Appalachia-Science
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ASPI TECHNICAL SERIES TP 34

THE PRACTICE OF ECOFORESTRY

PART 3. TENDING AND HARVEST

Introduction

Silviculture is the art and science of tending individual trees and entire forest ecosystems with the objective of producing conditions and products that are pleasing or essential to people, while maintaining, restoring, or at least not degrading, the health, integrity, and natural biodiversity of the ecosystem. The **silvicultural prescription** or **silvicultural plan** defines specific goals and provides a schedule of activities designed to achieve the goals. Although detailed, the plan must be case-specific and flexible, and should be used as a working hypothesis rather than as a cookbook. All techniques and technology used in the plan should be sustainable, and should represent an appropriate blend of scientific, traditional, and intuitive knowledge.

This paper is the third in a series on THE PRACTICE OF ECOFORESTRY and deals with concepts and techniques of silviculture. Important terms and concepts not previously discussed in this series of papers are printed in **bold-face** and are defined in the text. The emphasis of this paper is on the hardwood-dominated forests of Appalachia, and on providing principles and ideas that may serve as stimuli for innovation, or that may be modified to suit local conditions.

Stand Evaluation

Species Characteristics. **Silvical characteristics** (the life history, requirements, and general characteristics and responses of trees) may differ dramatically even among tree species occurring in a single stand. Since a tree's silvical characteristics determine its functioning within the ecosystem, its utility to people, and its response to management, it is essential that you become familiar with the silvical characteristics of at least the most important tree species encountered during your forest inventory. This may be done by consulting knowledgable local residents, field guides or books on local flora. Agriculture Handbook Number 654, *Silvics of North America* (1990; Volume I. *Conifers* and Volume II. *Hardwoods;* produced by the USDA Forest Service and available from the U.S. Government Printing Office), is relatively inexpensive and provides up-to-date information on the silvical characteristics of all North American tree species. The Tree Species Chart in the center of the present technical paper also provides some information on the silvical characteristics of 30 important Appalachian tree species.

Stand Characteristics. **Stand structure** refers to the distribution of trees in a stand (number of trees per acre) into categories based on age, DBH or some other variable of interest. Age distribution (Figure 1) is particularly interesting since a major goal of ecoforestry is to re-establish uneven-aged conditions in stands that have become even-aged due to management. Tree age may be determined by counting **annual rings.** These are concentric color and texture patterns observable in tree cross-sections and caused by differences in the sizes of the cells produced during the early and late part of a

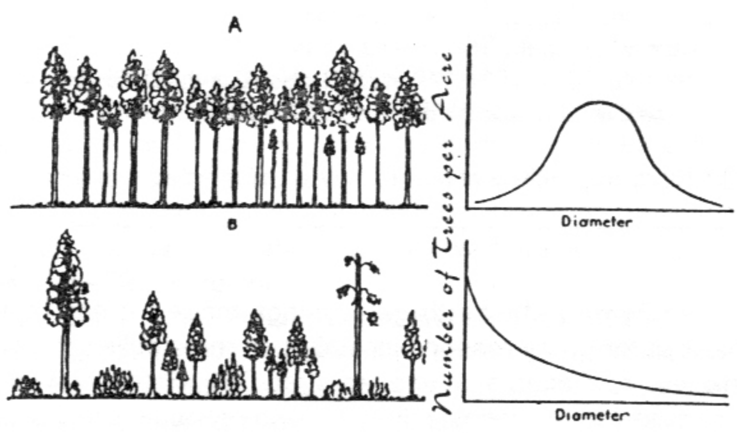


Figure 1. Distributions of diameter classes for: A, even-aged stand; B, uneven-aged stand. Note that diameter (DBH) is used in place of age (see text).

single growing season In regions where trees become dormant in the winter. Annual rings are often counted on increment cores collected with an **increment borer** (a coring device that extracts a thin cylinder of wood extending from the bark to the center of a tree). This is not recommended since increment boring harms living trees by producing entry points through the bark for fungi and other organisms that may decay wood, cause disease or reduce the usefulness of the tree for lumber. For this reason living trees should only be bored under exceptional circumstances. Reasonably good estimates of age may be obtained non-destructively by questioning people familiar with local forest history, by collecting increment cores from trees that have died recently enough that the wood is still sound, or by counting the annual rings on the stumps of harvested or wind-thrown trees.

Given the problems involved in determining tree age, DBH has conventionally been used in place of age when constructing age-distribution graphs such as Figure 1. This convention is based on the assumption that DBH and age are well-correlated, that is, that larger-diameter trees are older than smaller-diameter trees. In general, this assumption holds, but care must be taken since some small trees may be very old, or, due to differences in rates of growth, two individuals of the same age may have very different DBHs. Misjudgment of age is a problem when it affects the results of tending operations as, for example, when small trees judged to be young and vigorous are **released** (a cutting made to free the crown of a selected tree from competition by the crowns of other trees) but turn out to really be too old to respond to the release. Such a misjudgement would lead to inappropriate and ineffective tending, and would waste time and energy.

Age-distribution of a stand can be visually evaluated by plotting the average numbers of trees per acre (vertical axis) *versus* 2-inch DBH classes (horizontal axis). Your graph should have a shape similar to curve "B" of Figure 1, otherwise the stand is probably not uneven-aged, and you will need to restore uneven-aged conditions prior to practicing uneven-aged management or harvesting (see "Tending Stands" and "Harvesting" below). If you use the inventory procedures described in "Inventory and Description," Part 1 of this series of technical papers, the trees tallied in DBH-classes wider than 2 inches should be divided proportionally into 2-inch classes starting with the 2 - 3.9 inch class (see Example 1).

EXAMPLE 1

Refer to the sample data presented on p. 5 of Part 1 ("Inventory and Description") of this series of technical papers, and to the total number of tally trees recorded by DBH-class in the bottom line of the sample tally sheet :

Of the 16 trees tallied in the 2-4.9 inch DBH-class, two-thirds (11) would be assigned to the 2-3.9 inch class and one-third (5) to the 4-5.9 inch class

Of the 29 trees tallied in the 5-9.9 inch DBH-class, one-fifth (5) would be assigned to the 4-5.9 inch class, two-fifths (12) to the 6-7.9 inch class, and two-fifths (12) to the 8-9..9 inch class

11 trees were tallied in the 10-11.9 inch class

5 trees were tallied in the 12-13.9 inch class

8 trees were tallied in the 14-15.9 inch class

3 trees were tallied in the 16-17.9 inch class

Of the 1 trees tallied in the 22-27.9 in DBH-class, one-third of a tree would be assigned to the 22-23.9 inch class, one-third to the 24-25.9 inch class and one-third to the 25-27.9 inch class

NOTE: These are numbers of tally trees only; trees per acre must be calculated from the tally data separately for each DBH class .

Tending Stands

Intermediate cuttings (cuttings made for any purpose other than the final harvest of a tree) may be carried out for many reasons including: to re-establish an uneven-aged DBH-distribution in stands that are initially even-aged; to maintain an uneven-aged DBH-distribution once it has been established; to release **crop trees** (any tree selected to be intensively tended to produce forest products); and to release selected young trees growing in natural gaps or in openings created by tree harvest. Intermediate cuttings provide an opportunity to regularly harvest firewood and other small products, and occasionally sawtimber, while cutting to improve the overall quality of the stand or of selected trees in the stand.

A **patch cut** that removes all or most of the trees from the upper- and mid-canopy levels is an effective way to harvest firewood or other small products while increasing the biodiversity of a stand. Such cuts help convert an even-aged stand to an uneven-aged condition by increasing the light and temperature levels on the forest floor which, in turn, stimulate the growth of young trees in lower canopy levels and the germination of seeds in the **soil seed bank** (the reservoir of dormant but viable seeds that accumulate over many years in the upper soil and litter layers, and that may be "shocked" into germination by drastic alterations in the environment such as disturbance of the forest canopy, burning, and fertilization). Patch cuts may also increase species diversity if the species that are released or stimulated to germinate in the patch differ from the common species composing the stand. Increases in species diversity may also be encouraged by follow-up treatments that release selected species that have established by **natural regeneration** (renewal of a tree crop by natural seeding or sprouting) in the patches, or by **artificial regeneration** (planting seedlings or sowing seeds) or **enrichment plantings** of rare or valuable tree species in the patch. In any case, the size of a patch cut should approximate the natural size of a canopy gap that would occur from the death or blow-down of one or a few trees. In general, patches approximately one tree-height in diameter seem ideal in that they are large enough to allow for the growth of a variety of species including **intolerant species** (see definition of **tolerance** at bottom of Tree Species Chart), and are of such a size to prevent the gap from functioning as a **"frost pocket"** or a **"heat pocket"** (climatological phenomena whereby small openings in the forest serve as "traps" for cold or hot air and adversely affect the growth of some plants). Patches that are one tree-height in diameter could range in size from as little as 50 feet for poletimber-sized trees or for scarlet oak or pitch pine growing on dry and infertile sites, to more than 150 feet for yellow-poplar or white pine growing on moist and fertile sites.

Intermediate cuttings made to establish or maintain uneven-aged DBH distributions would remove trees from DBH-classes that have excessive numbers of trees, and would leave extra trees of appropriate size to grow into DBH-classes that have deficient numbers of trees. The goal would be to maintain a DBH-distribution similar to that shown in curve "B" of Figure 1. The following guidelines represent a convenient way to determine which sizes classes have deficient or excessive numbers of trees. Such a determination is the first step in **marking** (the process of determining which trees are to be cut, and of painting or otherwise marking these trees) a stand for an intermediate cut that is designed to maintain an uneven-aged DBH-distribution.

GUIDELINES FOR UNEVEN-AGED STANDS

(1) There should be about 2 times as many seedlings as saplings;
(2) There should be about 2 times as many saplings as poletimber trees;
(3) There should be about 5 times as many poletimber trees as sawtimber trees;
(4) About three-fourths of all sawtimber trees should be less than 15 inches DBH, and about one-fourth should be larger than 15 inches DBH.

Frequent fire is a natural process in some dry ecosystems dominated by pine and oak. On such sites prescribed fire may be used during tending to encourage natural regeneration, to thin out dense understories, or to reduce heavy accumulations of **forest litter** (decomposing foliage, bark, twigs, and other plant materials on the forest floor). The season and frequency of burning, the intensity of the fire, and the size of the area to be burned are among the variables that must be carefully chosen if the prescribed fire is to mimic natural fires in the same ecosystem. Before ever considering fire as a tool in your silvicultural plan, check with your state forestry agency and with your local fire marshall concerning restrictions and safety rules, and determine where you will recruit a fire crew of sufficient size and experience to safely monitor and control the fire.

In order for uneven-aged management to be successful, new trees must become established beneath a canopy or in gaps left by the harvest of one or a few trees. During tending consideration should therefore be given to assuring that sufficient numbers of seeds germinate and grow into established seedlings that can eventually grow into the upper canopy. In cases where regeneration is lacking due to consumption of seeds by seed predators such as chipmunks and squirrels, it may be possible to divert these small mammals from feeding on native tree seed by providing large amounts of another type of seed that is easily-available, inexpensive, and incapable of surviving to become a pest in the forest. For example, the sowing of large numbers of sunflower seeds seems to cause small mammals to key-in on sunflower seeds and to refrain from consuming pine seeds.

Common Name	Scientific Name	Tolerance	Longevity	DBH Growth
American Beech	*Fagus grandifolia*	Very Tolerant	Very Long	Slow
American Holly	*Ilex opaca*	Very Tolerant	Moderate	Very Slow
Basswood	*Tilia spp.*	Tolerant	Long	Medium-Fast
Black Cherry	*Prunus serotina*	Intolerant	Moderate	Medium-Fast
Black Gum	*Nyssa sylvatica*	Tolerant	Moderate-Long	Medium
Black Locust	*Robinia pseudoacacia*	Very Intolerant	Short-Moderate	Fast
Black Oak	*Quercus velutina*	Intermediate	Moderate	Medium-Fast
Black Walnut	*Juglans nigra*	Intolerant	Moderate	Medium Fast
Buckeye	*Aesculus spp.*	Tolerant	Moderate	Medium-Fast
Chestnut Oak	*Quercus prinus*	Intermediate	Long	Slow-Medium
Flowering Dogwood	*Cornus florida*	Very Tolerant	Short-Moderate	Very Slow
Hemlock	*Tsuga canadensis*	Very Tolerant	Very Long	Slow
Hickory	*Carya spp.*	Intermediate	Long	Slow-Medium
Magnolia	*Magnolia spp.*	Intermediate	Moderate	Medium-Fast
Pitch Pine	*Pinus rigida*	Intolerant	Moderate	Slow-Medium
Red Maple	*Acer rubrum*	Tolerant	Moderate	Medium-Fast
Red Oak	*Quercus rubra*	Intermediate	Moderate-Long	Fast
Sassafras	*Sassafras albidum*	Very Intolerant	Short	Medium
Scarlet Oak	*Quercus coccinea*	Intolerant	Short-Moderate	Medium-Fast
Serviceberry	*Amelanchier spp.*	Intermediate	Short	Slow
Shortleaf Pine	*Pinus echinata*	Intolerant	Long	Medium
Slippery Elm	*Ulmus rubra*	Intolerant	Long	Medium-Fast
Sourwood	*Oxydendrum arboreum*	Intermediate	Short-Moderate	Slow
Sugar Maple	*Acer saccharum*	Very Tolerant	Very Long	Medium
Sweet Birch	*Betula lenta*	Intermediate	Moderate	Slow-Medium
Virginia Pine	*Pinus virginiana*	Intolerant	Short	Medium
White Ash	*Fraxinus americana*	Intermediate	Moderate-Long	Medium-Fast
White Oak	*Quercus alba*	Intermediate	Very Long	Slow-Medium
White Pine	*Pinus strobus*	Intermediate	Very Long	Fast
Yellow-poplar	*Liriodendron tulipifera*	Intolerant	Moderate	Very Fast

Tolerance. Relative ranking of a tree's ability to survive and prosper in the shade of a forest canopy.

Longevity. Typical age (years) expected once a tree has survived the early period (seedling-sapling-pole) of hig mortality: "Very Long", greater than 450; "Long", 350-450; "Moderate-Long", 300-350; "Moderate", 200-300; "Short-Moderate", 150-200; "Short", less than 150.

DBH Growth. Relative ranking of rate of growth in diameter at breast-height. The reference tree is 12 inches DE has "High" vigor (Figure 2), and is growing on a good site. For this reference tree, DBH growth rates (inches) over 10 years are: "Very Fast", 3; "Fast", 2.5; "Medium", 2.0; "Slow", 1.5; "Very Slow", 1.0.

To account for deviations from the reference tree, estimated 10-year growth rates may be adjusted as follows:

-- 10-year growth rate is reduced 0.1-0.2 inches for every 2-inch increase in DBH from 12 to 36 inches.

-- 10-year growth rate of a tree with "Medium" vigor is 70-80% that of a tree with "High" vigor.

-- 10-year growth rate of a tree growing on a poor site is 50-75% that of a tree growing on a good site.

PECIES CHART

anopy Level	Width of Crown	Value to Animals	Utility as Firewood	Utility as Lumber
pper	Broad	High	Very High	Low
Iid	Medium	Low-Moderate	Moderate	---
pper	Medium	Low	Low	Moderate
pper	Narrow	High	High	Very High
pper	Medium	Moderate	High	Low
pper	Narrow	Low-Moderate	Very High	Low
pper	Broad	High	Very High	High
pper	Medium	Moderate	Very High	Very High
pper	Medium	Low-Moderate	Low	Low
pper	Broad	Moderate-High	High	High
ower-Mid	Medium	Moderate	Very High	---
pper	Medium	Moderate-High	Moderate	Low
pper	Medium	High	Very High	Low-Moderate
Iid-Upper	Narrow	Low	High	Moderate
pper	Medium	Moderate-High	High	Moderate
pper	Medium	Moderate-High	High	High
pper	Medium	High	Very High	Very High
Iid-Upper	Medium	Low-Moderate	High	Low-Moderate
pper	Broad	High	Very High	Moderate-High
Iid	Narrow	Moderate	Moderate	----
pper	Medium	Moderate-High	High	High
pper	Medium	Moderate	High	Low-Moderate
Iid-Upper	Narrow	Low	Very High	Low
pper	Broad	Moderate-High	Very High	Very High
pper	Medium	Moderate	High	Low
pper	Narrow	Moderate-High	Moderate	Low
pper	Narrow	Low	Very High	High
pper	Broad	High	Very High	Very High
pper	Medium	Moderate	Low	High
pper	Narrow	Moderate	Moderate	High

Canopy Level. The canopy stratum in which the tree crown normally occurs. Typically: "Upper" = 60-100 feet high; "Mid" = 30-60 feet high; and "Lower" is less than 30 feet high.

Width of Crown. Relative ranking of crown size, expressed in terms of width.

Value to Animals. Relative ranking of value as source of food, cover, nesting site, nectar, etc.

Utility as Firewood. Relative ranking of utility as firewood in terms of available heat content and burning properties. In general, the heat content is 20-30 million BTU/cord for "Very High" and "High"; 15-20 million BTU/cord for "Moderate"; and less than 15 million BTU/cord for "Low".

Utility as Lumber. Relative ranking of utility as lumber in terms of strength, shrink/swell potential, defects, ease of sawing, durability, etc.

Similar responses may occur if seeds are added to hardwood stands, although it may be that small seeds such as sunflowers will never be more attractive to mammals than larger seeds such as acorns and hickory nuts. Since seeds germinate and seedlings establish more dependably in mineral soil than in litter, regeneration may be encouraged by **soil scarification** (exposing bare mineral soil in small spots or strips on the order of 12 inches in size). To some degree this will be achieved in the course of normal operations, and especially during intermediate cuttings and harvest of crop trees. **Advance regeneration** (seedlings less than 2 inches DBH and greater than 4.5 feet tall) stems have well-established root systems and are generally capable of rapid growth when released, and are one of the most dependable ways of naturally regenerating many tree species including oaks. For this reason, if seedlings and saplings are scarce intermediate cuts should be made to release stems of advance regeneration, individually or in patches, as they are encountered during the course of other tending operations.

Tending Crop Trees

Crop trees may be selected for intensive tending with the goal of maximizing their health and longevity, and encouraging them to grow large **clear boles** (a lower trunk free of branches, knots, decay, or other blemishes). Unless dealing with species that are in danger of disappearing from the stand, it is best to delay selection of crop trees until they are at least 20 years old and have begun to exhibit their physical characteristics and potential for growth. If production of sawtimber is the goal, individuals of desirable species should be selected as crop trees based on their having high **vigor** (Figure 2); cylindrical stem **form** (shape and taper of the tree trunk;) and a low apparent tendency to produce **epicormic branches** or **epicormic sprouts** (branches originating in suppressed buds buried beneath the bark on the trunk of a tree, and stimulated to develop by increased temperature or light levels). Trees that are likely to produce abundant epicormic branches once released may be identified by the presence of numerous small branches on the trunk and by the occurrence of small bumps and bark irregularities that indicate that clusters of suppressed buds are hidden below the bark. Note also that of the 30 species listed in the Tree Species Chart, white, red, and chestnut oaks, and basswood and black cherry, have the greatest tendency to produce epicormic branhes following release. Up to 80 crop trees per acre may be selected, but remember that crop tree tending is labor-intensive and time-consuming.

High	Tree crown appears thick and dark green for the species; large or abundant dead branches are lacking in the crown; excessive numbers of epicormic sprouts are lacking from lower portion of tree trunk; evidence of disease and mechanical injury is lacking; twigs have good color and normal appearance for the species; bark is relatively smooth with shallow fissures.
Medium	Tree crowns appear more open or less healthy than those of "high" vigor trees in terms of dead or dying branches, excessive numbers of epicormic sprouts on the lower trunk, etc.
Low	Tree crowns appear to be thin and unhealthy, and excessive numbers of epicormic sprouts may occur on the lower trunk and at the base of the tree; evidence of excessive decay may occur along with sign of increased excavating activity by woodpeckers, bark beetles, and other animals; bark is rough with broad plates and deep fissures.

Figure 2. Tree vigor classes.

In order to maintain high vigor and rates of growth, the crowns of crop trees should be kept free of competition from the crowns of surrounding trees. Growth increases of 25-100%, highest for more tolerant species, have been recorded for crop trees during the first decade after release. The goal of crop tree release is to maintain a **live-crown ratio** (the proportion of the total tree height that is clothed with live branches, expressed as a percentage) of at least 35%. During the period of vigorous tree growth, whenever the live-crown-ratio of a crop tree approaches this threshold, it is time to again release the crown of that tree. Once height growth has peaked, however, trees expand their crowns very slowly. Beyond this age, release of crop trees will be ineffective and should cease since the trees will not be able to take advantage of additional open space created in the canopy.

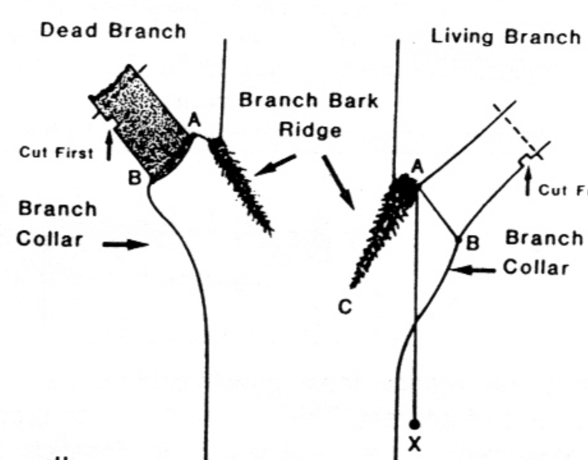
Once the crop trees have been selected, there are two simple methods of marking these trees for release. The "crown-touching" method simply cuts every tree whose crown touches the crown of the crop tree. Trees with crowns in canopy levels beneath the crown of the crop tree do not offer serious competition and are never cut; these subordinate trees may also conceivably function as "nurse trees" that shade the lower trunk of the crop tree and reduce the formation of epicormic branches. If it is desirable to create more open space in the canopy than is formed by the "crown-touching" approach, the following guidelines may be used to determine the **release radius** (the radius of the circle surrounding a tree which should be kept free of the crowns of competing trees) for individual crop trees. Note that the crowns of 30 Appalachian tree species are classified as narrow, medium, and broad in the Tree Species Chart.

	Release Radius (feet)		
DBH (in)	Narrow Crown	Medium Crown	Broad Crown
8	14	16	19
12	17	20	25
16	19	23	31
20	21	26	35
24	23	29	39
28	24	31	43
32	25	32	44
36	26	33	45

Table 2. Recommended release radii for crop trees with narrow, medium and broad crowns.

To guarantee that clear wood is produced, the lower 18 feet of all crop trees should be **pruned** (the artificial removal of selected branches from trees) at the time of release and kept free of epicormic branches by repeated pruning as often as necessary. **The Natural Target Pruning** method (described below) should be used to remove living and dead branches, both of which produce knotty wood. Branches should ideally be pruned before reaching 2 inches diameter, and no more than 25% of the live crown length should ever be removed in one year.

NATURAL TARGET PRUNING



1. Locate the branch bark ridge.
2. Find *target A* - outside of the branch bark ridge.
3. Find *target B* - where the branch meets the branch collar.
4. If B is hard to find - drop a line at AX. The angle XAC is equal to the angle XAB.
5. If the branch to be pruned is large, avoid splitting and tearing by making a stub cut a few inches from the branch collar.
6. Make the final cut at line AB.

CAUTION: *Do not cut behind the branch bark ridge. Do not leave stubs. Do not cut the branch collar. Do not paint cuts.*

Harvesting

Trees are considered candidates for harvest after reaching some large DBH that is site- and species-specific, normally in the range of 30 to 36 inches for trees on good sites. Trees that die before reaching this critical DBH are not harvested, but are left to become snags and logs. Harvesting is by **single-tree selection** (uneven-aged cutting method in which scattered individual trees are harvested throughout the stands) with individual trees evaluated on a **cutting-cycle** (the interval between visits to the stand to evaluate trees for harvest) of 10 years, and never harvested until judged not to be vigorous enough to survive another 10 years. This means that every tree has its own individualized **rotation** (the period of time over which a tree is grown before being harvested), and that an individual of a long-lived species such as white oak (See "longevity" column in Tree Species Chart) could conceivably be tended for 3 or 4 centuries before harvest.

Logging should be done using directional felling and other low-impact harvesting techniques described by Gary Anderson in SUSTAINABLE LOGGING AND LUMBER PRODUCTION (Technical Paper 35). Such methods minimize the length of roads needed on the forest and the amount of damage done to the remaining trees during logging. **Skidding** (hauling logs from the stump to the collection point) with horses or other draft animals and a logging arch (see TP-35) is least damaging to the soil and the remaining trees. Horse-logging is a practical and economical alternative on at least three-fourths of all Appalachian logging jobs.

Estimating Growth

Rough predictions of the volume growth of a tree for the next 10-year period may be made by making reasonable estimates of DBH- and height-growth rates. As described in Part 1 of this series, DBH and merchantable height are used in conjunction with a volume table to first obtain board-foot sawtimber volume at the beginning of a 10-year period. DBH-growth rates for the next 10-year period may be obtained from the Tree Species Chart, and height growth may be estimated using the rules given below. Finally, using these growth predictions, DBH and merchantable height at the end of the 10-year period may be estimated and a volume table again consulted to obtain tree volume at the end of the period.

RULES FOR PREDICTING MERCHANTABLE HEIGHT-GROWTH

(1) Trees with DBH-growth greater than 2 inches during the next 10 year period could increase as much as 1 log (16 feet) in merchantable height over the same period

(2) Trees with DBH-growth less than 2 inches during the next 10 year period could increase as much as ½ log (8 feet) in merchantable height over the same period.

(3) Trees greater than 30 inches DBH will not increase in merchantable height during the next 10 years.

(4) Maximum merchantable height is 5 logs for tall-growing species such as yellow-poplar and white pine, and 4 logs for other species.

(4) Trees with merchantable height limited by forks or large branches will never increase in merchantable height.

Conclusion

Hurt not the Earth, neither the sea, nor the trees...

Revelations 7:3

As with all predictions, these growth estimates assume that environmental conditions remain stable over the 10-year period of interest. This assumption was probably sound 50 years ago, but is questionable today due to widespread pollution of the air leading to global climate change, poisoning of soils and waters, destruction of native biodiversity (including pollinating and seed-dispersing animals) and other human abuses of the Earth. Now, more than ever, the survival of forests and of human communities which are dependent on the forest, requires us to accept responsibility to implement the principles and practices of ecoforestry.

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Text, layout & Design – **Paul Kalisz**

Project Director -- Al Fritsch

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