Basic Forest Management Principles

Forests change constantly. Because changes in a forest take place very slowly, sometimes over periods of hundreds of years, people often view forests as static. But forests are actually dynamic communities of plants and animals. Undisturbed forests go through a predictable series of changes in species composition and physical structure over time. These relatively slow changes continue until a major disturbance such as a fire, windstorm, or insect outbreak starts the growth cycle over again.

Prior to European settlement, the length of time between major disturbances in most Pennsylvania forests was probably about 300 years. However, much of today's forest did not exist 60 to 90 years ago. Large-scale industrial logging, subsequent widespread fires, and the devastating chestnut blight had eliminated nearly all of Pennsylvania's old-growth forest by 1930. Huge areas of the Commonwealth were entirely deforested, and the magnificent forests we enjoy today literally rose from the ashes naturally with the advent of effective forest fire prevention and control programs.

Even without further disturbance, Pennsylvania's forests will change substantially over time (see figures 1–6). The valuable black cherry trees on the Allegheny Plateau, for example, will give way to more shade-tolerant species, such as sugar maple and beech, and the proportion of oaks in the Ridge and Valley Region will decline in relation to red maple. Natural disturbances, such as the 1985 Memorial Day tornadoes (see figures 7–8) or insects and diseases, may accelerate or slow down these changes.

***Figure 1.** Little Arnot Run 1927—During logging. The sawtimber has been harvested. The following five photos, which were taken from the same point, illustrate the growth and development of a forest stand following harvest.*

***Figure 2.** Little Arnot Run 1928—Logging is complete and regeneration has begun.*

***Figure 3.** Little Arnot Run 1937—In ten years, a dense stand of saplings has developed.*

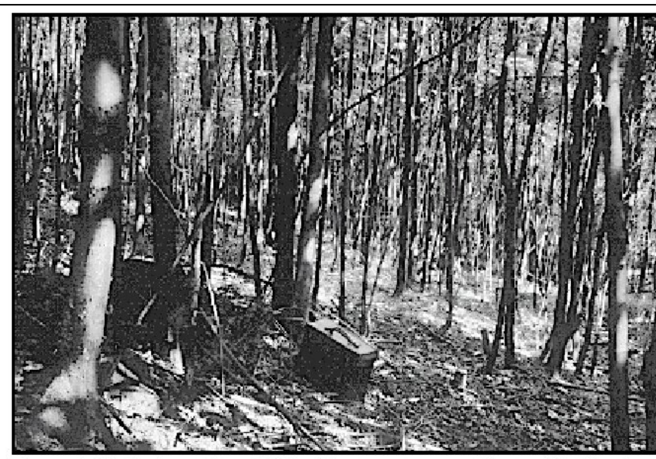


***Figure 4.** Little Arnot Run 1947—The twenty-year-old stand is thinning itself naturally as the trees compete for sunlight.*

Figure 5. Little Arnot Run 1968—Forty-one years after logging, natural thinning has reduced the stand to a few hundred trees per acre.

Figure 6. Little Arnot Run 1998—Seventy-one years after logging, with trees reaching 20 to 24 inches in diameter, the stand will soon be ready to harvest again.

Figure 7. Tionesta 1985—Tornado damage.

Figure 8. Tionesta 1992—Tornado site seven years later.

Timber harvesting mimics the natural disturbances that sustain forests. Foresters and loggers work with, not against, the processes of natural change by harvesting wood that would otherwise be lost to natural mortality, and by promoting the kinds of trees that best meet landowners' objectives. The patterns of natural change in forests result from variations in *shade tolerance* among different kinds of trees. Some species, such as black cherry and yellow poplar, require full sun to become established and to grow. These are known as *shade-intolerant specie*s. More tolerant species, such as sugar maple and hemlock, can become established and grow well in shaded areas, but they are soon surpassed by faster-growing intolerant species in sunnier locations. A third group, including northern red oak and eastern white pine, can tolerate moderate amounts of shade.

The techniques, or *silvicultural system*s, foresters use to harvest and regenerate trees generally manipulate the relative amounts of sun and shade to promote selected species. Intolerant species benefit from cutting practices that are more like the large-scale natural disturbances caused by fire, wind, or insect epidemics, while tolerant species benefit from smaller disturbances, similar to those caused by the death of an individual tree or a small group of trees. In Pennsylvania, some of the most important economic assets of forests are produced by species that are intolerant of shade.

Both clear-cutting and selection cutting are acceptable silvicultural practices for managing Pennsylvania's forests. Clear-cutting, in which an entire timber stand is cut, is one of the silvicultural systems used by foresters to *regenerat*e, or renew, forests. Like large-scale natural disturbances, clear-cutting promotes the establishment and growth of intolerant and intermediate species, such as black cherry and oak. It is used when landowners have a reason to harvest the existing trees, and when the seedlings that will become the future forest are already present or the area is to be replanted. Reasons to harvest might include the financial maturity of most of the trees or a desire to create temporary open habitat for certain wildlife species.

Clear-cutting is appropriate for Pennsylvania's two major forest types, northern hardwood and oak/ hickory. It creates a new forest with trees of roughly the same age, or an *even-aged forest.* Another way to promote the establishment of seedlings is with a technique called *shelterwoo*d, which temporarily retains 30 to 70 percent of the forest canopy. Without clear-cutting or other even-aged management and harvesting techniques, the proportion of black cherry and oak in Pennsylvania forests will be reduced in the future.

Basic Forest Management Principles

Selection cutting, a regeneration technique in which trees are removed singly or in small groups, is appropriate for forests comprised of trees of different ages, or *uneven-aged forests.* Properly applied, selection cutting will remove not only some larger, higher-quality trees, but also many smaller, lower-quality ones. This will increase the growing space for the remaining trees and create areas where new seedlings can become established. The intent is to retain a full range of trees, from large old trees to seedlings. This process is designed to control species composition, age structure, and tree quality. Since the forest canopy remains largely intact, selection cutting is best used on shade-tolerant species, such as sugar maple, beech, and hemlock.

Diameter-limit cutting generally is a destructive practice. It is well known that high-grading (also referred to as “selective cutting”), or taking only the largest, best trees of the most valuable species, leads to a progressive deterioration of forest variety and quality. However, many people do not realize that diameter-limit cutting can be almost as destructive. When all trees above a certain diameter (measured at 4.5 feet above the ground) are removed, the smaller, slower-growing specimens are left. In Pennsylvanian even-aged forests, small trees are usually about the same age as large ones. However, these small trees may be (1) a different species; (2) genetically inferior; or (3) in a poor location. Diameter-limit cutting shifts the composition of the forest toward slower-growing, less valuable shade-tolerant species, and it may degrade the quality of the forest by promoting inferior trees. It may also limit future options for the forest and slow down recovery from disturbance by eliminating the sources of seed for the species removed.

Tree planting (artificial regeneration) generally is not necessary in Pennsylvania. Through the use of acceptable silvicultural practices, most of Pennsylvania’s forests will regenerate naturally from seeds or sprouts. Studies show that naturally regenerated trees usually grow faster and survive better than planted trees. However, trees may have to be planted to reforest former strip mine sites, old fields, conifer plantations, and areas where insects or diseases have killed all the seed-producing trees.

The visual impacts of timber harvesting are temporary and infrequent. The visual evidence of logging is nearly invisible to the casual observer after 3 to 5 years, as slash rots and new tree seedlings and other vegetation renew disturbed areas. After a harvest, loggers are unlikely to revisit the area for another 15 years or more.

The visual impacts of timber harvesting can be reduced by good planning. Foresters have developed effective management guidelines to minimize unsightly effects of logging. For example, logging roads and landings can be screened by topography and vegetation. Landowners can retain selected large trees to provide fall color and interesting patterns. Other techniques that can make logging sites more attractive include cutting stumps close to the ground, minimizing debris by using as much of each tree as possible, and trimming or lopping the unused tops of trees in visually sensitive areas so that they lie close to the ground.

Forestry is not land development. Few landowners harvest timber in preparation for land development. History shows that landowners who have the relative freedom to harvest their woodlots for economic gain have an incentive to leave the forest in an undeveloped condition. Conversely, forest landowners who become subject to unreasonable levels of regulation, often to the point of making active management of their forests uneconomical, often convert their land to development uses. As with farmers, forest landowners should be encouraged by their communities to keep their lands in a perpetually forested condition.

Timber harvesting generally has little adverse effect on water quality and does not cause flooding. Forest soils are very absorbent. They act as living filters and reduce surface runoff much more than other surfaces such as grass, cultivated fields, or parking lots. Logging normally disturbs less than 10 percent of the forest soil in the harvest area and therefore does not change forest soil characteristics. In fact, the Department of Environmental Protection’s (DEP) water quality assessment of over 35,000 miles of rivers and streams found only 3 miles impaired as a result of silvicultural activities. (Silviculture ranked last among 32 land-use activities identified in the study as having an impact on water quality.) Also, forest management in Pennsylvania does not rely heavily on herbicides or fertilizers. Disturbed soils are a concern, but by law, a plan must be developed to address potential problems before a proposed timber harvest can commence. (See the section on state regulation below.)

Timber harvesting affects only a small portion of Pennsylvania forests each year. In spite of substantial increases in timber harvesting in recent years, a 1989 inventory of Pennsylvania forests showed that forest areas were increasing in volume twice as fast as they were being cut or lost to natural mortality. Overall, the annual Pennsylvania timber harvest is less than 1 percent of the current standing-timber volume.

Ecosystem Management on State Forest lands.

The management of Pennsylvania's state forests has been an evolving process, beginning with the first purchase of land in 1898. The initial management plans, as written in 1955, focused primarily on timber management and watershed protection. Major revisions in the plans written in 1970 and 1985 incorporated new knowledge and reflected changing management philosophies and cultural values. The current planning effort, a fourth generation of plans, has evolved into an ecosystem management-based approach.

Basic Forest Management Principles

In ecosystem management, the overarching goal of forest sustainability in turn assures the array of resources, uses, and values for current and future generations. **Ecosystem management** can be defined as an ecological approach to resource management, where all aspects of an ecosystem are considered important, and decisions are made based on the best understanding of ecological interactions and processes necessary to sustain the ecosystem's composition, structure, and function over the long term.

State Regulation of Timber Harvesting

Several aspects of timber harvesting are regulated extensively under state law. If local governments or citizens have concerns about regulated activities, the most cost-effective way to deal with them is to work with the appropriate state officials or their local agents. (The Appendix contains suggestions on whom to contact for help on various issues.) The following is a summary of the primary state regulations affecting timber harvesting in Pennsylvania.

All timber harvesting operations in Pennsylvania must have a plan to control erosion and sedimentation. Operations that disturb 25 or more acres of land require an erosion and sedimentation control permit; however, timber operations seldom need permits as they disturb very little land. While timber harvesting generally does not have a major impact on soil or water resources, the construction of access roads, log landings, and skid trails can cause temporary soil disturbance in the harvested area. As a result, state regulations (25 Pa. Code, Chapter 102) require that all earth disturbances have a site-specific erosion and sediment control plan. The plan must (1) be designed to minimize erosion and sediment pollution associated with timber harvesting; (2) be prepared by a person trained and experienced in erosion and sedimentation control methods; (3) consider such factors as topographic features, soils, and quantity of runoff; and (4) be available at the harvest site. DEP regional offices are responsible for enforcing the regulation. The program is also delegated to the County Conservation Districts (CCDs). Since the state-mandated requirements are already thorough and rigorous, communities are discouraged from adding regulatory standards that exceed the scope of existing state regulations in their local ordinances.

Stream crossings may require permits. Timber harvesting frequently requires that access roads and skid trails be constructed across streams. To minimize any impact on water flows or quality, stream crossings are allowed only under certain circumstances. State regulations (25 Pa. Code, Chapter 105) require permits for all types of crossings, including culverts, bridges, and fords, that drain more than 100 acres or require wetland fills. Permit applications must be accompanied by an erosion and sediment control plan approved by the local County Conservation District. DEP regional offices and CCDs are responsible for enforcement of Chapter 105 regulations. The DEP also issues general stream-crossing permits to the CCDs, which should be directly consulted for stream-crossing options.

All crossings of wetlands by logging access roads and skid trails require permits under both state and federal law. Wetlands are regulated jointly by the U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers, and the state Department of Environmental Protection (DEP). A goal of Chapter 105 is to protect water quality, the natural hydrologic regime, and the carrying capacity of watercourses, including wetlands. Although tree harvesting is allowed in wetland areas in most cases, Chapter 105 prohibits the “encroachment” (for example, a road crossing) of any wetland without a permit from the DEP. The permit application must be accompanied by the erosion and sediment control plan described above and a letter from the local CCD stating that it has reviewed the plan and found it to be satisfactory. The DEP and the Corps have a consolidated joint permit application process. The permit issued by the DEP will usually satisfy federal application requirements, utilizing a Federal State Programmatic General Permit (PASPGP); in special cases, the Corps issues a separate permit. Enforcement of Chapter 105, as it relates to watercourses such as wetlands, is the responsibility of the DEP regional offices.

Fish habitat must be maintained. Chapter 25 of the Fish and Boat Code (30 Pa. C.S.A. §§2051-2506) prohibits any alteration or disturbance of streams, fish habitat, or watershed that in any way may damage or destroy habitat without the necessary permits from the DEP, including those required under 25 Pa. Code Chapters 102 and 105. The Fish and Boat Code also states that no substance harmful to fish life may be allowed to run, wash, or flow into the waters of the Commonwealth. Enforcement of the code is the responsibility of the Fish and Boat Commission’s waterways conservation officers.

From *Timber Harvesting In Pennsylvania*, Penn State College of Agricultural Sciences, School of Forest Resources, 2001

Best Management Practices (BMPs)

Best Management Practices (BMPs) are scientific tools and methods designed to help forest landowner, foresters and other natural resource professionals and timber harvesters practice sustainable forest management. They were established under the assumption that voluntary compliance with BMPs reinforced with education, will serve the community better in the long run, both economically and socially. In practical terms, voluntary compliance in implementing BMPS can help avoid the establishment of additional regulatory statues many of which can be burdensome, time consuming, costly and not necessarily conducive to long-term forest health and productivity.

BMPs represent the minimum acceptable forest management guidelines for three areas of forest resource management – planning, forest operations and forest values They represent state-of-the-art knowledge concerning the management of Pennsylvania's forests – how trees should be harvested for timber production while enhancing wildlife. preserving aesthetics, ensuring future forest regeneration and protection soil and water quality, wetlands and area of special concern.

Many of the BMPs focus on wetlands and water quality, Streamside forests (riparian buffer zones) are especially important for maintaining the chemical physical and biological integrity of Pennsylvania's waters and serve as important wildlife habitat. BMPs help to prevent or reduce water pollution caused by runoff from road construction and other activities associated with timber harvesting. When BMPs are used, wetlands are protected and maintained and many of the requirements of federal and state permit processes are met.

A task force of forestry and natural resource professional from industry, academia, state government, conservation organizations and forest landowners under the direction of the Forest Issues Working Group formulated Pennsylvania's BMPs.

Some examples of BMPs include:

- Creating a written management plan based on a resource inventory and landowner objectives.
- Focus on protection of the residual stand rather than on the trees being removed. Retaining seed sources of species needed to achieve long-term management objectives.
- Promoting regeneration by controlling competing ferns and grasses and protecting seeds, seedlings and sprouts from deer and other wildlife.
- Minimizing soil compaction and rutting by matching operating techniques, season of operation and equipment to soil types and moisture levels.
- Provide adequate riparian buffers between disturbed areas, such as roads or landings, and streams or wetlands.
- Protect cavity trees, snags and food-producing shrubs and vines for wildlife.

Introduction

Pennsylvania's forests: importance, history, and description

Nearly 60 percent of the 28 million acres within Pennsylvania borders is covered with forests. Forests provide benefits we simply cannot live without. These benefits can be grouped into three categories: economic, environmental, and aesthetic.

Economic: Nearly 30 percent of Pennsylvania's economy is based on the forest. Our state's forest products are in demand worldwide. More than 100,000 people are employed in our $4.5 billion forest products industry, the fourth largest industry in the state. Each year, we produce more than one billion *board feet* of hardwood lumber and use approximately three-quarters of a million *cords* of *pulpwood* to produce paper and building board products. Approximately 20 percent of our private households supplement their winter heating with 250,000 cords of firewood—higher wood fuel usage than in any other state. Our forests are home to abundant populations of nongame and game animals. Wildlife watchers willingly spend money to feed, house, and otherwise care for the animals that dwell in or near the forest. Fishing and hunting licenses add more than $25 million to Pennsylvania's average annual state revenue. Other forms of recreation and tourism add to the high economic contribution from our forests.

Environmental: Forests protect soils from erosion, provide high-quality water (Pennsylvania has 25,000 miles of forested waterways), and improve air quality. (For every ton of new wood that grows, about 1.47 tons of carbon dioxide are removed from the air, and 1.07 tons of life-giving oxygen are produced.) The diversity of plants and animals that inhabit our forest lands across the state represent a wealth of cultural, medicinal, and environmental resources that we are just beginning to discover. The health of our forests is a prime indicator of the health of our total environment.

Aesthetic: There are few who venture into the forest who do not recognize the human need for the natural beauty and peace of mind that the forest provides. As the pace of our lives and the demands on our time seem only to increase, the value of time spent in the forest—whether we camp, hunt, hike, watch wildlife, or simply collect our thoughts—becomes more important. The forest also fulfills the aesthetic needs of those who simply enjoy viewing the wooded landscape from afar, as well as those who feel good just knowing the forest is "there," even if they never venture into it.

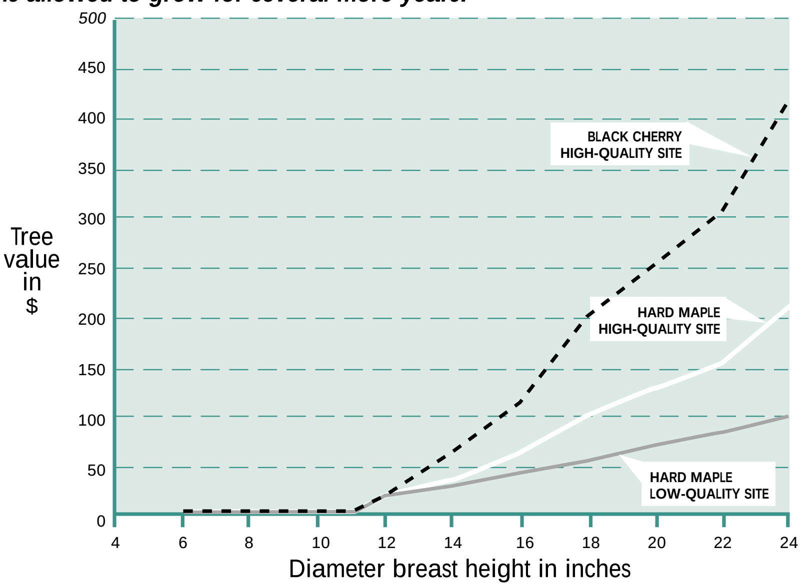
Several hundred years ago, Pennsylvania forests stretched from border to border. From the Piedmont region in southern Pennsylvania to the Northern Tier, a variety of hardwood species were intermingled with *stands* of Eastern white pine and hemlock. As settlers came in droves from Europe, the forests of Pennsylvania began to fall in their path. Farmers cleared forestland for agriculture. Lumber towns sprang up as Pennsylvania led the race to supply the growing nation with timber. By the early 1900s very little of the state's original forest remained. In the haste to harvest timber, other forest resources often were ignored. Steep hillsides were left bare, soil washed into streams and rivers, fires burned out of control, and wildlife habitats were drastically altered.

In all but a few small patches, the forests we have today grew on their own; vigorous fire control and prevention and low deer populations allowed *natural regeneration* to occur on abandoned farm fields and cut-over forests following several decades of widespread disturbance around the turn of the century. Consequently, most of the forests in the state are roughly the same age, give or take 25 years. A walk in a typical Pennsylvania woodland reveals that, in most areas, Eastern white pine and hemlock have become subordinate to a variety of mixed hardwoods—oak, cherry, hickory, maple, yellow poplar, and other species. Blight has reduced the once plentiful American chestnut to a shrub. White and red oaks and cherry have been joined by red maple as the *dominant* species in the *overstory*. In some areas of Pennsylvania, naturally induced mortality in the *deciduous canopy* is allowing Eastern white pine to make a comeback.

Economics and sustainable forestry

The promise of economic gain is a powerful lure. More significantly, economic gain, in the great majority of cases, provides the means to implement other management practices that can maintain and improve our forests for wildlife, recreation, *biological diversity*, and future woodland health and productivity. In realizing economic gain from the use of forest resources, we need to recognize that what we consume today can affect the resources available to our children. Ongoing management practices demonstrate that managing and using our forests wisely can provide at least as much as we need to sustain us now without jeopardizing the future resource, economically (Figure 1) and environmentally.

Figure 1. In some cases, the value of a tree will increase dramatically if it is allowed to grow for several more years.



Forest management basics

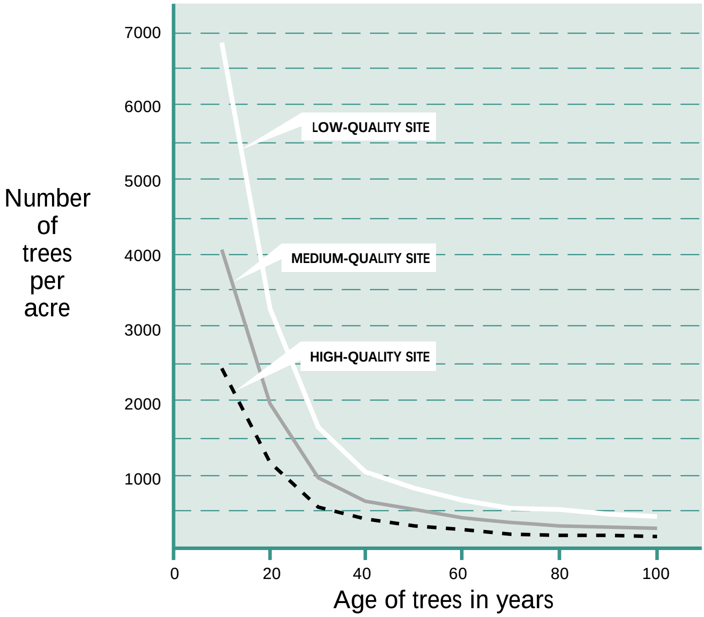
Ecological principles and processes

Forest *ecology* is the study of the forest as a biological community, with emphasis on the interrelationships among the various trees and other organisms constituting the entire community, and on the interrelationships between these organisms and the physical environment in which they exist. These interrelationships define or describe a forest *ecosystem*.

The forest ecosystem is dynamic—as in all living systems, change is inevitable (Figure 2). We can, to a degree, predict what will happen during the *successional* stages of a forest, and we are increasing our knowledge of the patterns of natural disturbances, such as winds, fires, damaging ice and snow, and outbreaks of native insects or diseases. We are less able to predict invasion by unexpected plant and animal species. Even for those disturbances whose patterns we can describe, it is difficult to predict their impact on a particular place at a particular time. What is certain is that no ecosystem remains forever the same. The domain of natural science has come to realize that management plans and techniques should try to work with, rather than prevent, changes in ecosystems.

The development of a forest is influenced by many factors—soil types and depths; groundwater patterns; the steepness and directional slope of the terrain; various microbial populations; the presence and fluctuating population sizes of numerous species of fungi, plants, and animals; the

Figure 2. Even without human intervention, the number of trees per acre decreases overtime.



regional climate; the microclimate on the forest floor; the conditions that exist in adjacent or nearby areas; human activity; and the neverending, cyclic process of growth, aging, death, decay, and *renewal*.

The vegetation that succeeds on any given site under some set of environmental circumstances and conditions has a great influence on the types and species of microbial and animal life that will thrive there. And the types and levels of microbial and animal populations, in turn, affect the future success and composition of the plant life.

As we have acquired some degree of understanding of the complex web of ecological principles at work in the forest, we have found ways to speed up or slow down these natural successional processes. The art and science of manipulating the pace of nature in the forest and controlling forest establishment, composition, *structure*, and individual tree growth is called *silviculture*.

The role of timber harvesting

Humans have always needed products from the forest, and over time that demand has increased with our overall standard of living. Timber harvesting is a vital tool in renewing or enhancing and improving the vigor, diversity, and beauty of the forest while providing benefits to society. In the process of cutting trees for wood products, we modify wildlife habitat and alter natural systems (e.g., increase or decrease water flow, increase or decrease *mast* production, or change species composition).

In any discussion of forestry practices, of which timber harvesting is just one, it is useful to define a "stand" and make the distinction between a stand and a forest. A stand is an area of forest with similar species composition, age, and site conditions. A stand can be *pure* (at least 90 percent of the dominant trees are of one species) or *mixed*. It also can be *even-aged* (all the trees in the stand are approximately the same age) or *uneven-aged* (trees in the stand are of different ages). A pure, even-aged stand has the simplest structure, while a mixed, uneven-aged stand has the most complex.

The forest is the sum of its stands. Keeping that in mind, it is easy to understand that the forest, as a whole, can be sustained even while timber harvesting and other regeneration practices are being carried out on individual stands.

Although timber harvesting accounts for only a small portion of our working forests' life cycles, how and when timber is harvested play a major role in determining the character of the forest far into the future. Experience has indicated that disturbance may contribute to higher diversity. We know that timber harvesting can be pivotal for *forest renewal* and forest improvement in areas that previously have been misused.

Timber harvesting can play an important role in forest management, regardless of the owner's objectives. Properly planned timber harvesting promotes the growth of desirable trees and other plants, stimulates regeneration, and alters wildlife habitat to favor certain species. Timber harvesting also can temporarily alter the aesthetic or recreational value of the forest. Timber harvesting should be done only when there are benefits to be gained, and it should always be done in a way that is intended to improve or renew a forest. However, it should not be a foregone conclusion that timber harvesting will be a part of every landowner's management plan. When timber harvesting is incorporated into management plans, it should be done to help landowners meet their objectives, whatever they might be.

Silvicultural practices

The goals of silviculture are the improvement and successful renewal of a forest community. Silvicultural practices are generalized procedures, usually involving cutting, that foresters adapt into individualized prescriptions for specific stands.

Classic silvicultural practices include *intermediate treatments* (*cleanings*, *thinnings*, and *improvement cuts*) and *regeneration methods* (done with the goal of starting a new forest). The complex mix of conditions from stand to stand dictates that silvicultural practices be modified or combined to suit site-specific conditions. Motives for managing forests have changed considerably since the early twentieth century, making the successful application of silvicultural practices an increasingly complex art. Objectives have expanded from timber management to multiple-use management to ecosystem management, in which maintaining the health, productivity, and continuity of the entire forest ecosystem is our principal goal.

The basic silvicultural practices in use today are briefly outlined here. Their application will be discussed more fully in the next section.

INTERMEDIATE TREATMENTS

Intermediate treatments are done while the forest is still growing to *economic* or *biological maturity*. Intermediate treatments are usually applied sufficiently before the forest reaches economic or biological maturity (economic maturity occurring before biological maturity) so that the *residual stand* will be able to respond to increased light, water, and nutrients or to reduced competition.

- *Cleanings*, which may also be thought of as "weedings," occur early in the life of a stand. They are made to favor species desired by the landowner by removing non-merchantable, undesirable (as defined by the landowner) *herbaceous* and woody species, including invasive, non-native species. Cleanings typically are not done past the *sapling* stage of the stand being treated. Because they do not have an immediate payoff, cleanings must be regarded as an investment in the future mature forest.
- T*hinnings and improvement cuts* have the goals of controlling *stand density*, increasing tree vigor, and selecting the species and individuals that will constitute the future forest. Thinnings and improvement cuts conducted in the latter stages of forest growth (or *rotation*, if timber management is the goal) frequently yield merchantable volume. The differences between thinnings and improvement cuts are sometimes difficult to discern, since they both are conducted using similar means to achieve similar ends. Thinning takes tree *spacing* into account, focusing on removing trees that are judged to be poor "competitors" and will probably die before they reach maturity. Improvement cuts, on the other hand, while not ignoring individual trees' competitive abilities, focus on removing trees of

undesirable species or form to concentrate growth potential on the most desirable species and individuals.

The net results of intermediate treatments are that undesirable trees are removed from the stand, and resources (sunlight, moisture, nutrients, and space), and therefore growth, are redistributed to selected trees. Intermediate treatments also can help check the spread of infectious agents.

REGENERATION METHODS

Regeneration methods mimic the creation of openings in the forest by natural disturbances. The most important goal of the regeneration process is to re-establish a healthy forest. It is important to understand that regeneration in Pennsylvania's forest types almost always occurs naturally, either by stump sprouts (new trees arising from residual stumps), by root sprouts, or by naturally dispersed seed. Planting and seeding (artificial regeneration) sometimes are used to regenerate Pennsylvania forests, especially to establish or renew pine plantations. A focal point of regeneration is to renew not only the trees, but also the other beneficial woody and herbaceous vegetation that contributes to a functioning forest ecosystem.

There are four requirements to consider before making a regeneration cut: (1) abundant advanced regeneration (seedlings and sprouts) should be present on the forest floor, or there should be ample seed in the forest-floor *litter* that can germinate after the overstory is removed; (2) seedlings and sprouts should be well distributed; (3) they should be desirable species; and (4) vegetation that will inhibit the growth and development of seedlings and sprouts should be controlled. In Pennsylvania, there often is a fifth requirement: protecting seedlings and sprouts from over-browsing by white-tailed deer.

Once the above requirements are met, the regeneration cut can proceed under several methods. Usually, as mentioned earlier, these methods are combined or modified according to the conditions of the area to be harvested. Regeneration cuts usually generate income from timber, regardless of whether the objective is to make some money, to salvage a dead or dying stand, or to alter wildlife habitat.

- T*he single-tree selection and group selection methods* mimic the natural processes of single trees or relatively small groups of trees dying and falling or being blown down by a localized burst of wind. Both methods favor the regeneration of *shade-tolerant* species. S*election* cutting should be applied with skill and care because it easily can degenerate into "*selective*" cutting, also known as diameter-limit cutting or high-grading (see page 15). Under both methods, establishing areas of advanced regeneration is an ongoing process, from the time of the first cut through each successive cut.
  - T*he single-tree selection method* removes individually selected trees throughout all diameter classes, creating small gaps in the canopy to facilitate regeneration. This method is generally the most expensive method of harvesting and requires the greatest amount of care and skill on the part of the forester and the logger. Advanced regeneration established before the harvest must be of shade-tolerant species that are known to grow well in the low-light conditions that persist even after harvest.

– *The group selection method* removes trees in a number of 0.1- to 1-acre areas to create openings in the forest canopy. The larger the opening, the more likely that regeneration of sun-loving (*shade-intolerant*) species will develop and persist in the openings. Shade-tolerant species are more likely to sprout and survive near the edges of the opening and in the uncut forest between the openings. For shade-tolerant species to compete successfully with shade-intolerant species in the openings, they should be present as advanced regeneration before the harvest.

- *Shelterwood, seed tree, and clear-cut methods* mimic nature's more catastrophic processes, such as wildfires, tornadoes, and hurricanes, which can bring down multiple acres of trees in one fell swoop. These three methods are used to regenerate tree species whose best germination and growth occur with full or nearly full sunlight.

– *The shelterwood method* leaves a large number of trees standing long enough to establish and protect "advanced regeneration" sites until the seedlings and saplings are well established. (Because the residual trees also serve as a continuing seed source, the shelterwood method is desirable when insufficient advanced regeneration is present.) After regeneration is well established, the sheltering trees are harvested, permitting the advanced regeneration to occupy the site fully.

– *The seed tree method* leaves a few of the best trees standing to become the parent trees of the new forest. This method has limited application in Pennsylvania forests.

– *The clear-cut method*, in its pure form, removes all the trees in a multi-acre area in a single cut. However, as management plans have evolved to include multiple objectives, it is not unusual to find that even in a clearcut area, some tree species are reserved in the interests of biodiversity, wildlife habitat, or aesthetics. These include rare or slow-growing species, good mast producers, and wolf trees, den trees, and some snags. This method is the most controversial and often the target of public outcry. However, there are biologically based justifications for clear-cutting, given that the four (often five) requirements for regeneration listed above have been satisfied. Clear-cutting may be the best way to promote early successional forests that are essential for numerous plant and wildlife species. Clear-cutting is the best method for regenerating those tree species (such as black cherry, aspen, and yellow poplar) that require full sunlight, at least in their early life.

CROP TREE METHOD

The crop tree method is a relatively new, hybrid method that combines features of both intermediate treatments and regeneration methods. Currently, the crop tree method is being used to release trees selected for retention to meet an owner's objective. Regeneration may become established as openings around the crop trees are created. This regeneration will be released when the crop trees are harvested in the future. Since most regeneration will develop in partial shade, the crop tree method appears to favor shade-tolerant species.