along the boles of residual trees. Epicormic branches are adventitious twigs found along the main bole below the crown of the tree. They develop from dormant buds that may be released at any time in response to several types of stimuli. Both problems commonly occur following partial cutting, but their magnitude and severity can be minimized through adherence to recommended guidelines presented in this paper.

**Logging Damage**

Logging damage, particularly in the form of open wounds to the lower bole, is a serious problem associated with any type of partial cutting in hardwood stands. Wounds that expose living sapwood generally lead to decay and/or discoloration of the underlying wood, and may result in reductions in both log grade and volume.

Meadows (1993) found that 62% of residual trees suffered some form of logging damage following partial cutting in a 45-year-old, green ash-sugarberry (Fraxinus pennsylvanica-Celtis laevigata) stand in the Mississippi Delta. Much of the damage occurred as logs pulled by the skidder scraped against the lower boles of residual trees. Careful skidder operation and greater supervision by the logging superintendent can reduce this type of damage. Some degree of logging damage must be expected during any partial cutting operation, but the landowner should not tolerate excessive damage to residual trees.

**Epicormic Branches**

The second serious problem associated with partial cutting in hardwood stands is the possible production of epicormic branches on boles of residual trees. Because most of them are counted as defects on all hardwood logs (Rast et al. 1973), epicormic branches are frequent contributors to log grade reduction in thinned hardwood stands. More importantly, the small knots caused by epicormic branches may greatly reduce the grade and subsequent value of lumber produced from those logs.

Meadows and Burkhardt (2001) evaluated the effects of epicormic branches on lumber grade and value in a 50-year-old, predominantly willow oak (Quercus phellos) stand in central Alabama. A poorly designed thinning conducted in the stand about 7-10 years prior to final harvest resulted in a proliferation of epicormic branches along the boles of many residual trees. Nearly half (49%) of the logs underwent at least a one-grade reduction due to the presence of epicormic branches. Defects caused by epicormic branches also had a significant effect on

---

**Table 2. Stand-level attributes, after thinning, of a red oak-sweetgum stand on a minor streambottom site in Alabama.**

<table>
<thead>
<tr>
<th>Tree class</th>
<th>Number of trees</th>
<th>Basal area</th>
<th>mean diameter</th>
<th>Stocking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-No./ac-</td>
<td>-Sq ft/ac-</td>
<td>-Inches-</td>
<td>-%</td>
</tr>
<tr>
<td>Preferred growing stock</td>
<td>10</td>
<td>21</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Reserve growing stock</td>
<td>70</td>
<td>52</td>
<td>12</td>
<td>46</td>
</tr>
<tr>
<td>Growing stock</td>
<td>80</td>
<td>73</td>
<td>13</td>
<td>63</td>
</tr>
<tr>
<td>Cutting stock</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cull stock</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Overburden</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>All trees</td>
<td>80</td>
<td>73</td>
<td>13</td>
<td>63</td>
</tr>
</tbody>
</table>
lumber grade, particularly in the higher grades. Over 50% of the lumber volume that would have been graded as high-value FAS in the absence of epicormic branch defects had to be downgraded to No. 1 Common or below due to defects caused by epicormic branches. Based on lumber prices prevailing at the time, defects caused by epicormic branches resulted in a 13% reduction in the value of lumber cut from this particular bottomland tract.

Production of epicormic branches on boles of hardwood trees is a poorly understood phenomenon that may be responsible for losses of millions of dollars in potential revenue each year for landowners across the South. Meadows (1995) proposed that production of epicormic branches in hardwoods appears to be controlled by complex interactions among species, stress, and sudden exposure to direct sunlight or other disturbances. Hardwood species vary significantly in their propensity to produce epicormic branches. For example, most oaks are highly susceptible to epicormic branching, whereas green ash generally is not. Any type of stress, such as that caused by climatic events, site and stand conditions, suppression, or disturbances, may reduce tree vigor and result in production of epicormic branches. Sudden exposure of the bole to direct sunlight may trigger release of those dormant buds that develop into epicormic branches, especially on low-vigor trees of susceptible species. Consequently, high-vigor trees, especially of resistant species, are much less likely to produce epicormic branches than are low-vigor trees when subjected to any stimulus that tends to trigger production of epicormic branches. Based on this theoretical model, Meadows (1995) developed practical guidelines to reduce the risk of epicormic branching in southern bottomland hardwood stands: (1) favor resistant species over susceptible species within the confines of management objectives, (2) discriminate against off-site species, (3) avoid overstocking and stand stagnation that reduces the vigor of all trees in the stand, and (4) use thinnings and other partial cuttings to maintain healthy stands composed of healthy trees.

THINNING GUIDELINES

Thinnings and other partial cuttings can be used to improve species composition, regulate stand density, increase diameter growth of residual trees, and maintain healthy stands composed of healthy trees. The resource manager, with the aid of hardwood tree classes, should cut the worst trees and leave the best to form the residual stand. Meadows (1995) presented general guidelines for thinning in southern bottomland hardwood forests:

Begin thinning early in the life of the stand.—If economically possible, thin the stand before it becomes overstocked and stagnates. With development of a stable pulpwood market for small hardwood trees, early thinnings are now more economically attractive than in the past. Timing of the first thinning should be delayed until after merchantable height of desirable trees has been set.

Leave the largest trees with well-developed crowns and high-quality boles.—Trees with these characteristics will likely be classified as preferred growing stock and should be left when marking a stand for partial cutting. Crown size and density, representative of the amount of photosynthetic surface, are generally considered to be good indicators of tree vigor.

Thin from below.—Low thinning is designed to remove merchantable trees from the subordinate crown classes. These trees generally have inferior crowns and low potential for future growth and development. However, partial cuttings in hardwood stands should also remove larger trees that are overmature, damaged, diseased, or of an undesirable species (cutting stock trees).

Use frequent light thinnings rather than infrequent heavy thinnings.—Manage stand density to improve the value of the stand. Using the criterion that thinnings should be performed when stocking reaches 100%, light thinnings will generally be needed about every 8-12 years, whereas heavy thinnings will likely be needed only every 15-20 years, depending on stand growth rates and site quality. Frequency and intensity of thinning involve trade-offs between individual-tree and stand growth, logging damage, and production of epicormic branches. For example, heavy thinnings may greatly increase diameter growth of residual trees, but also may reduce stand density to the point where stand-level volume growth is reduced to unacceptable levels. Heavy thinnings also may allow too much sunlight into the stand and promote development of epicormic branches on boles of residual trees.

Avoid excessive logging damage to residual trees.—Some logging damage is inevitable following any partial cutting in hardwood stands, but its magnitude and severity can be minimized through carefully planned, implemented, and supervised logging practices.

Leave large saplings near residual trees.—To reduce the risk of epicormic branching, large saplings
should be left to provide shade on the lower boles of nearby residual trees. These saplings will not pose a competitive threat to desired residual trees, but may actually serve to protect those trees from logging damage caused by passing skidders and other equipment.

DEVELOPMENT OF A MODEL FOR MANAGED STANDS

Our long-term goal is to develop practical recommendations for a planned program of intermediate operations over the course of 1 rotation in even-aged stands of southern bottomland hardwoods. To that end, a series of thinning studies was recently initiated in red oak-sweetgum stands on minor streambottom sites across the South. The series is designed to determine effects of various levels of residual stocking on stand-level growth and yield and on individual-tree-level growth and bole quality. About 10-12 installations within the series will be established over a 10-15 year period. All installations in the series will utilize the same study design, treatments, and methods. Combined data from all installations will be used to: (1) develop practical guidelines for intermediate management of southern bottomland hardwood stands, and (2) develop a growth and yield model for managed stands of southern bottomland hardwoods. Treatments in all installations in the series are (1) no thinning, (2) light thinning to 70-75% residual stocking, (3) heavy thinning to 50-55% residual stocking, and (4) B-line thinning to desirable residual stocking as recommended by Putnam et al. (1960). All thinning operations consist of a combination of low thinning and improvement cutting, in which the objective is to remove most of the smaller trees as well as larger trees that are damaged, diseased, or of poor bole quality, or of an undesirable species. Hardwood tree classes form the cutting priority for each treatment. Results through the first 4 years from one of our study sites in Alabama have previously been reported (Meadows and Goelz 1998, 1999, 2002).

Upon completion, this growth and yield model will simulate growth, quality, mortality, and species compositional changes in response to various thinning regimes over the course of one rotation in even-aged stands of red oak-sweetgum. Growth, survival, and tree-grade models have been developed for unmanaged stands of bottomland hardwoods in Mississippi (Belli et al. 1993, Perkins et al. 1995), but these models may not be appropriate to predict stand development following thinning.

Specifically, the model will be developed to predict diameter growth, survival, and changes in crown class, tree class, and log grade of individual trees in response to selected thinning regimes over the course of 1 rotation. These predicted variables are expected to be functions of species, initial diameter, stand density, and site quality. Changes in log grade also will likely be a function of the number of epicormic branches and initial log grade. To use this model, it is envisioned that the resource manager will need to supply measures of stand age and site index, as well as characteristics of trees in the stand, such as species, diameter, crown class, tree class, merchantable height, log grades, and the number of epicormic branches on each log. The manager also will be able to select the intensity of each thinning to be simulated during the rotation. For each thinning regime selected by the manager, the model will predict periodic and final yields, by product class (pulpwood and sawtimber), as well as predict volume distributions by log grade and species. Based on one's own economic criteria, the manager may then be able to calculate monetary values associated with each selected thinning regime.

Through analyses of data collected in the series of thinning studies and subsequent development of a growth and yield model for managed stands, practical recommendations can be provided for timing and intensity of the first and subsequent thinnings, as well as the optimum rotation age for various management objectives. However, the model development process cannot begin until 5-year response data have been collected from several installations within the series. Once these data are available, a preliminary model that is applicable to a range of site and stand conditions can be produced. The model will be refined as more data become available.

LITERATURE CITED


ECOLOGY AND MANAGEMENT
OF
BOTTOMLAND HARDWOOD SYSTEMS:
*The State of Our Understanding*

A SYMPOSIUM

March 11-13, 1999

The Peabody Hotel
Memphis, TN
Ecology and Management of Bottomland Hardwood Systems:
The State of Our Understanding

Publishers: University of Missouri-Columbia, Gaylord Memorial Laboratory Special Publication No. 10
Mississippi State University, Forest and Wildlife Research Center, Publication WF-212

Acknowledgements: Redactor and copy editing by Sandy Clark

Illustrations and photos courtesy of: Forest History Society, Durham, NC, Wylie C. Barrow, Jr.
for cover photo and use of photos by James T. Tanner, Frank Nelson, Karen Kyle, U. S. Fish & Wildlife Service

Editors: L. H. Fredrickson, S. L. King, and R. M. Kaminski

Production/design: Karen Kyle

Citation: