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TREE-COMPATIBLE GROUND COVERS FOR REFORESTATION AND EROSION CONTROL

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Introduction

Productive native forests create economic value for landowners, produce raw materials for wood-based products, and provide benefits such as watershed control, water quality protection, carbon storage, wildlife habitat, and native plant diversity. Owners of lands mined for coal in Appalachia are increasingly interested in assuring that productive forests are restored after mining.

Sediment control is essential to coal mine reclamation under the Surface Mining Control and Reclamation Act (SMCRA). Here, we describe how mining firms can achieve good tree survival and restore forest productivity by using tree-compatible ground covers, when necessary, to control erosion and meet ground cover standards.

The Forestry Reclamation Approach (FRA)

The FRA is a method for reclaiming coal-mined land to forest under SMCRA (see Burger and others, 2005). The FRA differs from past reclamation practices that used agricultural grasses and legumes such as K-31 tall fescue and red clover to create dense vegetative cover. Thick, vigorous agricultural grasses and legumes are necessary for postmining land uses such as hayland/pasture, but grasses and legumes are used only as needed for erosion control when reclaiming lands for forestry. For forestry, native herbaceous and woody ground cover is preferred because it seldom hinders tree survival and growth.

The FRA has 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.

This publication deals with the FRA's 3rd step; it describes methods for establishing ground cover vegetation to control erosion without hindering survival and growth of planted trees. Those methods include establishing soil conditions to encourage native, volunteer ground cover, and, when necessary, seeding grasses and legumes that will provide minimal competition with growing trees.

FRA Reclamation Controls Erosion

FRA steps 1 and 2, selection and placement procedures for mine soils that promote tree survival and growth, reduce the need for sowing agricultural grasses and legumes for erosion control. Mine soils with good chemical and physical properties for native trees are also good for native herbaceous plants, microbes, and soil animals.

When suitable mine soil is used, a variety of native plants often establish and provide nearly complete ground cover within several years (Angel and others 2006). High diversity often occurs when native topsoil is included in the mine soil (Wade 1989; Holl and others, 2001; Hall and others, 2009). On an eastern Kentucky area with three types of mine soils planted with trees but not sown with ground cover, Angel and others found that after 4 years, brown weathered sandstone had 79% cover made up of 69 volunteer species including 16 trees while gray unweathered sandstone had 4% cover made up of 18 volunteer species including only one tree species -- black locust (unpublished data). This example shows how native vegetation responds to different topsoil substitutes, and that little or no agricultural grasses and legumes are needed for ground cover when the FRA is used on favorable materials.

Figure 1. Ground cover vegetation on coal mine sites.

Upper left: A tree-compatible ground cover in mid-summer, about 3 months after planting. The cover is sparse but planted trees are able to survive and grow, and native plants can seed in and become established.

Lower left: A grass-dominated ground cover that is typical of conventional grassland reclamation 3 years after planting. The site is fully covered but the tree is growing at less than half its potential and is exposed to predation.

Top right: A tree-compatible ground cover also 3 years after planting on a site that is also fully covered. In this photo, at least half the cover is made up of native plants including trees that seeded in via wind and wildlife. Trees are growing faster because the cover is less competitive.

FRA step 2 leaves the surface soil looser and rougher than conventional grading (see Sweigard and others 2007). Loose spoil allows more water infiltration, so more rainwater enters the soil where it can be used by growing plants and less rainfall runs off the surface, limiting the amount of eroded soil; the soil that is carried by rainfall runoff often moves only short distances into depressions in the rough surfaces. Thus, when the soil surface is left rough and uncompacted, erosion can often be controlled without establishing dense ground cover vegetation.

Natural processes can establish ground cover readily when soil conditions are favorable for reforestation: uncompacted, with a rough surface; constructed from topsoil and/or weathered brown sandstones, either alone or mixed with overburden; and with pH in the range of 5.5 – 6.5. On steep slopes, on areas far from native seed sources within large mining operations, and in states with specific ground cover standards, grasses and legumes will need to be sown even when using the FRA.

New Ground Cover Regulations

Although each State has different regulations, federal regulations do not require establishment of ground cover where trees are planted using the FRA if tree establishment is successful, the postmining land use is achieved, and erosion and off-site sedimentation are controlled (Federal Register, 2007). Tennessee and Virginia have modified their ground cover requirements for FRA reclamation from set standards (80 and 90% cover, respectively) to ground cover as needed to control erosion. These changes recognize that the FRA reclamation reduces runoff and erosion on most mine sites, compared to traditional reclamation practices that compact the soil, and that aggressive ground covers inhibit tree seedling survival and forest productivity.

Tree-Compatible Ground Cover

Using tree-compatible ground cover with the FRA differs from the “grassland reclamation approach” used in past years to establish both hayland-pasture and unmanaged forest. The grassland reclamation approach uses fast-growing agricultural grasses and legumes to achieve rapid and complete ground cover. In contrast, FRA reclamation uses “tree-compatible” ground cover to minimize competition with tree seedlings. To establish tree-compatible ground cover:

- use less-competitive ground cover species,
- use lower seeding rates,
- use less nitrogen (N) fertilizer, and
- accept a less-dense herbaceous ground cover in the first few years after seeding.

The result will be a lower-growing, less vigorous, sparse ground cover that allows planted tree seedlings to survive and grow, and allows more recruitment of volunteer plants (Figure 1). Use of tree-compatible ground cover will achieve timely bond release on soils that are properly prepared for reforestation.

FRA seeding and fertilization rates, Table 1, are presented as general guidance. Because climate, soil conditions, and regulatory policies vary among states, and because state and federal regulatory policies change with time, the rates of Table 1 should not be considered a rigid recipe or prescription. We encourage mining firms to consider the guidance of Table 1, site conditions, and local regulatory policies when deciding ground cover seeding rates.

Instead of the high N and low Phosphorus (P) used for grassland reclamation, FRA reclamation uses low N to reduce the vigor of early-growing grasses and high P to nourish trees for the long term. The Table 1 fertilization rate is adequate to establish seeded ground cover; as the legumes mature, they convert N from the atmosphere to plant-available forms.

Generally, the three perennial grasses and both legumes listed in Table 1 would be seeded, along with one of the annual grasses. Because foxtail millet produces more organic material than annual rye, some agencies and companies may prefer it to annual rye, especially on steep slopes. Foxtail millet, however, is considered to be an invasive species and is not recommended for Tennessee (TEPPC 2008). Other disadvantages of foxtail millet, relative to annual rye, are that it produces large amounts of vegetative cover that can inhibit native vegetation recruitment during its first year. It also produces seed grains and cover that can attract animals such as rodents and deer that can damage the tree seedlings.

We have found the rates of Table 1 to be adequate for establishing FRA ground cover on a wide range of mine spoil materials where pH is greater than 5, but other seeding strategies are also possible. For example, in Tennessee ground cover mixes have been seeded that rely on native warm-season grasses to establish perennial cover. These species take 2 years to establish, so they are seeded with an annual such as annual rye or millet. Shorter-statured species (see Table 2) are recommended for this use, as tall species such as switchgrass can be expected to compete with the tree seedlings (Rizza and others 2007).

Table 1. Example of a seeding and fertilizer application for FRA reclamation on mine sites where soil conditions are favorable for forest vegetation (pH between 5.0 and 6.5). These rates are intended to achieve >80% ground cover after 2 years, although species and rates may differ based on local conditions. Before seeding, mining firms are encouraged to check with the SMCRA regulatory authority.

Species *	Rate (lbs/acre)
Perennial Grasses:	
perennial ryegrass	10
orchardgrass (steep slopes only)	5
timothy	5
Annual Grasses	
annual ryegrass, or	5
foxtail millet **	10
Legumes (with inoculant):	
birdsfoot trefoil (steep slopes only)	5
ladino or white clover	3
Fertilizer: ***	
Nitrogen (N)	50-75
phosphorus (as P)	80-100
(as P_2O_5)	180-230

* For more detail on each species, see Skousen and Zipper (2009).

** Foxtail millet can substitute for annual rye in late spring / early summer seedings.

*** Can be achieved by applying 400 lbs/acre di-ammonium phosphate, by blending 200 lbs/acre concentrated super phosphate (0-60-0) with 300 lbs/acre 19-19-19 fertilizer, or with other fertilizer blends.

Using tree-compatible ground cover helps establish forested postmining land uses in several ways:

- The lower-growing tree-compatible species allow more sunlight to reach the tree seedlings.
- Tree-compatible species withdraw water and nutrients from the soil more slowly than faster-growing grasses and legumes, leaving more of these essential resources for the planted trees.
- Tree-compatible species do not cover the ground as rapidly or completely, allowing more of the seeds that are carried to the site by wind and wildlife to land on the soil surface, germinate, and become established. In Appalachian mining areas, most of these seeds are generally of native forest species.
- Tree-compatible ground cover allows rapid establishment and growth of native trees which minimizes the invasion of troublesome exotic species such as multiflora rose and autumn olive.
- Tree-compatible species are less attractive to animals such as deer and rodents that may damage tree seedlings through browsing or other means.

Table 2. Short-statured native warm-season grasses (NWSG) that have been seeded* with annual grasses and hydromulch to establish tree-compatible ground cover successfully in Tennessee.

Common name	Botanical name
little bluestem	*Schizachyrium scoparium*
side oats grama	*Bouteloua curtipendula*
eastern gamagrass	*Tripsacum dactyloides*
broomsedge bluestem	*Andropogon virginicus*
Indian grass	*Sorghastrum nutans*

* typical rates: 8-10 lbs. total NWSG seed / acre

Revegetation using the FRA is typically done in two steps: 1) planting bare-root tree seedlings, and 2) hydroseeding ground cover seeds, fertilizer, mulch, and lime if needed. Because herbaceous ground cover often competes with the trees, reducing their survival and growth, we recommend that whenever possible the trees should be planted first in late winter, followed by hydroseeding in the following spring, or even in the following fall if allowed by the regulatory authority. Hydroseeding over planted seedlings in the spring should be done prior to leaf formation by the trees, while fall hydroseeding over planted seedlings should be delayed until after tree leaves change color so as to avoid the possibility of seedling damage. Planting trees in established ground cover can reduce seedling survival, especially if the young seedlings experience drought conditions.

If an area is ready for reclamation after the tree planting period ends in mid-spring and the regulatory authority or mining firm believes ground cover is needed before the next tree-planting season, the best option for reforestation is to seed an annual grass such as annual ryegrass or foxtail millet on that area. This annual vegetation will become a dead standing crop by the next tree planting season and will not interfere with the planted trees. In fact, these dead plant materials can be an asset to reforestation as they will aid recycling of fertilizer nutrients and help protect the soil surface from erosion. Having this plant material on-site in the fall will also aid in "catching" wind-blown seeds from surrounding areas. If soil conditions are favorable and good natural recruitment of native plants occurs, such sites may be able to meet regulatory ground cover requirements without overseeding. A mining firm using this strategy should confer with the regulatory authority to determine the need for overseeding and its timing. In some cases only spot overseeding on steeper slopes may be necessary.

When allowed by regulatory authorities, miners should avoid fall seeding followed by tree planting during that winter, as this practice will usually produce ground cover that is too competitive the following spring.

Should the Mine Site be Fertilized?

Growing trees require essential nutrients in adequate quantities. Weathering overburden releases calcium, magnesium, potassium, sulfur, and many micronutrients, but N and P are often lacking in mine overburden. Successful mine reforestation requires that N and P be supplied in sufficient quantities to support tree growth.

If the mine soil used for reforestation incorporates native topsoil in amounts similar to the unmined forests, that topsoil will usually carry sufficient N and P to support tree growth. The term "topsoil," as used here, means all soil materials that can be removed easily by a dozer, including stumps, roots, and woody debris left behind after timber removal. If topsoil is used as a substitute for fertilization, it is essential that organic materials from the forest soil surface be included because the surface is the most nutrient rich portion of the forest topsoil. The surface materials also include viable seed, so use of fresh topsoil for reclamation will encourage natural revegetation.

If topsoil is *not* used to restore the surface of a mine site where the miner is relying on natural processes for ground cover, the site should be fertilized using the rates in Table 1. Such fertilizer can be applied by a hydroseeder either just before planting seedlings or after planting when the seedlings are dormant, or broadcast as pelletized forms during any season.

Decisions regarding fertilization should be made in consultation with the regulatory authority.

Should a Soil Test be Performed?

If regulators require a soil test or if soil chemistry is not known, a soil test should be performed. However, miners reclaiming lands for forestry should be wary of soil test results not targeted for mining and forestry. Most soil testing recommendations are well suited for farms, golf courses, and homeowners that use plants with nutrient needs that are different from those of planted trees. Soil test N recommendations will generally exceed desirable levels for FRA ground cover, and P recommendations, although adequate for short-lived crops, will often be inadequate for forest trees' long-term nutrition needs. Fertilizer rates of Table 1 are tailored to FRA ground cover and tree requirements and are suitable for most mine sites.

Unless acid-forming materials are present, liming is generally not needed for FRA reclamation. Soil test lime recommendations are intended to achieve the near-neutral pH's preferred by crops and grasses, but FRA ground cover species do well in the 5.5-to-6.5 pH range preferred by most Appalachian hardwood trees. If soil pH is expected to stabilize at less than 5, lime should be applied to adjust pH to the 5.5-to-6.5 range.

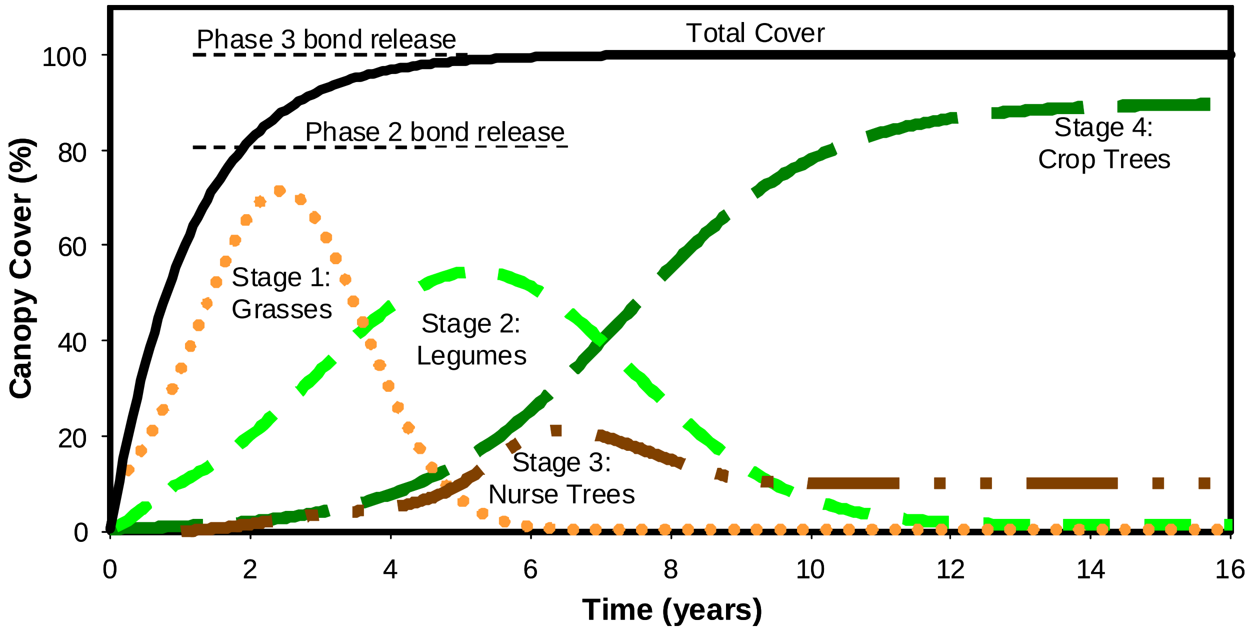

Figure 2. This figure represents how vegetative cover changes through time when FRA reclamation is used. All four vegetation types are sown or planted during reclamation, but each type is dominant at a different stages.

FRA Reclamation Encourages Ecological Succession

Succession is a term used to describe natural changes in plant community composition over time (see Groninger and others 2007). Figure 2 represents how the vegetation mix established by FRA reclamation changes through time. Four vegetation types are established during reclamation but they grow at different rates and flourish, or dominate, at different times.

Vegetation established by FRA reclamation is a combination of planted and volunteer herbaceous species, nurse/wildlife trees, and crop trees. As represented by "total cover" in Figure 2, FRA reclamation is designed to provide at least 80% cover by the end of the 2nd growing season and to approach 100% cover by the 5th growing season.

Four stages of cover development occur (Figure 2).

- *Stage 1:* Grasses dominate and provide most of the cover. The slow growing, bunch-forming grasses of Table 1 will be sparse at first but will produce more ground cover during the second and third years. When most of the fertilizer N has been utilized, the grasses thin, creating openings for native plants that are carried onto the site as seed by birds, other wildlife, and wind.
- *Stage 2.* Legumes and native plants dominate and provide most of the cover. The legumes add N to the soil and are less competitive than grasses. The herbaceous legumes persist until they are shaded out by the trees.
- *Stage 3:* Fast-growing nurse/wildlife trees make up 10 to 20% of the total trees planted in the FRA. Some of these trees fix N from the atmosphere and all provide habitat for wildlife and canopy cover for erosion control. Those nurse trees that grow edible fruits and seeds attract seed-carrying birds and other wildlife, thus aiding establishment of plant species from unmined areas.
- *Stage 4:* By the time the trees close canopy (i.e., when the tree tops grow together), the crop trees dominate and provide most of the cover. Fallen leaves and other organic litter accumulate and begin to decompose, providing additional fertility for the trees. Because much of the ground is shaded by trees, the non-tree vegetation closer to the ground ("understory") remains sparse.

Because the hydroseeded ground cover remains sparse during the first few years, native plants including forest trees are able to seed in, germinate, and emerge. Thus, the plant community is comprised of many species in addition to those seeded and planted by the mining firm. Rapid canopy closure by native species reduces invasion of troublesome exotic species such as autumn olive and multiflora rose. Over time, the plant community develops naturally to become more like the region's native forest.

The guidelines of Table 1 are intended to establish vegetation that can aid in controlling erosion, allow recruitment by native plant species for increased diversity, fix N from the atmosphere, create wildlife habitat, minimize invasion of exotic species, and develop into a productive forest dominated by native hardwoods. Experience has shown that many native tree species volunteer by seeds brought in by wind and wildlife, which can help the mining firm satisfy regulatory requirements if the permit describes those species as components of the postmining land use.

How FRA Ground Cover Looks and Works

"Tree-compatible" FRA ground cover (Table 1) is designed to be less competitive than grassland-reclamation ground cover. The FRA ground cover looks short and sparse on a rough-graded surface, especially during its first year (Figure 1). This is by design. Some miners and inspectors who are familiar with grassland reclamation may have trouble, at first, accepting the "look" of the FRA reclamation. What is important, however, is not the look but how it works. Use of native cover or sown, tree-compatible ground cover within the FRA allows operators to establish a productive forest while meeting regulatory standards.

When reforesting non-mined sites, foresters usually kill competitive grasses and weeds with herbicides as a standard practice before planting trees. Traditional mine reclamation has taken the opposite approach, sowing competitive grasses and legumes to the detriment of the planted trees. Reclamation procedures for establishing forests differ from those for establishing hayland-pasture and other uses that require agricultural grasses. The two reclamation approaches look different because they are intended to achieve different purposes.

Summary

The Forestry Reclamation Approach (FRA) is becoming more popular with mine operators and landowners as a way of reducing reclamation costs while improving the postmining land's value as productive forest. The FRA uses a slow growing, non-competitive, tree-compatible ground cover. Such a ground cover will have a sparse "look" for the first several years, but – when used within the FRA – such ground cover controls erosion while encouraging recruitment by native forest species and allowing planted trees to survive and grow. Because state regulations vary, mine operators are encouraged to confer with regulatory authorities when developing ground cover seeding plans.

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