Maintaining Species Diversity in the Central Appalachians

Maintaining species diversity is the key to sustaining production of desired benefits in central Appalachian forests. Long-term research indicates that traditional uneven-aged silviculture based on single-tree selection eventually reduces the abundance of certain species, but desirable species composition can be maintained in two-aged stands or in uneven-aged stands where sizable canopy openings are created. In both situations, silvicultural treatments are needed to prepare for desirable reproduction before harvest operations. The increased application of two-aged systems in the central Appalachians is an example of how silvicultural strategies can evolve in response to emerging management goals.

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Knowledge about the silvics and site requirements of tree species and their complex relationships within forest communities is continually refined through research and the experience of forest managers. Improved understanding of forest ecosystems has caused managers to rethink both management goals and the means to achieve them. For example, short-term goals focused on maximizing current revenue from timber sales are (slowly) being replaced by long-term goals focused on sustaining site productivity by protecting the soil and water resources and maintaining species diversity. The long-term goals necessitate a better understanding of how silvicultural practices affect stand structure and composition and the linkages between stand attributes and other ecosystem components.

The property rights of forest owners entitle them to define the forest benefits they desire, and owners in the Appalachian region desire a wide variety of outputs. Of the 11.9 million acres of commercial forestland in West Virginia, 83 percent belongs to more than 200,000 nonindustrial private owners (DiGiovanni 1990; Gillespie and Murriner 1990), the majority of whose holdings are less than 50 acres. That ownership pattern is characteristic of the central Appalachians (Birch 1996). Forest uses and management goals in the region are therefore highly variable.

What silvicultural strategies will satisfy a broad array of forest management goals? What stand structural conditions and species composition are appropriate for sustaining the production of desired woodland benefits?

Maintaining species diversity is the key to sustaining the productivity of Appalachian forests. The region's extremely diverse forests resulted from major disturbances—clearing of land for agriculture in the 1800s, heavy cutting and wildfires in the early 1900s, the death of the American chestnut *(Castanea dentata)* in the 1930s (Carvell 1986). Local, infrequent disturbances also shape the composition of these forests, as when several neighboring trees break under the weight of ice or are blown down, creating sizable canopy openings.

Controlled, small-scale manipulations of forest vegetation can be applied to create similar environmental conditions that enhance species diversity. Using improved understanding of forest ecosystems, managers can prescribe innovative silvicultural practices to mimic disturbances that are needed to sustain forest productivity and achieve multiple long-term goals. In some forests, a multiaged stand structure might be the most efficient means of achieving goals; in others, a multiaged landscape made up of even-aged stands might be more appropriate.

Research Results

Scientists and forest managers in the central Appalachians know that maintaining desired species composition is of paramount importance. Throughout the region there are more than 20 commercial timber species that form complex local forest communities. Among the species there is great variation in market value for wood products, ecological value for supporting associated plant and animal communities *(table 1)*, and sociological value for providing aesthetic benefits and recreational opportunities. Each species and mixture of species makes a unique contribution to the production of desired benefits.

Planning effective silvicultural treatments in the Appalachians is complicated because of the diversity of species and environmental conditions. For example, species differ in shade tolerance, regeneration mechanism, and competi-

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tiveness on a particular growing site *(table 1)*, and growing sites differ along elevation, moisture, and soil nutrient gradients. Forest structural attributes affect species composition at the stand and landscape scales because species differ in their use of growing space (Oliver and Larson 1996). To implement silvicultural strategies that are effective in achieving long-term goals, forest managers must recognize how species composition affects the production of woodland benefits and consider the environmental conditions needed to maintain desired species on a particular site (Trimble 1973; Miller 1997).

Single-tree selection practices based on the reverse-J curve for stocking control are not common in the central Appalachians, but experimental applications of this system have been studied since 1949 (Smith and Miller 1987; Lamson and Smith 1991). In general, these practices establish regeneration after each cut, improve the quality of the residual stand, and provide growing space for smaller (younger) trees to replace trees that are harvested. A serious drawback, however, is that regeneration and tree recruitment are dominated by shade-tolerant species, which leads to an eventual decline in species diversity. In the central Appalachian hardwood region, single-tree selection is feasible only on growing sites where commercial, shade-tolerant species such as sugar maple *(Acer saccharum)* are present and desired. Note that a feasible practice does not guarantee sustainable production of other desired outputs if species diversity declines. Selection practices may not be sustainable on nutrient-poor sites where maple decline has been observed (Long et al. 1997).

Some form of diameter-limit cutting is the most common harvesting practice in the central Appalachian region. In 1995 more than 80 percent of the harvests sampled in West Virginia were some form of diameter-limit cut (Fajvan et al. 1998). For diameter-limit practices that remove only sawtimber-size trees, the residual stand structure has the same effect on regeneration and eventual species composition as selection practices guided by a reverse-J curve (Miller and Smith 1991). For multiproduct diameter-limit harvests, which remove smaller trees and result in much lower residual stocking levels, it is possible to regenerate a higher proportion of shade-intolerant species (Smith and Lamson 1977). However, neither diameter-limit harvests nor single-tree selection is recommended if the goal is to sustain tree species diversity. These practices eventually lead to the loss of certain seed sources because valuable shade-intolerant species are

Table 1. Silvical characteristics[a] and value of some commercial central Appalachian hardwood tree species.

Shade tolerance/species	Seed longevity	Seed periodicity	Seeding age	Primary regeneration mechanism			Relative product market value[b]	Relative wildlife food value[c]
	years			Seeds	Advance seedlings	Sprouts		
Very intolerant								
Black locust	Several	1–2	6			x[d]	4	14
Intolerant								
Black cherry	3	1–5	10	x	x	x	100	96
Yellow poplar	8	1	15	x		x	26	14
Hickories	1	1–3	25–40		x		5	23
Intermediate								
White ash	3	3–5	20	x	x	x	34	22
Sweet birch	1	1–2	40	x	x		4	41
White oak	0	4–10	20		x	x[e]	27	100
Red oak	0	2–5	25		x	x[e]	60	100
Chestnut oak	0	4–5	20		x	x[e]	21	100
Tolerant								
Red maple	1	1	4	x	x	x	21	51
Very tolerant								
Sugar maple	2	2–5	40		x		28	51
American beech	1	2–8	40			x[d]	2	46

[a]*From Trimble and Tryon 1967; Trimble 1975; Beck 1988; Kelty 1988; Burns and Honkala 1990.*
[b]*Value relative to black cherry computed from Monongahela National Forest quarterly transaction evidence prices for January, 1998.*
[c]*Value relative to oaks computed from Martin et al. 1951.*
[d]*Sprouts from wounded roots and root suckers.*
[e]*Oak sprouting becomes more important as site index declines.*

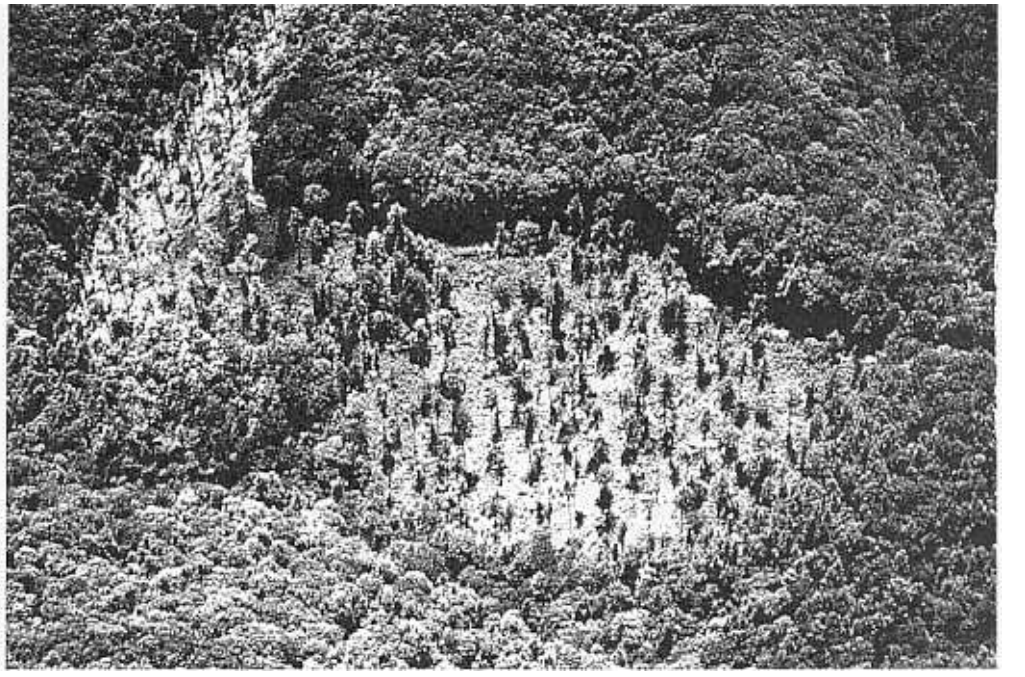
removed, and stand structure conditions conducive to their successful regeneration are not maintained.

Repeated partial harvests that do not create sizable canopy openings lead to a reduction in species diversity because the resulting light conditions favor relatively few species. Reproduction becomes dominated by shade-tolerant species, such as sugar maple, red maple *(Acer rubrum),* striped maple *(A. pensylvanicum),* and American beech *(Fagus grandifolia)* (Smith and Miller 1987; Miller and Smith 1993; Trimble 1973). Shade-*in*tolerant species, like black cherry *(Prunus serotina)* and yellow poplar *(Liriodendron tulipifera),* germinate from seed and survive for a few years but die as the canopy closes between harvests. The shade-tolerant species survive and grow slowly and eventually replace the shade-intolerant overstory trees that are harvested. Conversion from second-growth, mixed hardwood species stands to predominantly shade-tolerant species may occur after six to eight single-tree selection harvests spanning 80 to 100 years (Trimble 1965; Miller 1993).

Shade-intolerant species of Appalachian hardwoods can be regenerated by silvicultural practices that create sufficient openings in the overstory canopy. Canopy openings with a minimum diameter of 170 feet (0.5 acre) provide suitable light conditions for virtually all desirable species to develop and grow to maturity (Trimble 1973; Smith 1981). The proportion of shade-intolerant species increases as the canopy opening increases up to 1 acre (Dale et al. 1995). There are other advantages of larger forest openings: they are more recognizable on the ground, they are more practical for conducting harvest operations and subsequent cultural treatments, and average tree quality for timber products increases as the amount of forest edge is reduced. The quality advantage occurs because some trees along the edge of forest openings develop epicormic branches that can reduce tree quality and value (Smith 1981), and larger forest openings have less edge than an equal area comprising numerous small openings.

Canopy openings large enough to maintain desired species composition can be created through silvicultural practices that result in multiaged stands or landscapes. Group selection practices allow the silviculturist to control the number and size of openings and the frequency of harvest operations to promote uneven-aged structures (Miller et al. 1995). Shelterwood-with-reserves practices provide the opportunity to control the species, size, and density of residual trees to promote two-aged stand structures (Miller et al. 1997). Similarly, patch or strip clearcutting can be used to maintain uneven-aged landscapes comprising small, even-aged management units.

Group selection can be a very intensive regeneration method because many different silvicultural treatments can be applied to prepare the site for desirable reproduction or to improve stand development. For example, in parts of the stand that are nearing maturity, interfering plants in the understory can be controlled to allow desirable advance regeneration to develop for several years before a planned harvest (Loftis 1990). In immature parts of the stand, crop trees that meet management goals can be released to enhance their competitive position (Perkey et al. 1994). For planned harvests, openings are located where overstory trees are mature, desirable advance regeneration has been established, and the potential to meet regeneration goals is greatest. The size and shape of openings vary according to management goals.



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A two-aged Appalachian hardwood stand three years after a shelterwood-with-reserves cut on the Fernow Experimental Forest near Parsons, West Virginia.

Several terms are used to describe regeneration methods that result in a two-age stand structure: deferment cutting (Smith et al. 1989), clearcutting-with-reserves, irregular shelterwood, and shelterwood-with-reserves. In the central Appalachians, such practices leave desirable advance reproduction plus 15 to 20 codominant residual trees per acre, and all other stems are cut. Immediately after the regeneration harvest, two-aged stands resemble those following a seed-tree or shelterwood practice in that residual overstory trees are retained. Unlike traditional practices designed to form an even-aged stand, the residual trees are retained for many years to achieve goals other than regeneration, such as aesthetics or wildlife habitat. Similar practices can be repeated at appropriate intervals to maintain a two-aged stand structure for many years.

Shelterwood-with-reserves practices initially were applied on public land as an alternative to clearcutting because the residual trees improved aesthetics

after logging, yet the residual stand density was low enough to allow shade-intolerant species to regenerate (Miller et al. 1997). Long-term field trials indicated that species composition of regeneration in two-aged stands was as diverse as that observed after clearcutting (Miller and Schuler 1995). Crown expansion of residual trees is relatively slow (Trimble and Tryon 1966), thus allowing shade-intolerant species to develop in the openings between residual trees. The production of desired outputs can be enhanced by leaving appropriate residual trees and tending crop trees in the younger age class.

Preparing for Regeneration

Preparing for desirable reproduction requires proper management of stand structure in the overstory and understory components for many years before a regeneration harvest (Carvell and Tryon 1961; Sander and Clark 1971; Leak et al. 1987; Beck 1988; Loftis 1990; Hannah 1991; Marquis et al. 1992). After a regeneration harvest or natural disturbance, the primary regeneration mechanisms for important Appalachian hardwoods include (1) new seedlings that develop from seeds in the forest floor, (2) sprouts from the stumps of cut trees or wounded roots, and (3) advance seedlings that became established before the harvest *(table 1)*. The importance of each regeneration mechanism varies by species, site quality, stand conditions, and disturbance history (Beck 1988; Kelty 1988). Through long-term planning, the forest manager must assure that seed or sprout sources of desirable species are preserved on the site. In years leading up to a harvest, the forest manager often must also manipulate stand structure to suppress interfering plants in the understory and favor advance seedlings. The key to success, whatever the silvicultural system, is anticipating how stand structure in the overstory and understory will interact to affect the competitive status of desired species.

Widespread diameter-limit cutting has begun to remove desirable seed sources of the more valuable shade-intolerant hardwood species. These valuable species are replaced by less valuable tolerant species. Once seed sources are lost from local sites, it becomes difficult and costly to restore species diversity. For example, black cherry seed remains viable for only about three years in the forest floor (Marquis 1975; Wendel 1977). If black cherry is eliminated from an area through repeated partial harvests, restoring this species will require expensive planting or direct seeding. A more prudent course of action would be to rely on a natural seed source by maintaining stand structural conditions that favor black cherry reproduction and development.

Throughout much of the central Appalachians, dense understories of interfering plants have already begun to develop. Repeated partial harvests are partly to blame, as are suppression of fires (a natural means of controlling undergrowth) and browsing by white-tailed deer (which prefer the seedlings of desirable hardwoods, thus allowing striped maple and beech to become more prolific) (Marquis 1981).

Dense understories of weed species interfere with desirable reproduction in two ways. First, they prevent desirable species that depend on advance reproduction from becoming established and developing to an adequate size before planned harvest treatments. Oaks (*Quercus* sp.), hickories (*Carya* sp.), and white ash *(Fraxinus americana)* need relatively large advance reproduction so that they can compete after a harvest. Second, dense understories that remain in place after a harvest hinder the development of new seedlings of shade-intolerant species. Species like yellow poplar usually regenerate by germinating from stored seed after harvests, and they need relatively shade-free conditions to survive and become dominant.

In both situations, interference from weed species can be reduced by controlling dense understories before harvests (Marquis et al. 1975) with herbicides (Horsley and Bjorkbom 1983) or prescribed fire (Van Lear and Watt 1990). To some degree, it can be *prevented* by avoiding periodic partial harvests that favor the development of dense understories. Forest managers must consider how short-term weed-control treatments can have lasting effects on species composition and dominance (Zedaker 1986).

Comparing Strategies

Comparisons of alternative silvicultural strategies for managing Appalachian forests reveal that production of desired outputs is closely related to long-term species composition (Trimble 1971; Trimble et al. 1974; Smith and DeBald 1975; Smith and Miller 1987). For simplicity, we can group forest outputs into timber, wildlife, water, and aesthetics components. Shade-tolerant species generally have slower growth rates and lower commercial value than shade-intolerant species (Trimble 1967; Smith and Debald 1975). Consequently, practices that result in single-tree canopy gaps lead to an eventual reduction in economic returns from commodity products as the proportion of shade-intolerant species declines.

Reduction in tree species diversity also has an adverse impact on wildlife food production and habitat quality (DeGraaf et al. 1992). The best trees in the region for producing mast and other wildlife foods are shade-intolerant species that require sizable canopy openings to regenerate successfully *(table 1)*. Large openings also support abundant populations of blackberries (*Rubus* sp.), another excellent wildlife food, for several years before canopy closure (Core 1974). Silvicultural practices that promote diversity in tree species and vertical structure, particularly at multistand scales, are most likely to support diverse wildlife populations.

Silvicultural alternatives differ in the frequency and degree of site disturbance, but they need not differ in their impact on soil and water resources. Adverse impacts on soil and water resources can be controlled, regardless of the silvicultural system, if responsible logging practices are used during periodic harvest operations (Patric 1980; Martin and Hornbeck 1994; Kochenderfer et al. 1997).

Finally, visual impacts of silvicultural treatments are related to the relative reduction in stand density associated with harvest operations (Pings and Hollenhorst 1993). In the central Appalachians, harvested sites re-

cover rapidly, with some form of vegetation established within one year after logging (Kochenderfer and Wendel 1983). Tree regeneration becomes dominant within five years, and a new tree canopy averaging more than 20 feet tall usually develops within 10 years (Smith 1977). Though visual impact may vary by silvicultural treatment immediately after logging, the effect is short term, and aesthetic quality improves rapidly after harvest.

Summary

Species composition is the most important factor that determines the output of benefits from Appalachian forests. Forest managers need to understand the site requirements, regeneration mechanisms, and competitive interactions of hardwood species to prescribe treatments that maintain desired species composition. Long-term research in the region shows that certain silvicultural treatments can be applied to mimic natural disturbances, create the stand structural conditions needed to maintain species diversity, and achieve a variety of management goals. Maximum success is attained when preparatory silvicultural treatments are applied to develop adequate regeneration conditions before harvest operations.

O'Hara (1998) suggested that traditional uneven-aged silviculture based on maintaining a reverse-J diameter (age) distribution has serious shortcomings. Detailed examination of such practices spanning nearly 50 years in the central Appalachians confirms that management resulting in single-tree canopy openings promotes the regeneration and recruitment of shade-tolerant species. Consequently, repeated single-tree selection and diameter-limit harvests eventually reduce the abundance of valuable shade-intolerant hardwoods and often encourage the development of undesirable understory vegetation, which in turn threatens the productivity of these forests. Long-term research also confirms that silvicultural practices that create larger canopy openings (> 0.5 acres) at the appropriate times can be used to regenerate virtually all desirable tree species in the region. These practices include clearcutting, group selection, and shelterwood-with-reserves that promote even-aged, uneven-aged, and two-aged stand structures, respectively.

Group selection is most applicable on nonindustrial private forests where average tract size is relatively small or where owners are averse to harvesting their entire property at once. On larger public or industrial forests, it is probably more practical to maintain uneven-aged landscapes comprising even-aged or multiaged stands resulting from clearcutting or shelterwood-with-reserves practices. However, group selection also is a viable option on larger forests for meeting specific management objectives.

O'Hara (1998) also recommended that innovative multiaged silvicultural strategies must be developed to provide diverse stand structural conditions. The increased application of two-aged silviculture in the central Appalachians is an example of how such silvicultural strategies can evolve in response to emerging management goals. Experimental applications of shelterwood-with-reserves practices showed that desirable species composition can be maintained in conjunction with a diverse vertical structure. Forest managers in the region have since implemented many similar silvicultural prescriptions that promote multiaged structures for a variety of management goals. This evidence demonstrates that forest managers can add new silvicultural methods to their toolbox as the need arises.

Now is an appropriate time in the history of our Appalachian forests to take a new look at multiaged silvicultural systems. The majority of forestland is in small, private holdings, and the vast majority of timber harvest volume comes from these properties. The productivity of Appalachian forests will depend on the future structure and composition of these forests. Current harvest methods based solely on the removal of commercial products (diameter-limit harvests) often do not provide the environmental conditions necessary to maintain desirable species composition. It is clear that the need for innovative silvicultural systems and the opportunity to implement such systems coincide in the Appalachian hardwood region.

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