A New Tree Classification System for Southern Hardwoods

James S. Meadows and Daniel A. Skojac Jr.

ABSTRACT

A new tree classification system for southern hardwoods is described. The new system is based on the Putnam tree classification system, originally developed by Putnam et al., 1960, *Management and inventory of southern hardwoods*, Agriculture Handbook 181, US For. Serv., Washington, DC, which consists of four tree classes: (1) preferred growing stock, (2) reserve growing stock, (3) cutting stock, and (4) cull stock. Tree classes under the Putnam system are used as a basis for planning partial cuttings and for developing marking rules in southern hardwood forests. However, there are critical problems associated with field use of this system: (1) the reserve growing stock class is too broad and poorly defined; (2) in most partial cutting operations, the timber marker must decide which reserve growing stock trees to cut and which ones to leave; (3) the timber marker must try to mark the stand to some prescribed, quantitative level of residual density; and (4) the timber marker often is forced to either leave low-quality trees or cut high-quality trees to maintain the target residual density uniformly across the stand. Overall stand quality often is compromised through use of the Putnam tree classification system and through strict adherence to the concept of stand density management. Our new tree classification system consists of five classes used only for sawtimber-sized trees: (1) preferred growing stock, (2) desirable growing stock, (3) acceptable growing stock, (4) cutting stock, and (5) cull stock; and two classes used only for poletimber-sized trees: (1) superior poletimber stock and (2) inferior poletimber stock. Data from one of our hardwood thinning studies are used to illustrate differences between the Putnam and the new tree classification systems. Potential uses and adaptations of the new tree classification system are described also.

Keywords: partial cutting, thinning, marking guidelines

Numerous tree classification systems have been developed to assist forest resource managers in making silvicultural and management decisions in individual stands. Most of these systems were designed to assign individual trees into categories based on various external characteristics, such as species, tree health, crown class, crown size, damage from pathogens, bole quality, and product class. Some tree classification systems were developed for mixed-species stands, such as mixed conifers (Hanzlik 1924), upland hardwoods (Smith 1954), southern bottomland hardwoods (Putnam et al. 1960), and northern hardwoods (Meteer and Linjala 1973). Several other systems were designed for multiaged, single-species stands of various western conifers (Dunning 1928, Taylor 1937, Hornibrook 1939, Keen 1943) or for even-aged, single-species stands (Gevorkiantz et al. 1943).

Several of the earlier tree classification systems consisted of detailed hierarchies composed of several main classes with numerous subclasses. Many of the definitions for the categories within these systems were complex and highly subjective, making them difficult to use in the field and unsuitable for reliable and consistent tree class assessment, especially in mixed-species stands. More recent tree classification systems were composed of fewer classes, but definitions of individual classes consisted of long, subjective descriptions of various tree characteristics. The tree classification system currently used in southern hardwoods, hereinafter referred to as the Putnam tree classification system, was originally developed by Putnam et al. (1960) and revised by Meadows (1996). It was based on species, crown class, tree health, and potential product class. This system was designed to provide a basis for planning and implementing partial cuttings in southern hardwood forests.

This article describes a new tree classification system for southern hardwoods. We describe the Putnam system (Putnam et al. 1960, Meadows 1996) and point out some of the problems associated with its use in management of southern hardwood forests. We then propose a new tree classification system, describe how it has evolved from the Putnam system, and discuss potential uses and adaptations of our new system.

Description of the Putnam Tree Classification System

Putnam et al. (1960) described a set of hardwood tree classes that could be used as a basis for planning partial cuttings and for developing marking rules in southern hardwood forests. This system was designed to be used in stands where the primary objective of management is the production of high-quality hardwood sawtimber. This tree classification system, as later revised by Meadows (1996), is currently used today as an important silvicultural tool in southern hardwood management.

The Putnam tree classification system consists of four tree classes: (1) preferred growing stock, (2) reserve growing stock, (3) cutting stock, and (4) cull stock (Table 1). The **preferred growing stock** class, originally called "leave" trees by Putnam et al. (1960), consists of the most valuable and desirable trees in the stand. They may be thought of as "final crop trees" and are expected to continue to increase in value at a satisfactory rate if left in the stand to the end of

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James S. Meadows (smeadows01@fs.fed.us) and Daniel A. Skojac Jr. (dskojac@fs.fed.us), US Forest Service, Southern Research Station, PO Box 227, Stoneville, MS 38776; Daniel A. Skojac Jr.'s current address is US Forest Service, Ozark-St. Francis National Forest, 605 West Main Street, Russellville, AR 72801. *The authors thank John Adams, Wayne Clatterbuck, Andrew Ezell, J.C.G. Goelz, Allan Houston, Brian Lockhart, French Wynne Jr., and two anonymous reviewers for their constructive comments on earlier drafts of this article.*

Table 1. Tree classification system, originally described by Putnam et al. (1960) and later revised by Meadows (1996), currently used in management of southern hardwood forests.

Tree Class and Description
Preferred growing stock
1. Is in good condition
2. Is a desirable species for the site and for management objectives
3. Has a dominant or codominant crown
4. Can be left indefinitely if in good condition
5. Currently meets or has the potential to eventually meet minimum log grade specifications, which may vary by management and product objectives
Reserve growing stock
1. Is in good condition, but does not meet the minimum qualifications for preferred growing stock
2. Can be safely stored on the stump with little risk of mortality or degradation if left in the stand for one or more cutting cycles
Cutting stock
1. Must be cut during the next cutting cycle
2. May be in poor condition
3. May pose a significant risk of mortality or degradation in merchantability
4. May be a species that is unsuitable for the site or for management objectives
Cull stock
1. Is incapable of meeting the desired product goals

the rotation. The **reserve growing stock** class, originally called "storage" trees, contains good trees that otherwise do not meet the minimum requirements for preferred growing stock. These trees are not generally expected to increase in value at a satisfactory rate but also are not expected to significantly decrease in value if left in the stand for at least one more cutting cycle (a cutting cycle is generally considered to be a period of 10 years). Consequently, reserve growing stock trees can be safely stored on the stump at their current value with the reasonable expectation that they will retain that value and be available for harvest at the end of the next cutting cycle. The **cutting stock** class, originally called "cut" trees, consists of trees that must be cut during the next harvest operation. These trees form an unwanted component in the stand and are expected to reduce the value of the stand if left for another cutting cycle. The cutting stock class includes most fully mature trees and all overmature trees, as well as trees that are unsuitable for the site because of the biological requirements of the species and trees that are likely to suffer mortality, damage, decay, or degradation in merchantability during the next cutting cycle. Trees of species that are unsuitable for management objectives also are included in the cutting stock class, if they currently contain merchantable sawtimber. The **cull stock** class contains trees that are incapable of meeting the desired product goals. This class includes trees that are unmerchantable because of species, poor form, excessive defects on the bole, or severe damage from insects or disease. Unmerchantable species are those that cannot be marketed for sawtimber and can only rarely be marketed for pulpwood. In the Putnam tree classification system, preferred growing stock and reserve growing stock are collectively referred to as **growing stock**, whereas cutting stock and cull stock are collectively referred to as **overburden**.

These four hardwood tree classes are used to establish the cutting priority when marking a stand for partial cutting. The timber marker uses the tree classification system to identify the types of trees to be cut and the types of trees to be left to form the residual stand. The ideal procedure is to remove the cull stock, cutting stock, and reserve growing stock trees, leaving only the preferred growing stock trees for future growth. However, because preferred growing stock generally forms a relatively small proportion of any given stand, this prescription usually leaves an understocked residual stand that is unable to fully use the site for many years to come. Consequently, a more practical prescription is to (1) cut *all* of the cutting stock trees; (2) cut *none* of the preferred growing stock trees; and (3) cut *none*, *some*, or *all* of the reserve growing stock trees, according to the planned intensity of the cut to be made. Cull stock trees are cut or left, depending on management objectives and economic constraints. For example, if timber production is the only goal of management, all cull stock trees are removed from the stand. However, if wildlife habitat management also is an objective, some or all of the cull stock trees may be left in the residual stand. Under the Putnam tree classification system, the reserve growing stock class is used to regulate the intensity of the partial cutting. Intensity of the cut typically is depicted as some prescribed level of residual stand density, such as basal area per acre or stocking percent.

Problems with the Putnam Tree Classification System

There are several critical problems associated with the use of the Putnam tree classification system as a tool to assist the forest resource manager in southern hardwood management. These problems usually are encountered when cutting a stand to some specified measure of residual stand density.

The first problem associated with field use of the Putnam tree classification system is that the reserve growing stock class is both poorly defined and too broad. Consequently, it becomes a "catch-all" class when categorizing individual trees in a stand. Trees that are not desirable enough to be classified as preferred growing stock and trees that are not poor enough to be classified as cutting stock or cull stock typically are lumped together into the reserve growing stock class. In practice, the forest resource manager or timber marker may designate the higher-quality reserve growing stock trees as "reserve-plus" or "high reserve" to indicate that these trees should be left in the stand after partial cutting. In the same manner, the lower-quality reserve growing stock trees may be designated as "reserve-minus" or "low reserve" to indicate that these trees should be cut during the next partial cutting operation. The result of this field practice is to informally separate the reserve growing stock class into three undefined subclasses: (1) high-quality trees that resemble preferred growing stock trees, (2) medium-quality trees that are "true" reserve growing stock trees, and (3) low-quality trees that resemble cutting stock trees.

The prescription for partial cutting in most southern hardwood stands is to mark the stand to a predetermined, somewhat rigid target for residual stand density. Because the reserve growing stock class is so broad, this prescription dictates that a specified proportion of trees from the reserve growing stock class be cut to meet the target. Consequently, the second problem associated with field use of the Putnam tree classification system is that the timber marker must select which trees in the reserve growing stock class to cut and which trees in that class to leave. These crucial decisions must be made spontaneously as the timber marker quickly works through the stand.

Third, the timber marker also must try to mark the stand to a prescribed level of residual density. It is extremely difficult to accurately and consistently visualize stocking percent or any other quantitative measure of residual stand density, especially in multistrata, mixed-species hardwood stands. These decisions and visualizations must be made extemporaneously to ensure that the stand is marked efficiently and that the prescribed level of residual density is distributed uniformly across the stand. Thus, the timber marker typically bears the responsibility of shaping the residual stand to meet the goals of management.

Finally, the timber marker often is forced to either leave low-quality reserve growing stock trees or cut high-quality reserve growing stock trees to maintain the target residual density across the stand. Retention of low-quality trees reduces the quality and value of the residual stand because these trees interfere with and reduce the growth of the higher-value residual trees. Likewise, premature removal of high-quality trees reduces residual stand quality and value because these trees will not be available to contribute to the future value growth of the stand. Thus, the broad, "catch-all" nature of the reserve growing stock class in the Putnam tree classification system and strict adherence to the concept of stand density management lead to a situation where overall stand quality and value growth potential may be compromised by a predetermined target for residual stand density.

Description of the New Tree Classification System

Because of these problems, we developed a new hardwood tree classification system for use in the management of southern hardwood forests. This new system expands Putnam's set of four tree classes into a new set of five tree classes used only for sawtimber-sized trees and creates two new tree classes used only for poletimber-sized trees. In hardwoods, sawtimber is generally defined as those trees at least 12 in. dbh. Generally, poletimber is defined as those trees at least 5 in. dbh but less than 12 in. dbh. These definitions vary locally as market conditions dictate the minimum size requirements for sawtimber. As a result, the threshold diameter between poletimber and sawtimber may be as low as 10–11 in. dbh or as high as 14 in. to possibly even 16 in. dbh.

Definitions of the tree classes in the new system are more specific than in the Putnam system and are based on five characteristics important in predicting future performance and value growth potential of individual trees: (1) species, (2) crown class, (3) current condition of the tree and future risk of mortality or degradation in merchantability, (4) bole quality, and (5) expected change in value over time. Our new tree classification system was developed primarily for use in even-aged stands, but, because it is based solely on the merits of individual trees, it should be applicable in uneven-aged stands as well.

Species is one of the most important characteristics used to delineate tree classes in our new system. To properly apply the tree classification system, species should be grouped into four broad classes based on their ability to successfully fulfill the objectives of management, as dictated by the forest owner: (1) desirable, (2) acceptable, (3) undesirable, and (4) unmerchantable. Species in the **desirable** class are those that are best able to meet the goals of management. The forest resource manager actively wants these species in the stand because they provide benefits that are attractive to management. Pecan (*Carya illinoensis* [Wangenh.] K. Koch), green ash (*Fraxinus pennsylvanica* Marsh.), swamp chestnut (*Quercus michauxii* Nutt.), Nuttall (*Quercus nuttallii* Palmer), and cherrybark (*Quercus pagoda* Raf.) oaks are examples of desirable species if the production of high-quality sawtimber is the primary goal of management. Species in the **acceptable** class are those that adequately meet the goals of management but are not particularly desirable for management. The forest resource manager passively accepts these species in the stand. Sugarberry (*Celtis laevigata* Willd.), sweetgum (*Liquidambar styraciflua* L.), sycamore (*Platanus occidentalis* L.), and overcup oak (*Quercus lyrata* Walt.) are examples of acceptable species for timber production. Species in the **undesirable** class are those that are unsuitable for meeting the goals of management. The forest resource manager actively seeks to remove these species from the stand. River birch (*Betula nigra* L.), black tupelo (*Nyssa sylvatica* Marsh.), and swamp laurel oak (*Quercus laurifolia* Michx.) are examples of undesirable species for the production of high-quality sawtimber. Species in the **unmerchantable** class are those that are incapable of meeting the goals of management. In most cases, the forest resource manager actively seeks to remove these species from the stand. Unmerchantable species generally cannot be marketed as sawtimber and only rarely can be marketed as pulpwood. Boxelder (*Acer negundo* L.), American hornbeam (*Carpinus caroliniana* Walt.), red mulberry (*Morus rubra* L.), and eastern hophornbeam (*Ostrya virginiana* [Mill.] K. Koch) are typical examples of unmerchantable species. Individual species may be assigned to different species classes if the primary goal of management is something other than the production of high-quality sawtimber.

Our new tree classification system consists of five tree classes used only for sawtimber-sized trees: (1) preferred growing stock, (2) desirable growing stock, (3) acceptable growing stock, (4) cutting stock, and (5) cull stock; and two tree classes used only for poletimber-sized trees: (1) superior poletimber stock and (2) inferior poletimber stock (Table 2). In this new system, preferred growing stock, desirable growing stock, acceptable growing stock, and superior poletimber stock are collectively referred to as **growing stock**, whereas cutting stock, cull stock, and inferior poletimber stock are collectively referred to as **overburden**.

As in the Putnam tree classification system, the **preferred growing stock** class consists of the most valuable and desirable trees in the stand (Figure 1). This class is limited to only those species that are the most desirable for both the site and the goals of management (desirable species class only). It is characterized by sawtimber-sized, upper-crown-class trees that are in excellent condition and have high-quality boles. They are expected to remain in excellent condition to the end of the rotation with very low risk of mortality or degradation in merchantability. Preferred growing stock trees are expected to continue to increase in value if left in the stand for one or more cutting cycles. The cherrybark oak tree in Figure 1 is 34 in. dbh and has a dominant crown. Cherrybark oak is classified as a desirable species for the site and for management objectives. This tree has no epicormic branches on the lower bole and contains a 16-ft-long, grade 1 butt log. It is in excellent condition and is expected to remain so indefinitely. It will likely increase in value over time, with little or no risk to future merchantability. Because this tree clearly meets all requirements for the class, it is correctly classified as preferred growing stock.

The **desirable growing stock** class also consists of very good trees that are "desirable" for meeting the goals of management (Figure 2). However, these trees do not quite meet the minimum qualifications for preferred growing stock. For example, this class is not limited to desirable species only, but also may contain species that are acceptable for both the site and the management objectives (desirable or acceptable species classes). It is characterized by sawtimber-sized, upper-crown-class trees that are in good condition and have boles of at least medium quality. They are expected to remain in good condition to the end of the rotation with low risk of mortality or degradation in merchantability. Desirable growing

Table 2. A new tree classification system proposed for use in management of southern hardwood forests.

Tree Class and Description
Sawtimber-sized trees
Preferred growing stock
1. Is a desirable species for the site and for management objectives
2. Has a dominant or codominant crown
3. Is currently in excellent condition and is likely to remain so indefinitely (to the end of the rotation) with very low risk of mortality or degradation in merchantability
4. Currently contains a grade 1 log at least 10 ft in length, entirely within the 16-ft butt log section of the bole
5. Is expected to increase in value at a satisfactory rate if left in the stand for one or more cutting cycles
Desirable growing stock
1. Is a desirable or an acceptable species for the site and for management objectives
2. Has a dominant or codominant crown
3. Is currently in good condition and is likely to remain so indefinitely (to the end of the rotation) with low risk of mortality or degradation in merchantability
4. Currently contains a grade 2 or better log at least 10 ft in length, entirely within the 16-ft butt log section of the bole
5. Is expected to increase in value at a satisfactory rate if left in the stand for one or more cutting cycles
Acceptable growing stock
1. Is a desirable or an acceptable species for the site and for management objectives
2. Has a dominant, codominant, or intermediate crown (may have an overtopped crown if a shade-tolerant species)
3. Is currently in fair condition and is likely to remain so for one or more cutting cycles with moderate risk of mortality or degradation in merchantability
4. Currently contains a grade 3 or better log at least 8 ft in length, entirely within the 16-ft butt log section of the bole
5. Is expected to neither increase nor decrease in value if left in the stand for one or more cutting cycles
Cutting stock
1. Must be cut during the next cutting cycle if any of the following are true:
a. Is an undesirable species for management objectives or is a species unsuitable for the site
b. Has an overtopped crown (except if a shade-tolerant species)
c. Is currently in poor condition with significant risk of mortality or degradation in merchantability
2. Currently contains a grade 3 or better log at least 8 ft in length within the merchantable bole
3. Is expected to significantly decrease in value if left in the stand for one or more cutting cycles
Cull stock
1. Is incapable of meeting the desired product goals or is an unmerchantable species
Poletimber-sized trees
Superior poletimber stock
1. Is a desirable or an acceptable species for the site and for management objectives
2. Is currently in good condition and is likely to remain so for one or more cutting cycles with moderately low risk of mortality or degradation in potential merchantability
3. Has the potential to contain a grade 2 or better log at least 10 ft in length, entirely within the 16-ft butt log section of the bole, when minimum diameter requirements are reached
Inferior poletimber stock
1. Must be cut during the next cutting cycle if any of the following are true:
a. Is an undesirable or unmerchantable species for management objectives or is a species unsuitable for the site
b. Is currently in poor condition with significant risk of mortality or degradation in potential merchantability
c. Is diseased, damaged, or exhibits poor form
2. Is incapable, because of poor bole quality, of producing a grade 2 or better log at least 10 ft in length, entirely within the 16-ft butt log section of the bole, when minimum diameter requirements are reached

stock trees also are expected to increase in value if left in the stand one or more cutting cycles. The sweetgum tree in Figure 2 is 19 in. dbh and has a codominant crown. It has no epicormic branches on the lower bole and contains a 16-ft-long, grade 1 butt log. It is in excellent condition and will likely increase in value over time. However, because sweetgum is classified as an acceptable species for the production of high-quality sawtimber, this tree fails to meet all requirements for preferred growing stock but does meet all requirements for desirable growing stock. Thus, it is correctly classified as desirable growing stock.

The **acceptable growing stock** class does not necessarily form a desired component of the stand but does contain trees that are "acceptable" for meeting the goals of management (Figure 3). This class may consist of trees in either the desirable or the acceptable species classes and includes sawtimber-sized trees of any crown class except overtopped (trees of a shade-tolerant species may be in the overtopped class). Acceptable growing stock trees are generally in fair condition and are expected to remain so for at least one more cutting cycle, but with moderate risk of mortality or degradation in merchantability. Bole quality usually is fairly low but can be high if other criteria place the tree in this class. Acceptable growing stock trees are expected to neither increase nor decrease in value if left in the stand for one or more cutting cycles. The water oak (*Quercus nigra* L.) tree in Figure 3 is 21 in. dbh and has a codominant crown. Water oak usually is classified as a desirable species. However, this tree has several large epicormic branches on the lower bole and contains a 16-ft-long, grade 3 butt log. The presence of several epicormic branches is indicative of a tree in only fair condition and health. Consequently, there is at least a moderate risk of mortality or degradation in merchantability over the next 10 years. This tree fails to meet the requirements for either preferred growing stock or desirable growing stock. Because it is in only fair condition and exhibits low bole quality, this tree is correctly classified as acceptable growing stock.

The **cutting stock** class forms an unwanted component in the stand. It may consist of trees in any species class (except unmerchantable) and includes sawtimber-sized trees that, for a variety of possible reasons, must be cut during the next partial harvest operation (Figure 4). For example, this class includes trees of species that are undesirable for meeting the goals of management as well as trees of species that are unsuitable for the site. It also includes all sawtimber-sized trees in the overtopped crown class (except those trees of a shade-tolerant species) and all trees in poor condition that

Figure 1. This preferred growing stock tree is a dominant cherrybark oak that is 34 in. dbh and is growing in diameter at the rate of nearly 5 in./decade. It is in excellent condition, exhibits outstanding bole quality, and is expected to continue to increase in value over time.

Figure 2. This desirable growing stock tree is a codominant sweetgum that is 19 in. dbh. It is in excellent condition and exhibits very good bole quality. However, because sweetgum is classified as an acceptable species, this tree does not meet the minimum requirements for preferred growing stock.

exhibit a significant risk of mortality or degradation in merchantability. The cutting stock class also includes trees that have attained or will soon attain the maximum diameter allowed by the sawmill, i.e., trees that are or will soon be too large for the sawmill. However, to be classified as cutting stock, trees must contain a merchantable sawlog at least 8 ft long. Bole quality is typically poor. Cutting stock trees are expected to significantly decrease in value if left in the stand for one or more cutting cycles. The water oak tree in Figure 4 is 24 in. dbh and has a codominant crown. Even though water oak is classified as a desirable species, this particular tree is in poor condition and has severe disease problems. There is a significant risk of mortality or further degradation in merchantability over the next 10 years. Although much of the bole is unmerchantable, the tree does contain a 10-ft-long, grade 3 log beginning at a height of about 6 ft. The tree clearly does not meet the requirements for any of the three growing stock classes. However, because it does contain a merchantable sawlog at least 8 ft long, the tree qualifies for and is correctly classified as cutting stock.

The **cull stock** class contains sawtimber-sized trees that are incapable of meeting the desired product goals of management (Figure 5). This class includes trees that are unmerchantable because of species, extremely poor form, excessive defects on the bole, or severe damage from insects or disease. Cull stock trees cannot currently be marketed as sawtimber and they do not have the potential to be so in the future. Some cull stock trees may be marketed as pulpwood. The swamp chestnut oak tree in Figure 5 is 33 in. dbh and has a dominant crown. It is clearly hollow and contains no merchantable sawtimber. Thus, this tree is correctly classified as cull stock.

Our new tree classification system also consists of two tree classes used only for poletimber-sized trees (these two classes do not include sawtimber-sized trees that contain only pulpwood; those trees would be correctly classified as cull stock). The **superior poletimber stock** class consists of poletimber-sized trees with high potential to eventually develop into sawtimber growing stock (Figure 6). This class may consist of trees in either the desirable or the acceptable species classes and includes trees of any crown class that are in good condition and are likely to remain so for one or more cutting cycles with moderately low risk of mortality or degradation in potential merchantability. Superior poletimber stock trees must have the potential to develop grade 2 or better butt logs when minimum diameter requirements are met. The swamp chestnut oak tree in Figure 6 is 10 in. dbh and has a well-developed, but overtopped, crown. It is very straight and has only a few small epicormic branches along the upper bole. This tree has high potential to develop into a high-quality sawtimber tree. Thus, it is correctly classified as superior poletimber stock.

In contrast, the **inferior poletimber stock** class consists of poletimber-sized trees with low potential to develop into sawtimber growing stock (Figure 7). This class includes trees that must be cut during the next harvest operation. Although these trees may be in any species class, typically, they are of a species that is undesirable or unmerchantable for management objectives or a species that is unsuitable for the site. The trees usually are in poor condition and

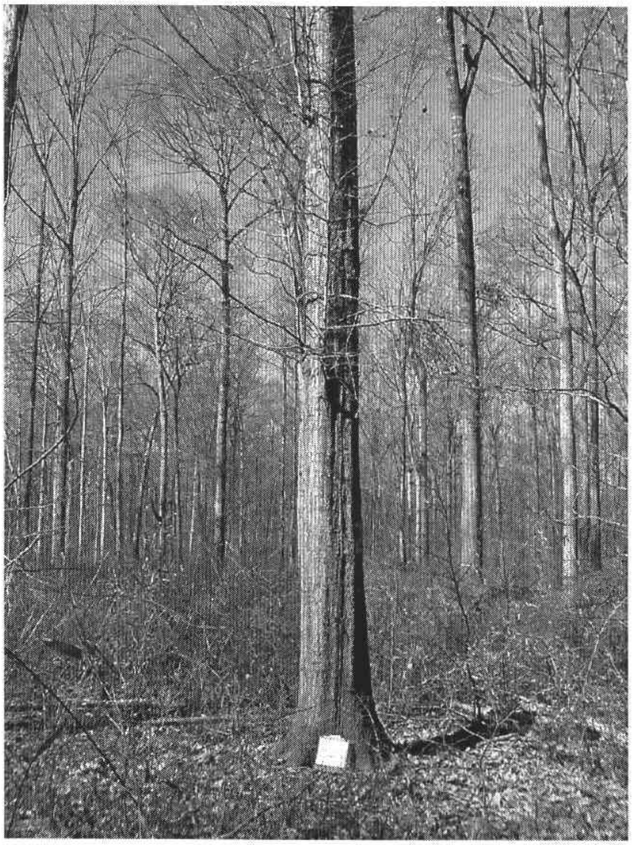

Figure 3. This acceptable growing stock tree is a codominant water oak that is 21 in. dbh. It is in fair condition, but the presence of several large epicormic branches along the bole reduces log grade and is an indication of only moderate health.

Figure 4. This cutting stock tree is a codominant water oak that is 24 in. dbh. It is in poor condition and has severe disease problems but does meet the minimum log grade requirements to be classified as cutting stock.

exhibit a significant risk of mortality or degradation in potential merchantability. This class also includes poletimber-sized trees that are diseased, damaged, or of poor form. Overtopped trees with a flat-topped crown should be classified as inferior poletimber stock. Because of poor bole quality, inferior poletimber stock trees are incapable of eventually producing grade 2 or better butt logs when minimum diameter requirements are met. The hickory (*Carya* spp.) tree in Figure 7 is 11 in. dbh and has an overtopped crown. It is crooked and in poor condition, with evidence of rot in the upper bole. This tree is incapable of eventually producing high-quality sawtimber. It is correctly classified as inferior poletimber stock.

Field Use of the New Tree Classification System

Our new tree classification system can be applied easily to most hardwood trees in most situations. To correctly apply the new tree classification system, the observer must be consistent, objective, and free of bias. Classification of each tree should proceed in a systematic fashion in which the tree's characteristics are compared with those outlined in Table 2, so that each tree is placed in the highest tree class for which it qualifies. A dichotomous key to the new tree classification system is provided in the Appendix. The observer may use either Table 2 or the dichotomous key, depending on personal preference, to evaluate the tree class of individual trees. The dichotomous key should be particularly useful as a learning tool for inexperienced observers.

The first step in the classification process is to determine tree size, specifically dbh. This characteristic categorizes the tree as either sawtimber or poletimber and determines which of the two sets of tree classes is applicable. Generally, sawtimber trees are at least 12 in. dbh and poletimber trees are at least 5 in. but less than 12 in. dbh. These threshold values may vary locally.

The second step is to evaluate each tree based on the five characteristics described earlier: (1) species, (2) crown class, (3) current condition of the tree and future risk of mortality or degradation in merchantability, (4) bole quality, and (5) expected change in value over time. These five characteristics are important in predicting future performance and value growth potential of the tree. As such, they form the basis for our new tree classification system. Each tree is assessed in terms of each of these five characteristics. The results of that assessment are compared with the criteria outlined in Table 2 to correctly place each tree in the appropriate tree class.

To correctly use the system, the observer should place the tree in the highest tree class possible. Use either Table 2 or the dichotomous key in the Appendix, depending on personal preference, to determine if the tree meets all the requirements for preferred growing stock. If it does not, determine if the tree meets all the requirements for desirable growing stock. If it does not, continue in this fashion until the tree meets all the requirements for the appropriate tree class. We recommend that inexperienced users of this new system proceed in this systematic fashion. With experience, the user should recognize that species, crown class, and minimum size requirements for each of the three log grades are criteria that can be used to quickly assign the tree to a preliminary tree class. Assessment of these three criteria is easy, rapid, and fairly objective. Final classification into the correct tree class requires confirmation that the tree also meets the

Figure 5. This cull stock tree is a dominant swamp chestnut oak that is 33 in. dbh. It is hollow and contains no merchantable sawtimber.

Figure 6. This superior poletimber stock tree is an overtopped swamp chestnut oak that is 10 in. dbh. It is very straight with few epicormic branches and a well-developed crown. This tree has high potential to eventually develop into high-quality sawtimber growing stock.

appropriate requirements of the remaining two criteria. There are two situations in which commonsense adjustments must be made to apply our new tree classification system correctly: (1) sawtimber-sized trees with abnormalities in the lower bole and (2) poletimber stands.

Sawtimber-Sized Trees with Abnormalities in the Lower Bole

Many sawtimber-sized trees have abnormalities that limit the development of quality sawlogs within the 16-ft butt log section of the bole. Bole sections that contain abnormalities generally do not contain sound wood that can be marketed as sawtimber. These cull sections usually are cut out of the bole and discarded rather than contained as cull areas within a marketable sawlog. Consequently, these abnormalities limit the length of the sawlog rather than reduce the grade of the sawlog. Abnormalities may be either physical or biological in nature. Physical abnormalities include forks, crooks, and sweep. These abnormalities generally, but not always, pose a moderate risk of future degradation in merchantability. Biological abnormalities include rot, hollow, and severe insect damage. These abnormalities almost always pose a significant risk of future degradation in merchantability.

If the abnormalities in the lower bole are not too extensive and the tree currently contains a grade 2 or better sawlog at least 10 ft in length entirely within the 16-ft butt log section of the bole, it is possible, but unlikely, to classify the tree as either preferred growing stock or desirable growing stock. Because physical abnormalities generally pose a moderate risk of future degradation in merchantability, these trees usually are classified as acceptable growing stock, at best, if all other requirements are met. On the other hand, because biological abnormalities pose a significant risk of future degradation in merchantability, these trees must be classified as cutting stock, even though they may contain a high-quality sawlog within the lower bole. The increased risk of future degradation in merchantability associated with both physical and biological abnormalities becomes the deciding factor in the tree classification process, even in situations where the tree contains a relatively high-quality sawlog.

In contrast, if the abnormalities in the lower bole are so extensive that the tree does not currently contain a grade 3 or better sawlog at least 8 ft in length entirely within the 16-ft butt log section of the bole, the tree must be classified as either cutting stock or cull stock. If the tree contains a grade 3 or better sawlog at least 8 ft in length anywhere within the merchantable bole below the crown, it should be classified as cutting stock. If the tree does not contain any sawlogs at least 8 ft in length, it must be classified as cull stock.

Field Use in Poletimber Stands

Although the new tree classification system is designed to be used in sawtimber stands, it can be easily adapted for use in poletimber stands, in which the majority of the trees in the overstory are below sawtimber size. In these stands, the five sawtimber tree classes should be used to classify poletimber trees in the overstory. To address the log grade requirements for trees in these stands, upper-crown-class poletimber trees should be evaluated on the basis of **potential** log grade. For example, to be classified as preferred growing stock, an upper-crown-class poletimber tree should have the potential to

Figure 7. This inferior poletimber stock tree is an overtopped hickory that is 11 in. dbh. It is crooked and in poor condition with some evidence of rot in the upper bole. This tree has very low potential to eventually develop into sawtimber growing stock.

eventually contain a grade 1 log at least 10 ft in length, entirely within the 16-ft butt log section of the bole, once minimum diameter requirements are reached. All other criteria for each of the five sawtimber tree classes remain the same. The two poletimber tree classes, as defined in Table 2, should be used to classify lower-crown-class poletimber trees in these stands.

Comparison between the Two Tree Classification Systems

Our new tree classification system is more specific and more consistently defined than the Putnam system. Specifically, it differs from the Putnam system in a number of important ways. The preferred growing stock class is essentially the same in both systems but is more precisely defined in the new system. The upper end of the reserve growing stock class (the "reserve-plus" or "high reserve" trees discussed previously) from the Putnam system are generally equivalent to the desirable growing stock class in our new system. These trees should be left in the stand after partial cutting. The medium-quality reserve growing stock trees from the Putnam system generally correspond to the acceptable growing stock class in the new system. The lower end of the reserve growing stock class (the "reserve-minus" or "low reserve" trees discussed previously) from the Putnam system are included in the cutting stock class in the new system. The cull stock class is the same in both systems. Poletimber-sized trees from all four classes in the Putnam system are designated as either superior poletimber stock or inferior poletimber stock in the new system.

Data from one of our hardwood thinning studies can be used to illustrate the differences between the Putnam system and our new tree classification system. The 24-ac study area from which these data were taken is located on a minor streambottom site in west central Alabama. The stand is approximately 60–65 years old and is composed of mixed bottomland hardwoods. The primary oak species are cherrybark, water, willow (*Quercus phellos* L.), and swamp chestnut oaks. Other principal species in the overstory include sweetgum and various species of hickory. The stand contains 122 ft^2 of basal area, 4.7 cords of pulpwood, and 9,509 bd ft (Doyle scale) of sawtimber per acre.

All trees 5.5 in. dbh or greater were assigned tree classes using both the Putnam and the new tree classification systems. The proportions of stand basal area, pulpwood volume, and sawtimber volume attributed to each tree class were calculated for each of the two systems. The resulting tree class distributions for the Putnam tree classification system and for our new tree classification system are presented in Tables 3 and 4. Under the Putnam system, 64% of the basal area and 63% of the sawtimber volume were classified as reserve growing stock (Table 3). These high percentages reflect the "catch-all" nature of the reserve growing stock class as defined in the Putnam system, a problem discussed in an earlier section. The reserve growing stock class is poorly defined and encompasses a broad range of tree quality characteristics. In contrast, a more uniform distribution of tree classes is found under our new tree classification system (Table 4). Trees classified as reserve growing stock under the Putnam system are somewhat evenly distributed among the desirable growing stock, acceptable growing stock, and cutting stock classes under our new tree classification system. Assimilation of the low-quality reserve growing stock trees into the cutting stock class results in increases in the cutting stock component from 12% of the basal area and 12% of the sawtimber volume under the Putnam tree classification system (Table 3) to 23% of the basal area and 20% of the sawtimber volume under our new tree classification system (Table 4).

Under the Putnam system, the overburden component of this stand (cutting stock and cull stock combined) accounts for 22% of the basal area, 27% of the pulpwood volume, and 12% of the sawtimber volume (all values presented in this example are derived from Table 3 through appropriate combinations of the data associated with the specific tree classes being discussed). A partial cutting operation designed to harvest only the overburden component would remove 1.2 cords of pulpwood and 1,163 bd ft of sawtimber per acre. The residual stand, composed of all trees in the preferred growing stock and reserve growing stock classes, would contain 96 ft^2 of basal area, 3.5 cords of pulpwood, and 8,346 bd ft of sawtimber per acre. A partial cutting of such low intensity would not reduce stand density sufficiently to promote the desired growth responses by residual trees. Furthermore, the volumes of pulpwood and sawtimber to be removed from the stand are likely inadequate to provide for a profitable logging operation.

A combination of the overburden component and the reserve growing stock class under the Putnam system accounts for 86% of the basal area, 100% of the pulpwood volume, and 75% of the sawtimber volume (see Table 3). A partial cutting operation designed to harvest these components of the stand would remove 4.7 cords of pulpwood and 7,123 bd ft of sawtimber per acre. The residual stand, composed of trees in the preferred growing stock class only, would contain 17 ft^2 of basal area and 2,386 bd ft of sawtimber per acre. Clearly, a partial cutting of such high intensity would

Table 3. Tree class distributions, as percentages of stand basal area, pulpwood volume, and sawtimber volume, for the Putnam tree classification system in a mixed-species bottomland hardwood stand in west central Alabama.

Tree class	Basal area (ft^2/ac)	Percent	Pulpwood volume (cords/ac)	Percent	Sawtimber volume (bd ft/ac)	Percent
Preferred	17	14	0.0	0	2,386	25
Reserve	79	64	3.5	73	5,960	63
Cutting	14	12	0.4	10	1,163	12
Cull	12	10	0.8	17	0	0
Total	122	100	4.7	100	9,509	100

Table 4. Tree class distributions, as percentages of stand basal area, pulpwood volume, and sawtimber volume, for our new tree classification system in a mixed-species bottomland hardwood stand in west central Alabama.

Tree class	Basal area (ft^2/ac)	Percent	Pulpwood volume (cords/ac)	Percent	Sawtimber volume (bd ft/ac)	Percent
Preferred	16	13	0.0	0	2,290	24
Desirable	33	27	0.0	0	3,559	38
Acceptable	22	18	0.0	0	1,736	18
Cutting	28	23	0.0	0	1,924	20
Cull	6	5	0.0	0	0	0
Superior pole	6	5	1.8	38	0	0
Inferior pole	11	9	2.9	62	0	0
Total	122	100	4.7	100	9,509	100

produce a severely understocked residual stand that would be unacceptable for future management.

Neither scenario under the Putnam system is attractive to the forest resource manager, a situation that necessitates removal of some proportion of the reserve growing stock class to achieve a viable partial cutting prescription. The timber marker, without benefit of adequate guidelines, must then select which reserve growing stock trees to cut and which ones to leave, a critical problem discussed in an earlier section.

In contrast, under our new tree classification system, the overburden component of this stand (cutting stock, cull stock, and inferior poletimber stock combined) accounts for 37% of the basal area, 62% of the pulpwood volume, and 20% of the sawtimber volume (all values presented in this example are derived from Table 4 through appropriate combinations of the data associated with the specific tree classes being discussed). A partial cutting operation designed to harvest only the overburden component would remove 2.9 cords of pulpwood and 1,924 bd ft of sawtimber per acre. The residual stand, composed of all trees in the preferred growing stock, desirable growing stock, acceptable growing stock, and superior poletimber stock classes, would contain 77 ft^2 of basal area, 1.8 cords of pulpwood, and 7,585 bd ft of sawtimber per acre. A partial cutting of this intensity would reduce stand density sufficiently to promote the desired growth responses by residual trees. The volumes of pulpwood and sawtimber to be removed from the stand are likely great enough to provide for a profitable logging operation.

A combination of the overburden component and the acceptable growing stock class under our new tree classification system accounts for 55% of the basal area, 62% of the pulpwood volume, and 38% of the sawtimber volume (see Table 4). A partial cutting operation designed to harvest these components of the stand would remove 2.9 cords of pulpwood and 3,660 bd ft of sawtimber per acre. The residual stand, composed of all trees in the preferred growing stock, desirable growing stock, and superior poletimber stock classes, would contain 55 ft^2 of basal area, 1.8 cords of pulpwood, and 5,849 bd ft of sawtimber per acre. A partial cutting of this intensity clearly would promote the desired growth responses by residual trees, but also would produce a residual stand that may be marginally understocked. The volumes of pulpwood and sawtimber to be removed from the stand are more than ample enough to provide for a profitable logging operation.

Both scenarios under our new tree classification system are attractive to the forest resource manager. Both are likely to produce the desired growth responses by residual trees. Both will remove enough volume to make the logging operation profitable. A partial cutting prescription to remove only the overburden seems to be the most reasonable option for this mid-to-late-rotation stand. This prescription should promote satisfactory growth responses by residual trees, while maintaining a well-stocked stand. On the other hand, a prescription to remove all trees in the acceptable growing stock class in addition to the overburden component may be a reasonable option if final harvest of the stand is anticipated within the next 10–15 years. This expanded prescription should produce a residual stand that is sufficiently open to promote the establishment and development of desirable advance reproduction in adequate quantities to successfully regenerate the stand in the near future. Both prescriptions only require the timber marker to have the ability to recognize tree classes. Both eliminate the need to select a proportion of individual trees to be cut from within a tree class. Conceptually, both prescriptions lead to improved marking rules and procedures that produce more ideal residual stands with higher potentials for future value growth.

Applications of the New Tree Classification System

Our new tree classification system can be used as an educational and training tool for inexperienced hardwood forest managers. It also gives experienced hardwood forest managers a better grasp of those five characteristics important in predicting future performance and value growth potential of individual trees: (1) species, (2) crown class, (3) current condition of the tree and future risk of mortality or degradation in merchantability, (4) bole quality, and (5) expected change in value over time. Our new system emphasizes that the ability of an individual tree to meet the goals of management is determined by a combination of these five characteristics rather than being exclusively dependent on a single factor, such as species or log grade. Because our system is based on a well-organized and well-defined set of criteria for each tree class, we are able to more consistently, more accurately, and more reliably categorize an individual tree's ability to meet the goals of management than was possible using the Putnam system.

Our new tree classification system is easy to understand and simple to use. New users should be able to consistently and proficiently apply the system after just a short period of training and field practice. Because some of the elements of the system are subjective, it is likely that there will be some variation among users. However, variation among experienced users should be small and inconsequential.

Although our new tree classification system is designed to be used in stands in which the primary goal of management is the production of high-quality hardwood sawtimber, it can be readily adapted for use in stands in which the goals of management are something other than timber production. Some of the criteria that form the definitions of the various tree classes may need to be revised or even deleted. Other criteria specific to a particular goal of management may need to be added. For example, in those stands in which wildlife habitat management is the primary goal, species groups may need to be revised; criteria related to merchantability, bole quality, and economic value may need to be deleted; and criteria related to mast production, cavity/den occurrence, and canopy position may need to be developed and added to the definitions. Our new tree classification system is very flexible and thus can be adapted easily to any set of landowner objectives by revision and modification of the appropriate definitions to reflect those objectives. The tree classes, with suitable criteria and definitions specific to the goals of management, can be used to categorize individual trees as preferred, desirable, acceptable, undesirable, or even incapable of meeting the goals of management, whatever those goals may be.

An important application of our new hardwood tree classification system is for forest inventory purposes. We recommend that tree class be assessed as an additional variable taken during measurement of continuous forest inventory permanent plots. Changes in tree class, and therefore in a tree's ability to meet the goals of management, can be easily documented over time. Similarly, changes in the tree class distributions summarized from these data can be used to evaluate changes in vitality and value at the stand, forest, and ownership levels.

The new tree classification system also should be an important component of timber cruises taken for stand management planning purposes or for land/timber acquisition purposes. Tree class data collected during the timber cruise and expressed as a tree class distribution across the stand provide valuable information that the forest resource manager can use to help make important management decisions. For example, a tree class distribution that reveals a high proportion of cutting stock, cull stock, and inferior poletimber stock may indicate that the stand is in need of some type of silvicultural treatment, such as a partial cutting to improve species composition, growth, quality, and value of the stand. A very high proportion of these tree classes may indicate that the stand needs to be regenerated. Conversely, a tree class distribution in which there is a high proportion of preferred growing stock and desirable growing stock may indicate that the stand is developing in a satisfactory manner and that no silvicultural activities are needed at this time.

However, the most important application of our new tree classification system is in the development of improved marking guidelines for partial cuttings in hardwood stands. The tree classification system identifies the trees that contribute to the goals of management and, therefore, should be retained during a partial cutting operation. The system also identifies the trees that detract from the goals of management and, therefore, should be removed during a partial cutting operation. In fact, it may be possible to develop partial cutting prescriptions based solely on tree class, without regard to residual stand density. For example, a reasonable prescription in a previously unmanaged, midrotation hardwood stand might be to retain all trees in the preferred growing stock, desirable growing stock, acceptable growing stock, and superior poletimber stock classes and to remove all trees in the cutting stock, cull stock, and inferior poletimber stock classes. The decision to retain or remove specific tree classes will vary with initial stand conditions. Partial cutting prescriptions based solely on our new tree classification system are simpler and easier to implement than prescriptions that dictate the stand be cut to a predetermined level of residual stand density. To successfully implement prescriptions based solely on our new tree classification system, the timber marker needs only the ability to differentiate tree classes and does not need to be concerned with the level of residual stand density.

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Appendix

Key to the New Tree Classification System

1. Meets minimum size requirements for **sawtimber** 2
1. Does not meet minimum size requirements for sawtimber, but does meet minimum size requirements for **poletimber** 21
2. Species class is **desirable** for the site and for management objectives 3
2. Species class is **acceptable, undesirable,** or **unmerchantable** 8
3. Crown class is **dominant** or **codominant** 4
3. Crown class is **intermediate** or **overtopped** 14
4. Current condition is **excellent** and is likely to remain so indefinitely (to the end of the rotation) 5
4. Current condition is **less than excellent** 10
5. Risk of mortality or degradation in merchantability is **very low** 6
5. Risk of mortality or degradation in merchantability is **greater than very low** 11

6. Currently contains a **grade 1** log at least 10 ft in length, entirely within the 16-ft butt log section of the bole 7
6. Does not currently contain a **grade 1** log at least 10 ft in length, entirely within the 16-ft butt log section of the bole 12
7. Value is **expected to increase** at a satisfactory rate if left in the stand for one or more cutting cycles . . **Preferred Growing Stock**
7. Value is **not expected to increase** at a satisfactory rate if left in the stand for one or more cutting cycles 18
8. Species class is **acceptable** for the site and for management objectives 9
8. Species class is **undesirable** for the site or for management objectives or species class is **unmerchantable** 19
9. Crown class is **dominant** or **codominant** 10
9. Crown class is **intermediate** or **overtopped** 14
10. Current condition is **good** or **excellent** and is likely to remain so indefinitely (to the end of the rotation) 11
10. Current condition is **less than good** 15
11. Risk of mortality or degradation in merchantability is **low** or **very low** 12
11. Risk of mortality or degradation in merchantability is **greater than low** 16
12. Currently contains a **grade 2 or better** log at least 10 ft in length, entirely within the 16-ft butt log section of the bole 13
12. Does not currently contain a **grade 2 or better** log at least 10 ft in length, entirely within the 16-ft butt log section of the bole 17
13. Value is **expected to increase** at a satisfactory rate if left in the stand for one or more cutting cycles . . **Desirable Growing Stock**
13. Value is **not expected to increase** at a satisfactory rate if left in the stand for one or more cutting cycles 18
14. Crown class is **intermediate** (or **overtopped** if a shade-tolerant species) 15
14. Crown class is **overtopped** and species is not shade tolerant 20
15. Current condition is **fair or better** and is likely to remain so for one or more cutting cycles 16
15. Current condition is **poor** 20
16. Risk of mortality or degradation in merchantability is **moderate or less** 17
16. Risk of mortality or degradation in merchantability is **significant** 20
17. Currently contains a **grade 3 or better** log at least 8 ft in length, entirely within the 16-ft butt log section of the bole 18
17. Does not currently contain a **grade 3 or better** log at least 8 ft in length, entirely within the 16-ft butt log section of the bole 20
18. Value is **not expected to significantly decrease** if left in the stand for one or more cutting cycles . **Acceptable Growing Stock**
18. Value is **expected to significantly decrease** if left in the stand for one or more cutting cycles . . . . **Cutting Stock**
19. Species class is **undesirable** for the site or for management objectives 20
19. Species class is **unmerchantable** . . . . **Cull Stock**
20. Currently contains a **grade 3 or better** log at least 8 ft in length within the merchantable bole . . . . . . **Cutting Stock**
20. Does not currently contain a **grade 3 or better** log at least 8 ft in length within the merchantable bole and is incapable of meeting the desired product goals . . . . **Cull Stock**
21. Species class is **desirable** or **acceptable** for the site and for management objectives 22
21. Species class is **undesirable** for the site or for management objectives or species class is **unmerchantable** . . . . **Inferior Poletimber Stock**
22. Current condition is **good** and is likely to remain so for one or more cutting cycles 23
22. Current condition is **poor** . . . . **Inferior Poletimber Stock**
23. Risk of mortality or degradation in potential merchantability is **moderately low** 24
23. Risk of mortality or degradation in potential merchantability is **significant** . . . . **Inferior Poletimber Stock**
24. Has the potential to contain a **grade 2 or better** log at least 10 ft in length, entirely within the 16-ft butt log section of the bole, when minimum diameter requirements are reached . . . . **Superior Poletimber Stock**
24. Is incapable, because of poor bole quality, of producing a **grade 2 or better** log at least 10 ft in length, entirely within the 16-ft butt log section of the bole, when minimum diameter requirements are reached . . **Inferior Poletimber Stock**