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.
- *Thinnings 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.

- *The 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. *Selection* 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.
  - *The 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.

Forest protection and health

Pennsylvania forests are subject to attack by insects, diseases, and fire. Gypsy moth has decimated untold acres of oak stands. Chestnut blight has virtually eliminated one tree species. Beech, hemlock, and dogwood are each battling their own pests. In many areas of the state, tree seedlings, shrubs, and wildflowers are losing the battle to over-browsing by white-tailed deer. Wind, snow, ice, and drought also take their annual toll on forest vegetation.

Some losses are unavoidable, but they can be minimized by incorporating BMPs that support a landowner's objectives into a sound forest management plan. Sometimes the best way to minimize a loss is through a salvage cut—literally, a harvesting operation conducted to salvage timber that has been damaged or killed by insects, disease, weather, or other natural phenomena. Details on BMPs that will protect and improve forestland and minimize the adverse effects of forest management operations are presented in the next section.