

HARDWOOD REFORESTATION FOR PHASE III BOND RELEASE: NEED FOR REDUCED GROUND COVER¹

J. A. Burger², D. O. Mitchem, C. E. Zipper, and R. Williams

Abstract: During the past five years, a forestry reclamation approach has been adopted by some coal companies. To ensure adequate tree survival and growth, competition from erosion control groundcovers must be reduced. The purpose of this study was to test the effect of herbaceous groundcover on reforestation success after five years for Phase III bond release. An herbaceous ground cover mix consisting of orchard grass, redtop, birdsfoot trefoil, and red clover was hydroseeded on reclaimed mined land in Wise County, Virginia. The mine soil was a mix of weathered sandstone and unweathered siltstone that was lightly graded and left uncompacted. The following winter, 100 each of white oak, red oak, sugar maple, white ash, and tulip poplar (“crop trees”) were mixed and planted per acre. An additional wildlife mix of crab apple, dogwood, white pine, and bristly locust was planted at a combined rate of 100 trees/ac. Three half-acre treatment plots were spot-sprayed with Roundup herbicide (3-ft circle around each tree, achieving 70% groundcover (reduced cover) for three years, and three half-acre treatments were left untreated (full cover). After five years, average crop-tree survival rates were 58% and 69% on the untreated plots (full cover) and sprayed (reduced cover) plots, respectively. The actual numbers of trees planted by the professional tree planting crew were 687 and 663 per acre for the full cover and reduced cover plots, respectively. After five years, 415 and 419 surviving trees per acre remained which exceeded the minimum number needed for bond release in Virginia. Tree growth on the full cover plots was suppressed, but growth was excellent on reduced cover plots compared to that expected for these species on undisturbed sites. Reduced cover doubled the growth rate for most species except for red oak, which grew three times faster, and white ash, which grew four times faster when released from some of the ground cover competition. All species in this mix appeared to be compatible and should grow into a valuable tree stand. This study shows that this reforestation approach is quite viable for restoring native hardwoods, except that commonly used ground cover could compromise reforestation success.

Additional Key Words: reforestation, tree planting, herbicides, reclamation.

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Introduction

Purpose of Study

Forest landowners in the Appalachian region of the United States who have significant amounts of reclaimed mined land are increasingly interested in restoring the native forest. Productive native forests have economic value and provide landscape benefits such as watershed control, water quality protection, carbon sequestration, and native plant biodiversity. However, few Appalachian coal mining operations have successfully established productive, commercially-valuable forests with species compositions similar to the native forest.

One of the greatest impediments to reforestation of native species is competition from herbaceous ground cover required by some regulatory agencies for erosion control. In this study we tested the survival and growth of a native hardwood mix for five years at two levels of ground cover: full cover and reduced cover (approximately 70%). Reduced cover was achieved by spraying herbicide around each tree for the first three years after planting. All other conditions were optimum for good survival and growth. This paper updates and finalizes preliminary results presented at an earlier meeting of the American Society of Mining and Reclamation (Burger et al., 2005).

Background

During a 40-year period prior to the implementation of the Surface Mining Control and Reclamation Act (SMCRA), native hardwood trees were often planted on surface mine spoils in the Appalachian and Midwestern Coalfield Regions. Most trees were planted directly into the loose, cast overburden and suffered little competition from other vegetation. The quality of the spoils was highly variable, but when conditions were right most species grew well and some exceeded the growth of trees on adjacent non-mined sites (Ashby 1987; Rodrigue, 2002). With the implementation of the SMCRA in 1978, the condition of reclaimed surface mines changed dramatically. Surface mines are larger and deeper now, and mountaintop removal allows mining of multiple coal seams. Unweathered overburden from deep in the geologic profile usually becomes the plant growth medium on the surface. Federal and state laws require that most mined sites be returned to approximate original contour, and that all reclaimed surfaces be seeded with erosion-control ground covers as soon as practicable. Post-SMCRA mine spoils are often heavily graded and compacted, especially on gentle slopes and flat areas. Vigorously growing, dense groundcovers are commonly sown or hydroseeded for erosion control.

Except for several early-successional woody species such as black locust, Virginia pine, and white pine, few native tree species survived and grew normally under these new conditions (Ashby and Kolar, 1998). The unweathered mine spoils had very different physical and chemical properties compared to native soils, and they were usually heavily compacted as the new landscape took shape. The erosion control ground cover, often consisting of hardy and aggressive species such as tall fescue and serotia lespedeza, quickly overtopped planted seedlings, causing poor survival and growth. As a result, during a 20-year period between 1980 and 2000, most coal operators created grasslands, wildlife habitat (grasslands with a mix of woody wildlife food plants), or unmanaged forest (ground cover grasses with a mix of black locust, pine species, and woody shrubs) rather than attempting return of the land to its original use, which in most cases was native hardwood forest. The majority of these reclaimed lands have been abandoned to natural succession and many are covered with thickets of autumn olive, black locust, and a number of other early-successional species, many of them non-native, invasive, and of no commercial value.

In the past five years, interest in restoring the native forest on mined land has resurged as landowners desire to put the land to productive use for economic reasons. As a result, some landowners and coal operators are using a Forestry Reclamation Approach (FRA). The FRA is different from the Grassland Reclamation Approach (GRA), which is commonly used to establish hayland, pasture, wildlife habitat, and unmanaged forest. The FRA is presented in full in an Appalachian Regional Reforestation Initiative Advisory (Burger et al., 2005). In a nutshell, it entails four steps: (1) selecting soils and topsoil substitutes for trees rather than for grass; (2) applying the mine soil so it remains loose and uncompacted; (3) seeding ground cover at rates that control erosion at acceptable levels without compromising tree establishment and growth; and (4) planting a silvicultural mix of valuable native tree species.

The objectives of this study were to use the four steps of this forestry reclamation approach (1) to determine if a mix of commercially-valuable, native hardwood species would meet the reclamation performance standards required by Virginia's reclamation regulations for Phase III bond release; (2) to determine if, and to what extent, tree survival and growth would respond to reduced cover (approximately 70% by spot spraying with herbicides); and (3) to evaluate the reforestation potential of this mined site in terms of its diversity, productivity, and value.

Methods and Procedures

In the spring of 2002, a 10-acre reclaimed mine site in Wise County, Virginia, owned by Penn Virginia Resource Partners Corporation and mined by Red River Coal Company, was planted to a mix of hardwood and pine species by Williams Forestry & Associates. The topsoil substitute consisted of a loosely graded mix of sandstone and shale taken from above the Taggart coal seam. These mine spoils commonly have a neutral pH and high level of fertility. During the summer prior to tree planting, the site had been reclaimed and seeded with a standard grassland ground cover mix consisting of orchard grass, timothy, redtop, birdsfoot trefoil, and red clover, which achieved 95 to 100% ground cover within the first year after seeding.

A mix of commercially-valuable native hardwood species, including white ash, red oak, white oak, chestnut oak, sugar maple, and tulip poplar, was planted on 8 x 8-foot spacing at a rate of 600 trees/acre, 100 trees/acre of each species. An additional 75 wildlife/nurse trees/acre were planted in the mix, including: 25 trees/acre each of crab apple, bristly locust, and silky dogwood. Although a commercial hardwood stand was intended, 25 trees/acre of white pine were planted to serve as a growth-rate indicator through time and to provide winter cover for wildlife; white pine is counted as a crop tree. Therefore, 625 crop trees and 75 wildlife trees/acre were planted, for a target planting rate of 700 woody stems/acre. An average expected survival rate of 70% would leave 420 crop trees and 52 wildlife trees/acre (420/52) to meet the 400 crop and 40 wildlife trees/acre (400/40) required for bond release of commercial forestland in Virginia.

Three blocks of 1/2-acre comparison plots were marked off wherein the amount of ground cover was maintained at two levels: (1) *full cover*, no herbicide was applied, and (2) *reduced cover*, a 3-foot diameter circle around the stem of each tree. RoundUp (41% active ingredient) at a rate of 2 oz/gal was sprayed twice each year for three years. Herbaceous ground cover for the control (full cover) and spot-sprayed (reduced cover) plots was estimated ocularly and averaged 95 and 70%, respectively, during the five-year study period. In October of each year, a tree count was made by species, and the height and ground-line stem diameter of each tree were measured. For a general estimate of growth, a biomass volume index was calculated by multiplying the tree height by the square of the stem diameter (d^2h). The effects of the three treatments on tree survival, height, and biomass volume were tested using a one-way ANOVA

for a randomized block design, and Fisher's LSD test was used to separate mean treatment values ($P < 0.10$) (SAS, 2001).

Results and Discussion

Stocking

The original tree count average by treatment is shown in Table 1. There were slightly fewer trees planted than the target of 700 trees/acre. The average tree counts by treatment were 687 and 663 trees/acre in the full cover and reduced cover plots, respectively. After five years, the average tree counts were 415 and 419 in the full cover and reduced cover plots, for overall survival rates of 58 and 69%, respectively. In Virginia, 400 trees/acre are needed for Phase III bond release for "unmanaged forest land;" therefore, an adequate number of stems for this post-mining land use were present in both cases. Required stocking rates for managed forest land or "commercial forestry," the goal of this study, are 400 crop trees and 40 wildlife trees/acre (400/40). The counts after five years were, 335/80 and 394/52 trees/acre for the full cover and reduced cover plots, respectively. The reduced cover plots had an overall survival rate of 69%, which nearly met the target of 400 crop trees/acre. A 70% survival rate is often achieved for hardwoods planted under a variety of conditions on both mined and non-mined land. Had the planned 700 trees/acre been planted instead of the 663 actually planted, the performance standard of 400 for commercial forestry would have been met at this rate of survival. With a survival rate of only 58%, the full cover plots did not meet the crop tree performance standard.

Table 1. Crop and wildlife tree stocking (trees/acre; each value is average stocking across three ½-ac replicate plots) by species immediately after planting and after five years.

Treatment	Crop Trees						Wildlife Trees				Total Stocking
	White Ash	Sugar Maple	Yellow Poplar	Chestnut Oak	White Oak	N. Red Oak	Crab-apple	White Pine	Silky Dogwood	Bristly Locust	
	----- Prescribed Stocking (trees/acre) -----										
	100	100	100	100	100	100	25	25	25	25	700
	----- Original Stocking after Planting (trees/acre) -----										
Full cover	100	99	95	94	84	102	28	27	32	26	687
Reduced cover	84	92	94	86	78	108	31	33	28	29	663
	----- Stocking after 5 Years (trees/acre) -----										
Full cover	94	39	39	39	51	73	24	10	32	14	415
Reduced cover	73	48	45	53	70	78	9	11	26	6	419
	----- Survival (%) -----										
Full cover	92	43	43	43b	57b	73	84	38	100	61	Ave. Crop Tree Survival 58
Reduced cover	88	52	47	65a	85a	74	26	28	92	20	69

Different letters following mean values for a species within treatment and year are different at $P < 0.1$.

Survival

White and chestnut oak survivals were higher on plots with reduced cover (Fig. 1). White oak survival rates were 57 and 85% for the full cover and reduced cover treatments, respectively, and 43 and 65%, respectively, for the chestnut oak. The reduced cover treatment had no significant effect on survival of the remaining species. White ash and red oak survived well regardless of ground cover level, meeting the goal of 70%, an average target survival rate for hardwoods on mined land. When released from some of the ground cover competition, chestnut and white oak also met the survival goal of 70%. Tulip poplar, sugar maple, and white pine all had survival rates below 50%, and reduced ground cover had no apparent effect on their survival. These species do not endure transplanting shock as well and are more sensitive to soil conditions. Survival for most species is more a function of mine spoil type and compaction than ground cover density, while ground cover competition has a greater influence on growth, as shown below. The differences in survival among species concur with those reported by Vogel (1973), Washburn et al. (1993), Chaney et al. (1995), Ashby and Kolar (1998), and Kost et al. (1998), and they concur with many anecdotal field observations. That is, white ash survives well across

a range of sites, while oaks are more site-specific and do best on loose, uncompacted, moderately acid spoils (Burger et al. 2002). However Larson et al. (1995) reported that white ash survived poorly (45%) on sites seeded the previous fall compared to those seeded at time of tree planting (85%). Overall, grasses reduced survival and growth of all species in their study. Tulip poplar and sugar maple are especially site-sensitive and typically survive at rates below 50% regardless of site quality (Auch et al. 2005). White pine usually survives well in competitive environments on moderately acid sites, and its poor survival in this case can be attributed to the alkaline mine soils of this mined area.

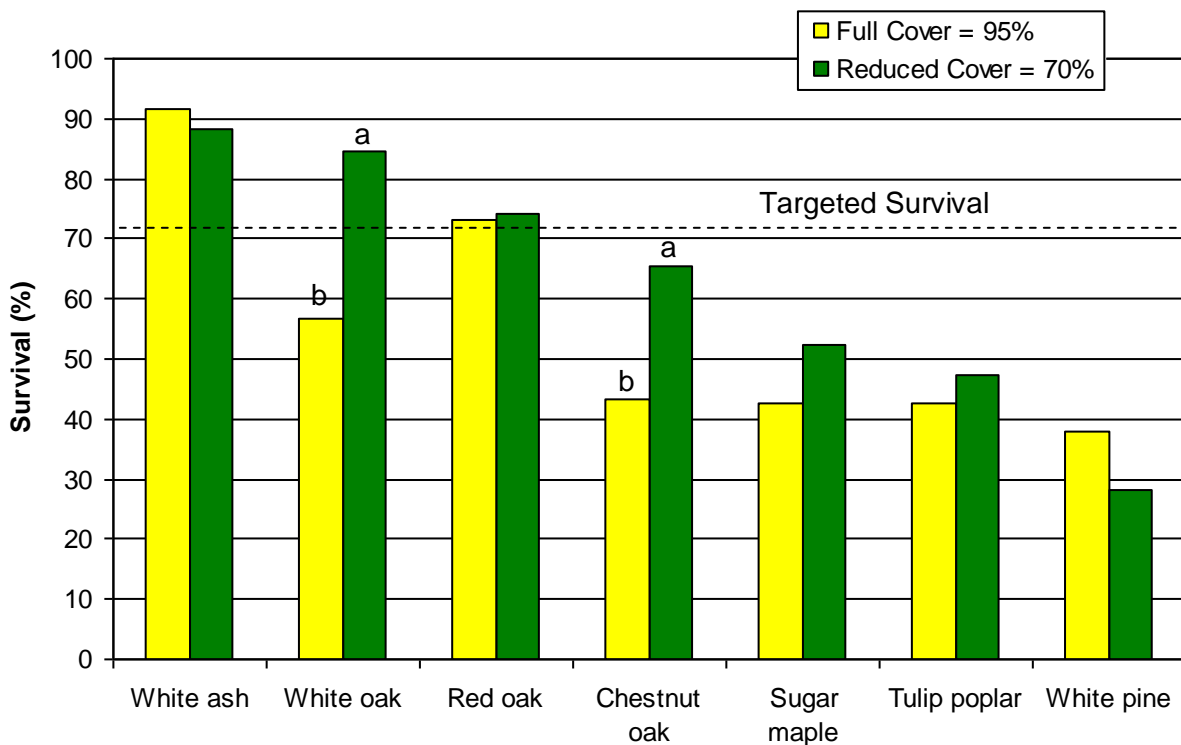


Figure 1. Effect of different levels of ground cover on mean SURVIVAL five years after establishment. Different letters indicate a significant difference ($\alpha = 0.10$).

Growth

The biomass of white ash growing in plots with reduced cover was nearly four times that in full cover plots (Fig. 2). This dramatic growth response of early-successional hardwoods, when free of herbaceous competition, was reported by other researchers working on mined land reforestation (Vogel, 1973). In a recent study on mined land in Tennessee, Rizza et al. (2007)

reported a disproportionate increase in growth of 2-yr-old eastern redbud and Virginia pine, compared to N. red oak and sugar maple, with decreasing ground cover. Most important, but less dramatic, is that all species on average doubled their biomass growth when ground cover was reduced from full cover to 70%. This is important for several reasons: (1) fast, stress-free, early growth increases the likelihood that trees will survive and meet performance standards for bond release; (2) trees will suffer less damage and stress from rodent and deer browse; (3) fast early growth by planted trees reduces the likelihood that invasive trees and shrubs will obtain a foothold; and (4) the planted trees will remain as part of the stand over the long term.

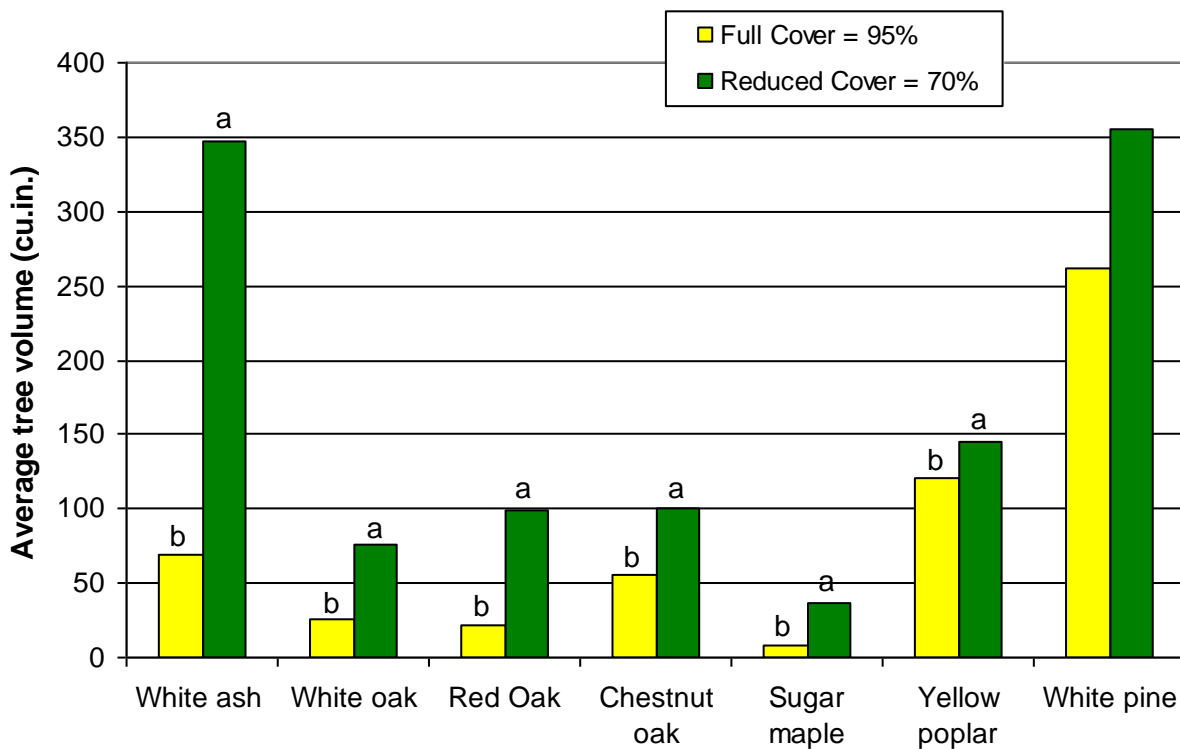


Figure 2. Effect of different levels of ground cover on mean TREE VOLUME five years after establishment. Different letters indicate a significant difference ($\alpha = 0.10$).

Tree Growth Over Time

Ground cover control is more critical for some species than others due to each species' growth habit. A generalization is that early-successional pioneer species like white ash and white pine have a progressive shoot-growth habit; that is, their shoots extend incrementally each year after planting. Many mid- to late-successional species like the oaks and sugar maple have a habit of extending their root systems first at the expense of shoot growth, often dying back to

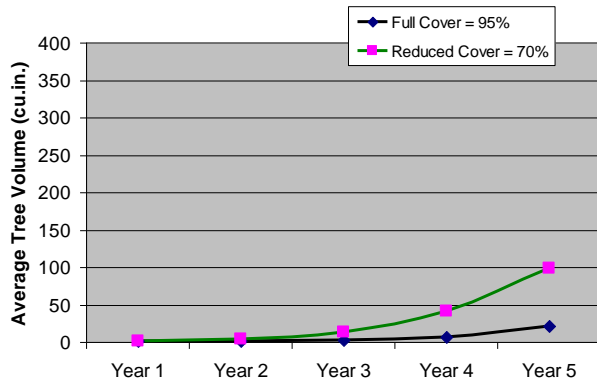
their root collar and re-sprouting again in the spring. Dieback can recur from one to four years, especially in competitive environments, before significant shoot growth occurs. This habit was evident in the growth of sugar maple and white oak, where both species experienced some dieback the second and third years, which is reflected by little or no average growth until the fourth year (Fig. 3). However, by the fourth year, both species extended their shoots, but predominantly in the reduced cover plots. The growth trajectory of all species in even the reduced cover plots shows how slowly trees grow for the first three years until they recover from transplant shock. This illustrates the importance of using tree-compatible herbaceous ground cover that grows slowly with the trees for the first three years, achieving 70% cover by age 2 and 100% cover by age 4. Planting older, containerized stock (e.g., 3-0 stock) or 3-2 transplants with large root systems reduces dieback and slow early growth, but older stock is more expensive and much more difficult to plant in mine spoils.

Overall, some species are more sensitive to ground cover than others (Fig. 4). White pine, when planted in suitable topsoil or topsoil substitutes, can tolerate the competitive effects of ground cover until it recovers from transplanting shock. White ash growth, on the other hand, is very sensitive to competition, as are most early-successional species, and grows rapidly when released (Fig. 4).

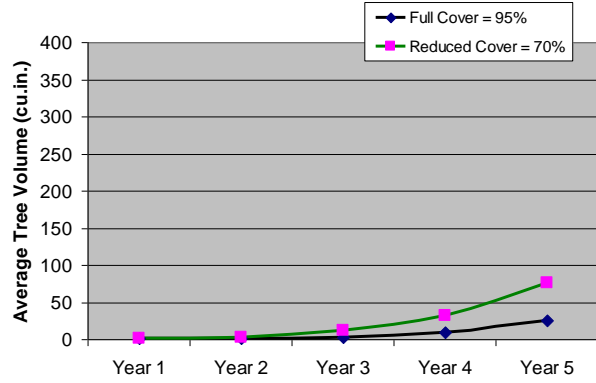
Management Implications

Many landowners would like to restore their mined land to diverse, commercially-valuable native hardwood species. The results of this study suggest this is possible provided that site-sensitive species survive the difficult conditions of reclaimed mined land, including the competitive herbaceous ground cover used for erosion control. Reduced ground cover competitiveness increased the growth of most species. Tree survival on reduced cover plots was 69%, which was just adequate for meeting bond release stocking standards. With full cover, survival was 58%, which fell short of the minimum requirement. Herbicides can be a useful management tool to increase survival and growth of planted hardwoods; however, it is an expensive practice. Considering chemical costs and applicators needing to work on difficult terrain in uncertain weather, a single application will cost \$70 to \$100/acre, a cost that mine operators would be reluctant to pay if they had other options.

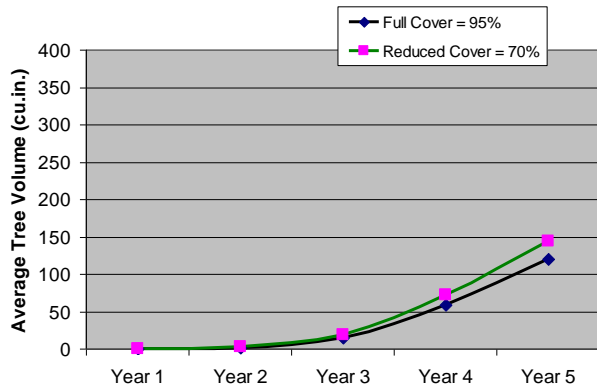
Red Oak



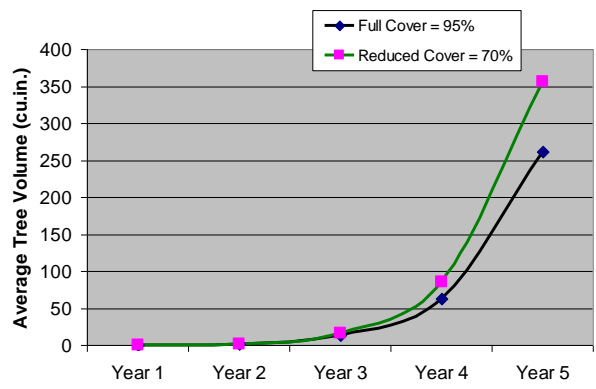
White Oak



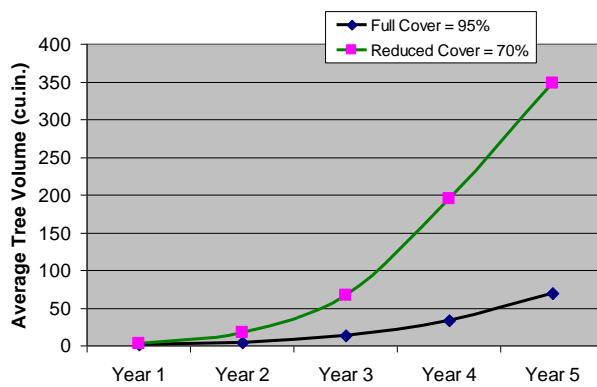
Tulip Poplar



White Pine



White Ash



Sugar Maple

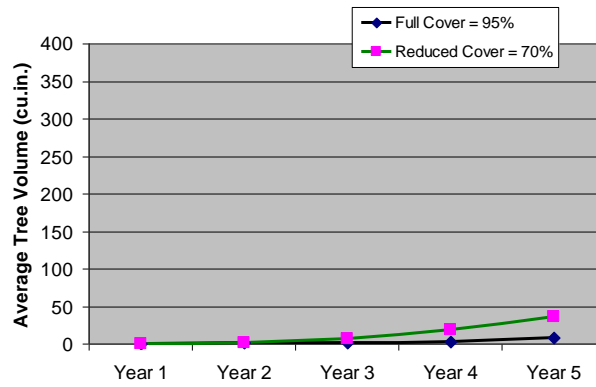


Figure 3. Crop tree growth rate in full cover and reduced cover. On average, age 4 is when trees recover from transplant shock. It is important to protect them from excessive herbaceous competition until that time.

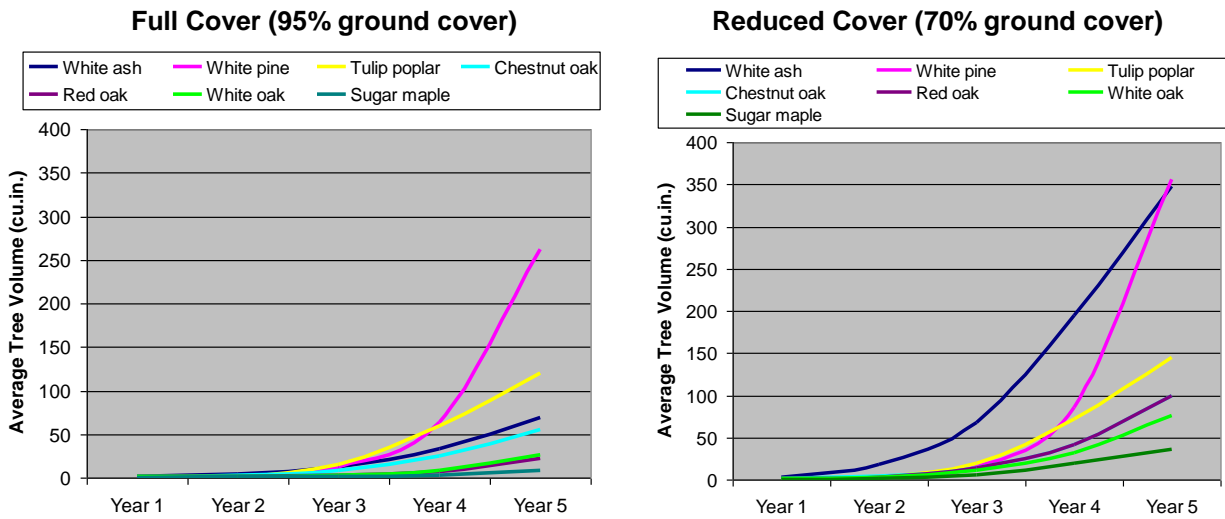


Figure 4. Relative growth of crop trees under full cover and reduced cover conditions.

An alternative way of achieving successful reforestation of native hardwoods is to adopt a Forestland Reclamation Approach outlined by Torbert and Burger (2000) and by Burger and Zipper (2002). The Forestland Reclamation Approach requires coal operators and inspectors to think and do differently compared to how they normally reclaim land for grassland, wildlife, or unmanaged forest. The Forestland Reclamation Approach requires (1) selecting topsoil substitutes specifically for trees, (2) rough-grading surfaces to leave 4 feet of spoil material uncompacted, (3) using a tree-compatible ground cover that is less competitive than standard grassland mixes, (4) a reduced rate and a change in the composition of applied fertilizer to high phosphorus and low nitrogen, and (5) a professional tree planting contractor who specializes in planting hardwoods on mined land and who guarantees his work.

Reduced amounts of ground cover (70% or less) during reclamation should allow seedlings to survive at rates exceeding the 70% necessary to achieve regulatory compliance without the expense of follow-up herbicide treatment. Furthermore, our experience indicates that sowing tree-compatible groundcovers at reduced rates often allows recruitment of native woody species from adjacent forests. Non-compacted mine soils have higher infiltration rates and erode less than graded soils. When using the Forestland Reclamation Approach, less ground cover is needed to prevent erosion and protect water quality, and in the process, diverse mixes of trees are able to survive and grow at rates that will create an economically viable forest (Fig. 5).



Figure 5. Sites prepared using the Forestland Reclamation Approach (FRA) are easier to plant and greatly increase reforestation success (left). Mix of native hardwoods growing with reduced ground cover (70%) 5 years after planting (right).

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