Establishing Ground Cover for Forested Post-Mining Land Uses

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Introduction

Productive native forests can create economic value for the landowner, while providing landscape benefits such as watershed control, water quality protection, carbon sequestration, and native plant biodiversity. In the highly forested Appalachian region, owners of lands mined for coal are increasingly interested in assuring that productive forests are restored on the land after mining. However, few Appalachian coal mining operations have successfully established productive forests with species similar to the native forest as a post-mining land use.

Revegetation with herbaceous species to control erosion is essential to mine reclamation under the Surface Mining Control and Reclamation Act (SMCRA). This publication describes a revegetation practice that can be used by mining operators seeking to establish productive forests through reclamation. This revegetation method is intended for use within a "system" of reclamation practices known as the Forestry Reclamation Approach (FRA).

The Forestry Reclamation Approach (FRA)

The FRA differs from reclamation practices that have been used successfully for many years by the mining industry to establish agricultural grasses (such as Kentucky 31 tall fescue) and aggressive legumes (such as red clover) on mine sites, so as to prepare the land to support hayland-pasture, grazing land, and even unmanaged forest land post-mining land uses. The FRA is described by Burger and others (2005; see also Burger and Zipper, 2002). The FRA has five steps:

1. Create a suitable rooting medium for good tree growth that is no less than four 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 1 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 third step, and describes how to establish erosion control ground cover without compromising the survival and growth of planted native hardwood trees.

Revegetation for the FRA

The revegetation approach described in this publication differs from the "grassland reclamation approach" that has been applied commonly in past years by coal-mining reclaiming lands to support grazing, hayland-pasture, and unmanaged forest postmining land uses, with full support by SMCRA regulatory authorities. While the grassland reclamation approach emphasizes fast-growing agricultural grasses and legumes, intended to achieve rapid and complete groundcover, the FRA emphasizes establishment of a "tree compatible" groundcover. In order to establish a tree-compatible groundcover, we recommend that mining operators seed in a manner that differs from common grassland reclamation practices, by:

1. using grass and legume species than are less competitive,
2. using lower seeding rates,
3. using less nitrogen fertilizer, and
4. accepting a lower herbaceous groundcover in the first few years after seeding.

The result will be a lower-growing, less vigorous, sparse, grass and legume ground cover that allows planted seedlings to survive and grow and more invasion by plant species from nearby forested areas while achieving a more complete groundcover over time.

A list of recommended groundcover species, seeding rates, and fertilizer rates, is shown as Table 1. The grass and legume species are selected to be slow and low growing, to be tolerant of low fertility and pH, and to grow in bunches rather than as a continuous cover. Inoculants for the legume species should also be included in the planting mix, so as to assure that the legume species are able to convert ("fix") atmospheric nitrogen to plant-available forms. The seeding rates are lower than those used in grassland reclamation approaches so that openings are left on the surface for invasion by native herbaceous plants and trees. Lower nitrogen fertilizer rates are also used to minimize the height of the ground cover. Instead of high nitrogen and low phosphorus rates used for grassland reclamation, low nitrogen and high phosphorus are used in FRA reclamation to reduce the vigor of the early-growing grasses while providing more phosphorus to nourish the trees for the long term. The recommended nitrogen is adequate until the seeded legumes become established; as the legumes mature, they provide nitrogen to the soil from the atmosphere.

Using tree-compatible groundcovers, as opposed to the faster-growing agricultural grasses and legumes that are used commonly in grassland reclamation, can help mine operators achieve forested post-mining land uses successfully in several ways:

- The lower-growing tree-compatible species do not block as much sunlight that would otherwise reach the young planted seedlings.
- The slower-growing tree-compatible species do not withdraw water and nutrients from the soil as rapidly as the faster-growing grassland-reclamation species, leaving more of these essential resources for the planted trees.
- The tree-compatible species do not cover the ground as rapidly or completely as the faster-growing grassland-reclamation species, allowing more of the seeds that are carried to the site by wind and wildlife to land on the soil surface, and thus to germinate and survive. In the heavily forested Appalachian region, most of these are generally from the native forest, and they often include native forest trees.

Table 1. Recommended grass and legume species and rates of application for the FRA. Source: Burger and Zipper, 2002.

Species	***Application Rate* (lbs/acre)**
Perenial Grasses:	
perennial ryegrass	10
orchardgrass (steep slopes only)	5
timothy	5
Annual Grasses	
foxtail millet (spring seeding only)	5
annual rye grass (fall seeding only)	20
Legumes (with inoculant):	
birdsfoot trefoil	5
ladino or white clover	3
*Fertilizer * :*	
nitrogen	50-75
phosphorus (as P)	80-100
(as P_2O_5)	180-230

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

Revegetation using the FRA is typically done in two steps: (1) tree planting using bare-root seedlings, and (2) hydroseeding ground cover mix that includes grass and legume seed, fertilizer, mulch, and lime if needed. The herbaceous ground cover is required for erosion control, but it invariably competes with the trees and can reduce tree survival and growth. Therefore, we recommend that whenever possible, the trees should be planted first in late winter, followed by hydroseeding the following spring, or even in the following fall if allowable by regulatory authorities. Planting trees in established ground cover can reduce seedling survival, especially if the young seedlings experience drought or near-drought conditions.

Lower rates of groundcover can be used when Step 2 of the FRA approach is used (see Sweigard and others, 2007). Step 2 encourages less compaction of the rooting medium, which allows for greater infiltration and less need for the groundcover to control erosion. Research has shown that loose spoil allows greater rates of water infiltration, which means that rainfall causes less surface runoff and soil movement. The data in the figure below are from a study conducted on an active coal surface mine in eastern Kentucky (Torbert and Burger, 1994). Areas of the site were graded and tracked-in using practices that were conventional at that time; some areas received “moderate grading” (2 passes with a D-10 dozer), while others received “intensive grading” (3 dozer passes plus tracking), and a portion of the graded areas were “ripped” (i.e.,disturbed to a depth of about 4 feet by a heavy-steel single-shank ripper pulled by a D-10 dozer). The data show that the moderate grading reduced soil loss compared to intensive grading, while the rough surface created by ripping this compacted mine site nearly eliminated soil loss. The amount of ground cover (80%+) was essentially the same on all treatments showing that a heavily graded, tracked-in surface is not necessary for establishing ground cover. We interpret these data to indicate that roughly-graded, non-compacted mined land slows water movement, increases water infiltration for plant use, and creates depressions and void spaces that can be used by forest plants and animals to establish themselves.

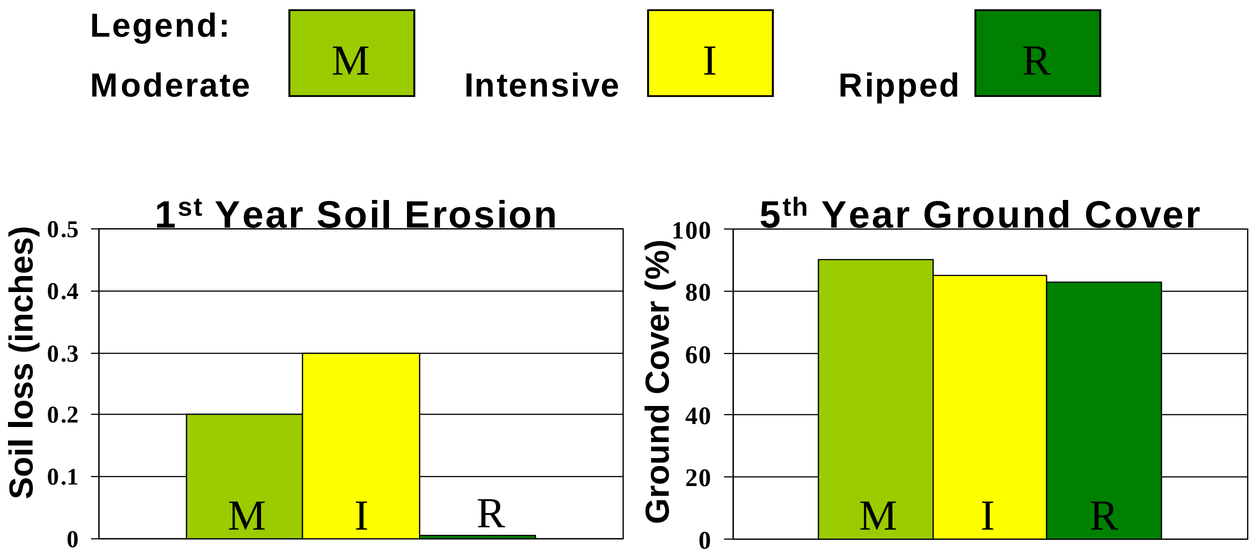

Figure 1. Mine soil density affects soil erosion. Less grading and ripping compacted mine soils reduces soil loss. Ground cover is adequate on rough graded and ripped mine soils.

FRA Revegetation Encourages Ecological Succession

Succession is a term used to describe natural changes in plant community composition over time (see Groninger and others, 2007). The graph on the next page shows how the vegetation mix on a coal-surface mine that is being restored to a forested post-mining land use changes through time. Four different types of species are sown or planted within the first year after site preparation, but they all grow at different rates and flourish, or dominate, at different times. As shown by the top bold line ("total canopy cover") of Figure 2, the revegetation mix is designed to provide a groundcover of at least 80% by the end of the second growing season, and complete groundcover (equal to or approaching 100%) by the end of the fifth growing season. The groundcover is provided by a combination of grasses, legumes, wildlife trees, and crop trees.

Four stages of plant community development occur after reclamation. Our revegetation recommendations are intended to accelerate that development which will control erosion, allow establishment of native species for increased diversity, fix nitrogen from the atmosphere, create wildlife habitat, and close the tree canopy as a productive, valuable, native hardwood forest (Fig. 1):

- Stage 1: The grasses dominate for the first 3 years and provide most of the cover for erosion control. These slow-growing, bunch-forming grasses recommended with the FRA will be sparse at first, especially during the first year. When fertilizer-applied nitrogen has been fully utilized, the grasses fade, creating openings for emergence of native plants and trees that are carried onto site as seed by birds and wind.
- Stage 2: The nitrogen-fixing legumes dominate and provide most of the cover between years 4 and 6. The legumes add nitrogen to the soil and are less competitive than grasses. The herbaceous legumes persist until they are shaded out by the trees.

- Stage 3: When using the FRA reclamation approach, fast-growing nurse/wildlife trees make up 10 to 20% of the total trees planted (see Burger and others 2005). Some of these trees continue to fix nitrogen from the atmosphere and they all provide habitat for wildlife and cover for erosion control. Those wildlife trees that grow edible fruits and seeds will attract seed-carrying birds and other wildlife to the area, thus aiding establishment of plant species from nearby unmined areas, including native forest.
- 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. At this time, a duff or litter layer has accumulated and begins to decompose at a rate that provides additional fertility for the rapidly growing trees. Because much of the ground is shaded by the trees, the non-tree vegetation closer to the ground ("understory") remains sparse. Because the sparse ground cover that was applied by the hydroseeder during reclamation remained sparse during the first few years after seeding, native plants including forest trees were able to invade the reclaimed site. Thus, the plant community at this stage is comprised of many species in addition to those that were planted. Over time, the plant community composition has become more similar to that found in the region's native forest.

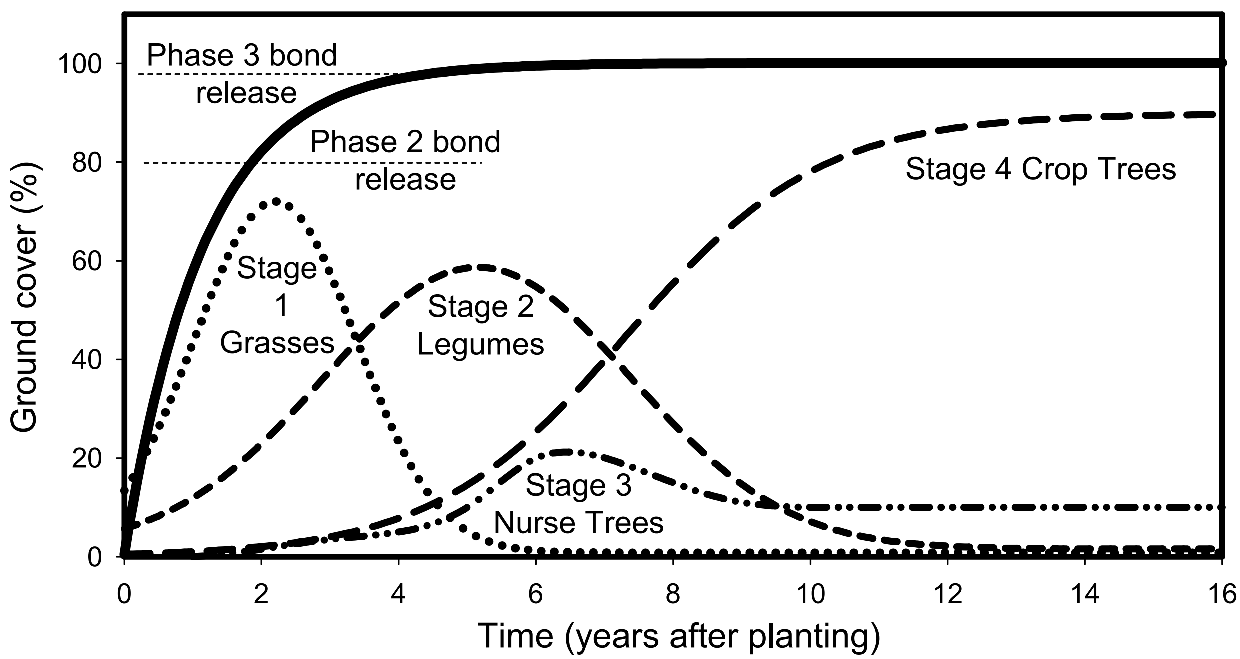

Figure 2.

Understanding the Structure (How it Looks) and the Function (How it Works) of FRA Groundcover

The FRA "tree-compatible" ground cover (Table 1) is designed to be less competitive than grassland-reclamation ground cover. The FRA cover looks short and sparse on a rough-graded surface, especially during the first year after planting. This is by design, because it allows the trees to survive and grow and encourages invasion of native vegetation. Some operators and inspectors who are used to grassland reclamation may have trouble, at first, accepting the "look" of the FRA reclamation approach. However, what is important is not the look but how it works. The FRA allows operators to establish a productive native forest while meeting regulatory performance standards. On non-mined sites. foresters as standard practice kill competitive grasses and weeds before they establish trees. On mined land we have been doing the opposite by sowing competitive non-native grasses and legumes, then planting trees and expecting them to survive and grow. That is why we need to make a clear distinction between procedures for establishing grassland vegetation, compared to procedures used to establish forestland. The two approaches look different, and they function differently as the vegetation communities develop as post-mining land uses.

In a study at the Powell River Project, Burger and co-workers demonstrated the effect of ground cover on native hardwood trees after five seasons. The planting site was prepared using FRA procedures, except that a standard grassland-reclamation ground cover mix was seeded, as per the standard revegetation practices being used by that mining firm in the early 2000s. A mix of native Appalachian tree species was planted into the grassland-reclamation groundcover, and a glyphosate herbicide was applied to some of the experimental plots during the first three years to artificially create ground-cover differences. Tree survival and growth in plots that received no herbicide treatment were compared to those plots where groundcover was controlled by spot-spraying a 3- to 4-foot circle around each planted tree seedling during each of the first three years.

A mix of native species was prescribed at 700 trees/acre (8 foot x 8 foot spacing): six crop tree species at 100 per acre, and four wildlife tree species at 25 per acre. The actual number of trees planted was 687 and 663 per acre for the no-spray and spot-spray treatments, respectively (Table 2). After five years, 415 and 419 surviving trees per acre were present. In Virginia, 400 trees/acre are needed for Phase III bond release; therefore, an adequate number of stems were present in both cases. However, crop tree survival was much greater on the spot-sprayed treatment (69%, vs. 58% for the no-spray treatment), which is an important consideration for future forest value. Spot-spraying allowed targeted crop tree survival approaching 70%, which is typical without competing ground cover on good sites.

Table 2. Crop and wildlife tree stocking (trees/acre) by species immediately after planting and after five years.

Treatment	Crop Trees						Wildlife Trees				
	White Ash	Sugar Maple	Yellow Poplar	Chestnut Oak	White Oak	N. Red Oak	Crab-apple	White Pine	Silky Dogwood	Bristly Locust	Total Stocking
	Prescribed Stocking (trees/acre)										
	100	100	100	100	100	100	25	25	25	25	700
	Original Stocking after Planting (trees/acre)										
No Spray	100	99	95	94	84	102	28	27	32	26	687
Spot Spray	84	92	94	86	78	108	31	33	28	29	663
	Stocking after 5 Years (trees/acre)										
No Spray	94	39	39	39	51	73	24	10	32	14	415
Spot Spray	73	48	45	53	70	78	9	11	26	6	419
	Survival (%)										**Ave. Crop Tree Survival**
No Spray	92	43	43	43	57b	73	84	38	100	61	58
Spot Spray	88	52	47	65	85a	74	26	28	92	20	69

The growth of most tree species was greatly affected by the competitive ground cover (Fig. 3). Because all experimental areas were prepared using similar spoil materials and with similar grading practices and planted with similar species mixes, differences in tree growth were primarily due to differences in ground cover competition. Overall, spraying with herbicides to reduce the competitive ground cover more than doubled the size of most of these hardwood species.

The results of this study demonstrate clearly that groundcovers affect survival and growth of planted trees. We recommend that the FRA revegetation approach be used to establish a groundcover that is compatible with growing trees. Ground cover control using herbicides should not be necessary if the FRA revegetation approach is used.

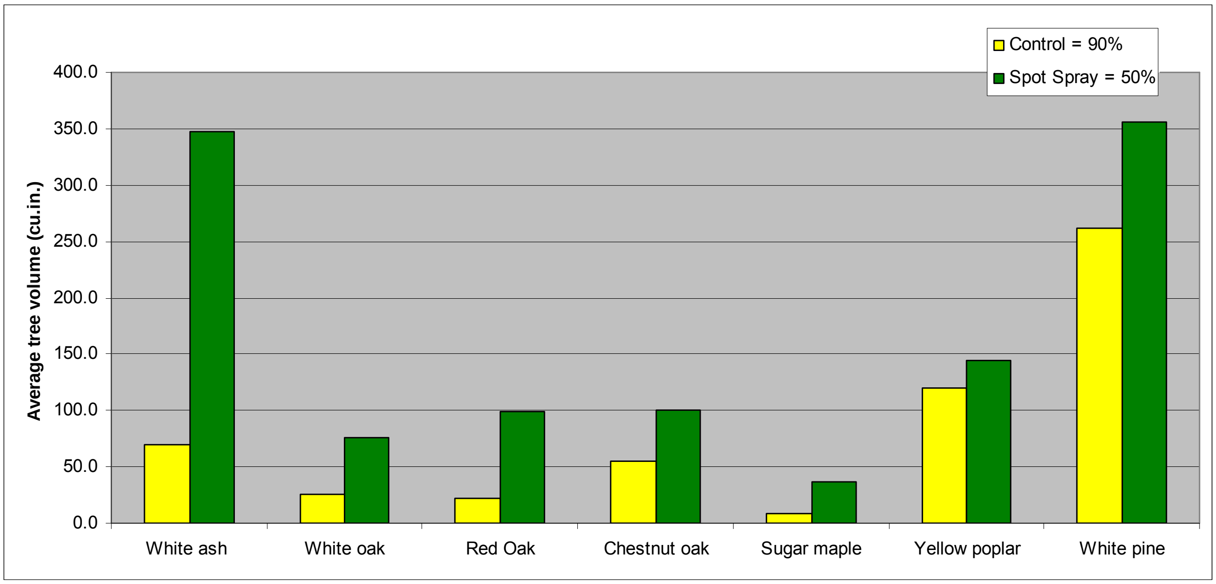

Figure 3. Effect of ground cover control with herbicides on TREE VOLUME after five years. Different letters indicate a significant difference ($\alpha = 0.10$).

Conclusion

The Forestry Reclamation Approach (FRA) is becoming more popular with mine operators and landowners as a way of reducing reclamation costs while improving forest land capability and forest value (see Burger and others, 2005). A slow-growing, non-competitive erosion control ground cover allows planted trees to survive and grow while encouraging invasion of native species. The FRA produces a sparse "look" for the first several years after reclamation compared to cover produced by common grassland reclamation approaches.

For the past 30 years it has been difficult to establish diverse, native forests on mined land because of our inadequate knowledge of reclamation procedures for trees. The good news is that the Forestry Reclamation Approach (FRA) includes new procedures specific for trees that ensures timely bond release, less cost, better mine soil quality, and productive, diverse native forests that provide the same or better products and services as before mining. Use of the FRA in the eastern U.S. is supported by federal and state regulatory authorities.

References

Burger, J.A. and C.E. Zipper. 2002. How to restore forests on surface mined lands. Virginia Cooperative Extension Publication 460-123. http://www.ext.vt.edu/pubs/mines/460-123/460-123.pdf

Burger J., D. Graves, P. Angel, V. Davis, and C. Zipper. 2005. The Forestry Reclamation Approach. U.S. Office of Surface Mining. Forest Reclamation Advisory No. 2. http://arri.osmre.gov/fra.htm

Groninger J., J. Skousen, P. Angel, C. Barton, J. Burger, and C. Zipper. Mine Reclamation Practices to Enhance Forest Development through Natural Succession. US Office of Surface Mining, ARRI Forest Reclamation Advisory No. 5. 5p. http://arri.osmre.gov/fra.htm

R. Sweigard, J. Burger, C. Zipper, J. Skousen, C. Barton, and P. Angel. 2007. Low compaction grading the enhance reforestation success on coal surface mines. ARRI Forest Reclamation Advisory No. 3. 6p. http://arri.osmre.gov/fra.htm

Torbert, J. L., and J. A. Burger. 1994. Influence of grading intensity on ground cover establishment, erosion, and tree establishment on steep slopes. p. 226-231. In: Intl. Land Reclamation and Mine Drainage Conf. Vol. 3. Reclamation and Revegetation. USDOI Bureau of Mines Special Pub. SP 06C-94.

U. S. Government Printing Office. 2003. Code of Federal Regulations, Title 30, Volume 3. Section 816.111.