



MINE RECLAMATION PRACTICES TO ENHANCE FOREST DEVELOPMENT THROUGH NATURAL SUCCESSION

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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 after such a disturbance usually begin quickly and result in development of another forest. On former 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 (see Photo 1).

Conventional surface mine reclamation as practiced from the late 1970's to the present commonly featured smooth grading of topsoil or topsoil substitute material

followed by establishment of grasses and legumes that grow rapidly to form a thick groundcover. These compacted mine soils and 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 1).

This advisory describes the ways in which reclamation methods can encourage rapid succession and accelerate development of high quality postmining forests.



Photo 1. Succession and invasion of native species over 47 years formed a forest on this mine site in eastern Tennessee. This site was mined and reforested with various pine species and black locust in 1959 on un-compacted spoil with no planted ground cover. Succession has occurred over the years and 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, ground pine, Virginia creeper and ferns in the understory (photo by Vic Davis)

Box 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 seed and bud banks (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.



Photo 2. On this eight year old mine site in Perry County, Kentucky the following species of trees were planted: white oak, white ash, eastern white pine, northern red oak, black walnut, and yellow poplar. The high-quality growth medium on this site (loose-dumped, uncompacted mine spoils) allowed planted seedlings to achieve greater survival and faster growth while allowing more invasion by non-planted forest species, compared to an adjacent mine site that was graded using conventional practices (Angel 2006) (Photo by Mike Hiscar).

In some cases, mine sites that have been reclaimed using FRA (see Burger 2005) will undergo succession more rapidly than natural forest sites after timber harvest. The canopy of trees established on an ungraded eastern Kentucky mine site (see Photo 2) experienced closure about seven years after an initial planting at 6 x 6 foot spacing. The dense planting of early- and later-successional tree species kept competing weeds at a

minimum, which allowed rapid invasion by 27 forest tree species that were growing nearby. In addition, the number of naturally invading 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 (see Figure 1).

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

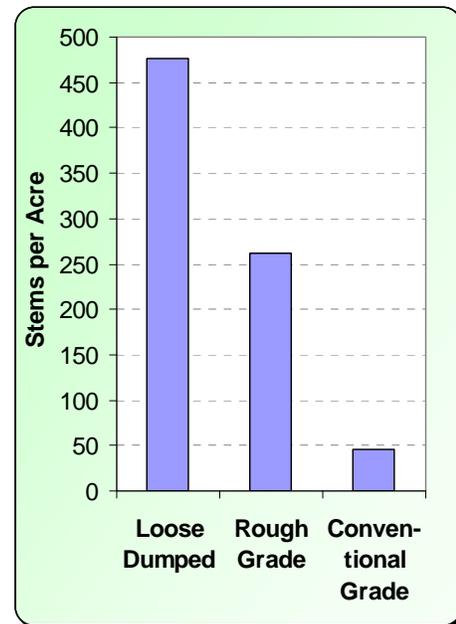


Figure 1. Naturally seeded forest species after eight years in loose dumped, rough graded, and conventionally graded areas of the Perry County, Kentucky, surface mine pictured in Photo 2. The loose dumped spoils allowed natural succession to occur, as noted by a higher number of invading stems per acre compared to the conventionally graded spoil. Succession occurred most rapidly in the loose-dumped spoil where canopy occupied more than half the area. In contrast, canopy cover was only 5% percent in the "Conventional Grade" areas of the mine site (Data from Cook, 2007).

Succession: From bare ground to forest

When land is disturbed in a manner 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 invade 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 within several years by other kinds of plant communities, including forest trees.

When soil and vegetation conditions are favorable for trees, fast-growing short-lived (early-successional) trees

like 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 like 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 as a 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 following disturbance, while slower-growing hardwoods may require 50-60 years or longer (see photo 3).

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-successional species to invade and eventually dominate a site (see Box 2). Arrested succession also occurs in areas where high deer or rodent populations consume or destroy tree seedlings.

What factors affect succession on a mine site?

Rooting medium quality: 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>7) or too low (pH<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 establish 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 invasion 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.

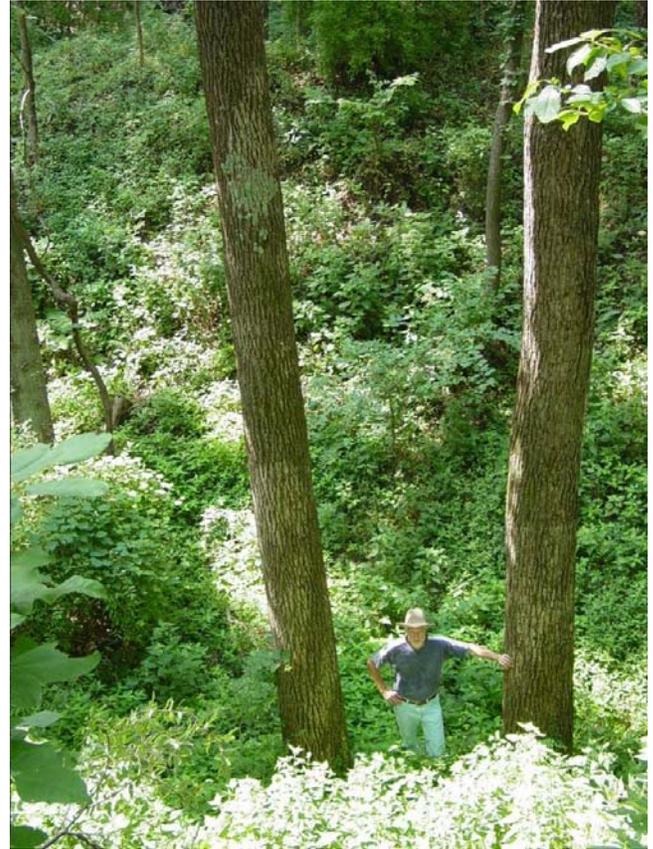


Photo 3. These 55-year-old black walnut trees were planted and grew on spoil banks in Pike County, Indiana (Photo by R. Rathfon).

Box 2: “Arrested Succession”



Photo 4. Black locust and grass vegetation were planted on this Garrett County, Maryland, coal surface mine in 1990. As a result, the development of natural forest community through natural succession has been delayed, a condition known as “arrested succession.” (Photo by Mike Hiscar, 2006).

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 (see Photo 4).

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 ground cover seeding mix. This practice produced thick vegetation that easily satisfied bond release requirements of those times. But within 10 years after planting, most black locust trees become infested by a tiny insect known as the locust borer which causes them to lose vigor, and they break down to a shrub-like form. Because the black locust trees’ sparse canopy and nitrogen-fixing capability allows the groundcover grasses to persist, the thick herbaceous cover under the black locust remains intact, preventing the invasion 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.

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 groundcover 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 groundcovers also remove water and nutrients from the soil rapidly, leaving fewer of these essential resources for the slower-growing trees. These groundcovers also attract deer, which can consume the tree seedlings, and they provide cover for small rodents which can gnaw on planted seedlings.

A mixture of tree species: Natural forests in the Appalachians 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.

- **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, 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 occurs through unassisted natural succession.

Box 3. Making post-reclamation vegetation more diverse

Natural Appalachian forests contain hundreds of plant species. Replacing all of these species through re-planting 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 2001, 2002). In 1992, and then again in 1999, they documented the species present on 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 1972-77 sites which had been reclaimed with aggressive groundcovers, 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 those woody species with small seeds that can be carried by wind and birds, including red maple and sweet birch. While most native forest species were present, some understory species such as trillium, wintergreen, and serviceberry were not found on any of the reclaimed mines, even by 1999 despite the fact that most of these small contour mine sites were located within a few hundred yards from undisturbed forest.

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 1994). For example, at a mine site in Kentucky that was reclaimed using topsoils reclaimed from the adjacent natural forest, 63 species from the natural forest donor site were found on the reclaimed mine site within one year after the soils were spread (Hall 2007). Some important points must be considered when implementing this treatment:

- Native forest soil aids succession most effectively when moved directly from the mining area to the reclamation area. Soil storage prior to re-spreading 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 groundcovers, 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. Careful inspection of the source site prior to mining and keeping soil moving machinery clean are precautions needed 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.

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, early-successional trees and shrubs should only be planted 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 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 further from unmined forests (see Box 3).

What reclamation practices aid establishment of forest by accelerating natural succession?

Reforestation researchers have developed the Forestry Reclamation Approach (FRA) that, when implemented properly, can accelerate natural succession on reclaimed mine sites, aiding formation of healthy, diverse hardwood forests (see Burger and others 2005). 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 comprised of topsoil, weathered sandstone, and/or the best available material.
2. Loosely grade the topsoil or topsoil substitute established in step one to create a non-compacted growth medium.
3. Use ground covers 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.

The FRA accelerates natural succession by creating conditions similar to those where native forests thrive.

Conclusion

Landowners and mine operators are increasingly choosing forest as the postmining land use. Compared to conventional reclamation practices, reclamation using the Forestry Reclamation Approach (FRA) allows more planted seedlings to survive and more species from the surrounding forest to invade the reclaimed mine site. Agencies in the ARRI States allow both planted trees that survive and invading trees 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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