Chapter 8: Mine Reclamation Practices to Enhance Forest Development through Natural Succession

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INTRODUCTION

"Natural succession" is a term used to describe natural changes in plant community composition over time. In the forested Appalachian region, disturbances from storms, fire, logging, or mining can disrupt or destroy established forests. Natural processes that lead to restoration of the forest vegetation following such a disturbance usually begin quickly and result in development of another forest. On reclaimed mine sites, the quality of that forest and the speed with which it develops depend upon the conditions created by the mining and reclamation process (Fig. 8-1).

Figure 8-1.—Reclaimed mine site in eastern Tennessee 47 years after reforestation. This site was reforested with various pine species and black locust in 1959 on uncompacted spoil with no planted ground cover. Succession and colonization have occurred over the years. The pine forest has been replaced with vegetation similar to the nearby native forest: yellow-poplar dominant in the overstory; red maple, sassafras, and northern red oak in the mid-story; and blueberries, groundpine, Virginia creeper, and ferns in the understory. Photo by Vic Davis, OSMRE.

Conventional surface mine reclamation as practiced from the late 1970s until recently under the federal Surface Mine Control and Reclamation Act of 1977 (SMCRA) commonly featured smooth grading of topsoil or topsoil-substitute material followed by establishment of grasses and legumes

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that grow rapidly to form a thick ground cover. These compacted mine soils and the competitive grasses hinder tree establishment and growth and delay the process of succession to forest cover.

In contrast, reclamation practices known as the Forestry Reclamation Approach (FRA) are intended to encourage succession in a manner that helps the mine operator satisfy regulatory requirements cost effectively and achieve prompt bond release (see Box 8-1). This Forest Reclamation Advisory describes the ways in which these reclamation methods can encourage rapid succession and accelerate development of high-quality postmining forests.

SUCCESSION: FROM BARE GROUND TO FOREST

When land is disturbed in a way that removes all vegetation, including seeds and plant material capable of resprouting, and nothing is done to revegetate, succession occurs slowly. At first, "pioneer" plant species including grasses, other herbs such as goldenrods and ragweed, vines, and shrubs such as raspberry and blackberry colonize and dominate the site. Depending on soil and site conditions, this plant community type may continue to dominate for many years, or it may be replaced sooner by other kinds of plant communities, including forest trees. (Please see the Appendix starting on p. A-1 for scientific names of species mentioned in this chapter.)

When soil and vegetation conditions are favorable for trees, fast-growing short-lived (early successional) trees such as black locust, sassafras, Virginia pine, and hawthorn overgrow the shrubs. In time, these early successional trees make the site more habitable for slower-growing but longer-lived (later successional) trees such as oaks, hickories, cherry, sugar maple, and ash. As succession proceeds, the open spaces between trees continue to decrease. When the tree tops (or "canopy") of the emerging forest grow together so that very little light reaches the ground, a phase of succession called canopy closure occurs, often 15 to 20 years after the initial disturbance. After canopy closure, lower-growing vegetation beneath the forest canopy (called the understory) declines in response to decreased sunlight until another disturbance opens up the forest.

HOW LONG DOES IT TAKE FOR A FOREST TO MATURE?

When succession occurs under good conditions, some fast-growing timber trees may grow to a size that can be harvested as soon as 30 to 40 years after disturbance; slower-growing hardwoods may require 50 to 60 years or longer (Fig. 8-4). Other sites may still be in the grass-herb-shrub stage with only scattered trees for several decades after a disturbance because soil conditions are not suitable or the understory vegetation is too competitive for tree recruitment. This is called "arrested succession," which is a failure of later

Figure 8-4.—Fifty-five-year-old black walnut trees that were planted and grew on spoil banks in southwestern Indiana. Photo by R. Rathfon, Purdue University, used with permission.

Box 8-1. Can the Forestry Reclamation Approach Achieve the Rapid Succession of Natural Forests?

After harvest in natural forests, most regenerating hardwood trees grow as sprouts from well-established root systems. This type of regrowth cannot occur on reclaimed mines because those rooting systems have been removed. Unless native forest soils are used in reclamation, mine sites lack the seedbanks and budbanks (live seeds on or in the forest floor and buds that can produce sprouts) of native forests, so the vegetation immediately following reclamation is unlikely to be as diverse.

In some cases, mine sites that have been reclaimed using the FRA (Chapter 2, this volume) will undergo succession more rapidly than natural forest sites following timber harvest. After an initial planting of saplings at 6-foot × 6-foot spacing on an ungraded eastern Kentucky mine site (Fig. 8-2), canopy closure occurred within about 7 years. The dense planting of early and later successional tree species kept competing weeds at a minimum, which allowed rapid colonization by 27 forest tree species that were growing nearby. In addition, the number of naturally recruited forest species (trees and other vegetation types) was 10 times greater on loose-dumped spoils than on those spoils that were graded using conventional reclamation practices. The loose-dumped spoils allowed natural succession to occur, as indicated by a far higher number of recruited stems per acre (475) compared to the conventionally graded spoil (49 stems per acre) (Fig. 8-3). Tree canopy occupied more than half the area on the loose-dumped spoils. In contrast, canopy cover was only 5 percent in the conventionally graded areas of the mine site.

As the FRA is used on more reclaimed mines, researchers will have the opportunity to improve these techniques and further increase the value of reclaimed lands for future generations.

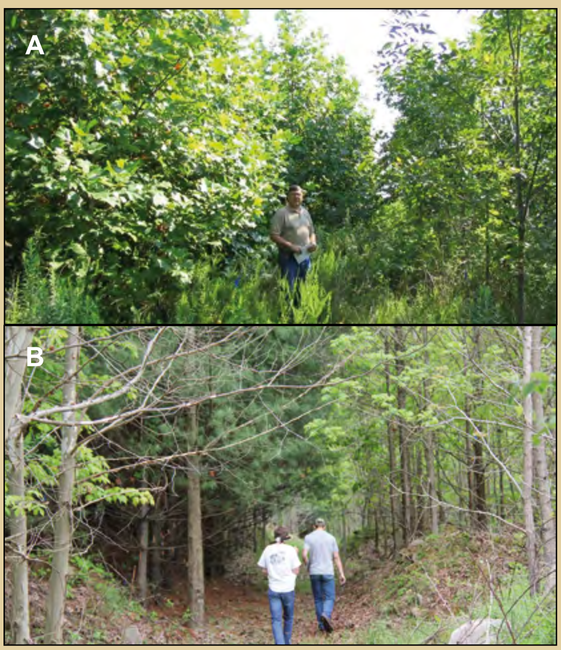

Figure 8-2.—Reforested mine site in southeastern Kentucky (A) 8 years and (B) 18 years after reforestation. White oak, white ash, eastern white pine, northern red oak, black walnut, and yellow-poplar were planted. The loose-dumped, uncompacted mine spoils allowed planted seedlings to achieve greater survival and faster growth while allowing more colonization by nonplanted forest species, compared to an adjacent mine site that was graded by using conventional practices. The closed canopy forest with abundant native plants remaining in the understory was achieved in the 10 years between the photos, indicating how rapidly forests can develop on a high-quality growth medium. Photos by OSMRE.

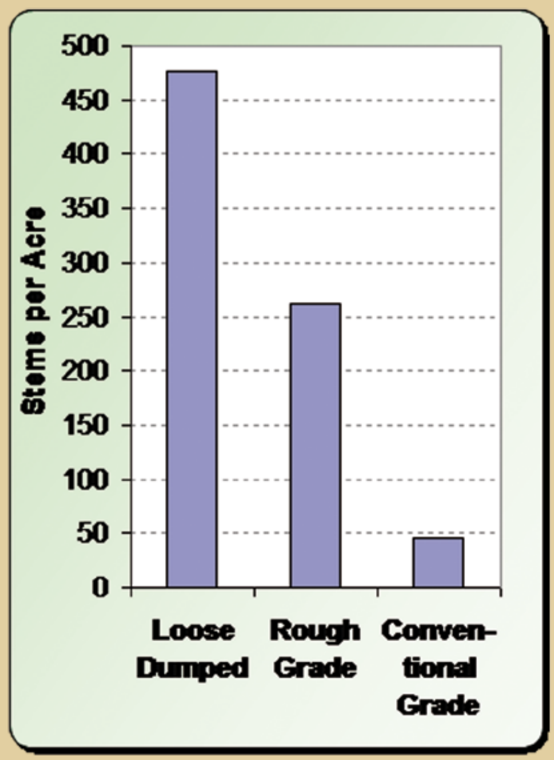

Figure 8-3.—Number of stems per acre of naturally seeded forest species after 8 years in loose-dumped, rough-graded, and conventionally graded areas of the southeastern Kentucky surface mine shown in Figure 8-2 (data from Barton and others, in press.).

successional species to become established and eventually dominate a site (see Box 8-2). Arrested succession also occurs in areas where large populations of deer or rodents consume or destroy tree seedlings.

Box 8-2. "Arrested Succession"

A condition known as "arrested succession"—a failure of later successional species to colonize a site—can occur after reclamation if principles of natural succession are ignored (Fig. 8-5).

For decades, a common reclamation practice consisted of seeding fast-growing grasses such as tall fescue and sericea lespedeza to rapidly revegetate mine sites. Often, black locust seed was added to the groundcover seeding mix. This practice produced thick vegetation that easily satisfied the bond release requirements of those times. But within 10 years after planting, most black locust trees become infested with a tiny insect known as the locust borer beetle. This pest causes the trees to lose vigor, and they break down to a shrub-like form. In this form, their sparse canopy and nitrogen-fixing capability allow the groundcover grasses to persist, so the thick herbaceous cover under the black locust remains intact, preventing the recruitment of other trees and forest vegetation. Because other native tree species are not present to replace the black locust, tall fescue and companion species such as sericea lespedeza can dominate such sites for decades.

Figure 8-5.—Reclaimed surface mine in western Maryland. Black locust and grass vegetation were planted 16 years earlier. As a result, the development of a natural forest community through natural succession has been delayed, a condition known as "arrested succession." Photo by OSMRE.

WHAT FACTORS AFFECT SUCCESSION ON A MINE SITE?

Quality of the Rooting Medium

If soil replacement results in a rooting medium that is shallow or has been compacted, the site will be prone to drought and plant nutrition problems. Mine soil pH that is too high (pH more than 7) or too low (pH less than 5) and mine soils that have high levels of soluble salts can also cause plant nutrition problems. Seeds of unplanted forest species that are carried to the mine site by wind or wildlife will not germinate and grow if the soil surface is compacted or has chemical properties that are not well suited to their needs. Those grass and shrub species that are able to become established and grow on such soils will dominate on such sites, and forest succession will progress slowly. In contrast, a deep and loose growth medium that contains plant nutrients encourages colonization and canopy development by species from the native forest. These soil properties promote a diversity of trees and other vegetation and are productive for timber and wildlife.

Groundcover Vegetation

Where tall, aggressive grasses are established on the site through reclamation, or where herbs, shrubs, and vines become established in dense thickets, new tree establishment is hindered and young trees become stunted. Because a sparser ground cover allows sunlight to reach the soil surface, planted seedlings can grow and seeds from the surrounding area carried in by wind and wildlife can become established more easily. Tall, thick ground covers also remove water and nutrients from the soil rapidly, leaving fewer of these essential resources for the slower-growing trees. These ground covers also attract deer, which can consume the tree seedlings; and they provide cover for small rodents, which can gnaw on planted seedlings.

The Mixture of Tree Species

Natural forests in the Appalachian region consist of a mixture of tree species. Some become dominant soon after disturbance and play an important role in establishing the full range of forest plant species. In time, these typically short-lived species die, decline, or are harvested as the longer-lived tree species take over. A mature, closed forest canopy then results. Mine operators can shorten the time it takes nature to produce a valuable forest by preparing the site with loose, good-quality mine soils that encourage establishment of volunteer early-successional species, and by planting a mixture of early and later successional tree species, such as those described next.

- Early successional trees are fast-growing species such as pines, sweet birch, sourwood, red maple, and bigtooth aspen that provide habitat for birds and other seed-moving animals and help suppress grasses, thus allowing native forest plant species to become established. Early successional species such as dogwoods and redbud produce fruit and may further contribute to forest development by attracting seed-carrying birds and other wildlife.
- Later successional tree species are those which typically dominate a site later in the natural succession process. These include many of the commercially valuable hardwoods—such as the oaks, hickories, walnut, and cherry—that are characteristic of mature Appalachian and midwestern forests. Many of these species have relatively large and heavy seeds that are not moved quickly over long distances by natural forces. Planting later successional species on a mine site can help these species become established more rapidly than through unassisted natural succession.

To maximize forest value where reclamation has produced soil, groundcover vegetation, and other conditions favorable to reforestation (FRA conditions), planted trees should be compatible for growth in mixed stands. High-value later successional species capable of living for at least several decades should be favored for planting. On such productive sites, plant early successional trees and shrubs in significant numbers if they will help improve the growth and value, and further aid the colonization, of longer-lived and more valuable trees.

Other Factors

Other soil and site factors will also influence the speed of natural succession on mine sites. For example, use of excavated soils that contain living seeds and roots from the native forest in reclamation areas can accelerate natural succession. Mined areas that are close to unmined native forest will be colonized by native forest species more rapidly than sites farther from unmined forests (see Box 8-3).

WHAT RECLAMATION PRACTICES AID ESTABLISHMENT OF FORESTS BY ACCELERATING NATURAL SUCCESSION?

Reforestation researchers have developed the FRA, which, when implemented properly, can accelerate natural succession on reclaimed mine sites, aiding formation of healthy, diverse hardwood forests (Chapter 2, this volume). The FRA can be summarized in five steps:

1. Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and consists of topsoil, weathered sandstone, or the best available material, or a combination of these materials.
2. Loosely grade the topsoil or topsoil substitutes established in Step 1 to create a noncompacted growth medium.
3. Use groundcover species that are compatible with growing trees.
4. Plant two types of trees: early successional species for wildlife and soil stability, and commercially valuable crop trees.
5. Use proper tree planting techniques.

Box 8-3. Making Post-reclamation Vegetation More Diverse

Natural Appalachian forests contain hundreds of plant species. Replacing all of these species through replanting and seeding is virtually impossible. Natural colonization and replacing topsoils are two mechanisms that can increase plant diversity of reclaimed sites.

Reclaimed mine sites are naturally colonized by native vegetation

In Virginia, researchers studied vegetation change on mine sites over time (Holl 2002, Holl and others 2001). In 1992, and again in 1999, they documented the species present on contour mine sites of three different age classes—reclaimed in 1967-1972, 1972-1977, and 1980-1987 using techniques typical for those times—and in the adjacent natural forests. Succession was clearly evident because many more species were present on reclaimed sites than had been originally planted, and many of the unplanted species also occurred in the adjacent forests.

However, natural succession occurs slowly when conventional reclamation practices are applied. On the 1972-1977 sites, which had been reclaimed with aggressive ground covers, grass-like herbaceous vegetation was still dominant 15 to 20 years after the initial reclamation. By 1999, the herbaceous cover was finally beginning to yield to woody species, including red maple and sweet birch, that have small seeds which can be carried by wind and birds. But even though most native forest species were present by 1999, some understory species such as trillium, wintergreen, and serviceberry were not found on any of the reclaimed mines despite the proximity of most of these sites to undisturbed forest (within a few hundred yards' distance).

In another study established in 2005 in Kentucky, FRA reforestation plots of loose-dumped brown weathered sandstone were planted with four native hardwood species, but no ground cover was applied (Sena and others 2014). In 2013 seedling survival was high (86 percent) and vegetation completely covered the ground. The total number of colonizing species on the plots was 57, and 68 percent of those were native to the region. There were 26 naturally colonized tree and shrub species. Under the conditions of this experiment, the physical and chemical makeup of the mine spoil, linked with available seed sources, led to the development of a diverse forest community.

Accelerating succession by spreading forest soils

In some areas, soils salvaged from the pre-mining forest floor can be recycled to produce a plant-growth medium after mining. In these cases, seeds or roots contained in the soil can sprout, establishing species not typically spread by wind or wildlife or where potential seed sources are far away (Wade 1989). For example, at a mine site in Kentucky that was reclaimed by using topsoils from the adjacent natural forest, 63 species from the natural forest donor site were found on the reclaimed mine site within 1 year after the soils were spread (Hall 2009). Some important points to consider when implementing this treatment are:

- Native forest soil aids succession most effectively when moved directly from the mining area to the reclamation area. Storage of soil before respreading causes seeds and roots to lose viability, with longer storage periods causing greater losses.
- Fast-growing agricultural grasses and legumes are incompatible with most native forest vegetation. As a result, spreading native topsoil is most effective as a reforestation practice when other ground covers, especially agricultural grasses and legumes, are not seeded.
- Moved topsoil must be free of invasive plant species such as multiflora rose, oriental bittersweet, and Japanese honeysuckle for this treatment to provide a long-term benefit to forest development. Carefully inspect the source site prior to mining and keep soil-moving machinery clean as precautions to prevent spread of these species through topsoil replacement. Spreading soils from areas with undesirable species during reclamation can lead to establishment of those species on the mine site, causing "arrested succession."

Use of the FRA practices can accelerate natural succession by creating conditions similar to those where native forests thrive.

SUMMARY

Landowners and mine operators are increasingly choosing forest as the postmining land use. Compared to conventional reclamation practices, reclamation using the FRA allows more planted seedlings to survive and more species from the surrounding forest to colonize the reclaimed mine site. Agencies in the Appalachian Regional Reforestation Initiative states allow both planted trees that survive and tree recruits that are compatible with the postmining land use to be counted toward the tree-stocking standard for reclamation success. Reclamation practices that encourage natural succession can help mine operators meet regulatory requirements and achieve prompt bond release while restoring native forests.

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