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Tree Survival on Mountaintop Mines in Southern West Virginia

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Introduction

Recent changes in the West Virginia Surface Mining and Reclamation Rule (38CSR2) have established that commercial forestry is one of only a few agriculturally-related post-mining land uses that are acceptable for mountaintop surface mines that seek a variance from returning the land to approximate original contour (AOC). The new regulations have eliminated the past land use options of forestland or woodlands, rangeland, and wildlife habitat for permits receiving an AOC variance. Those coal operators pursuing commercial forestry have fairly strict performance standards. To achieve full bond release, standards require high survival rates of transplanted, commercially valuable tree species and these trees must demonstrate suitable growth over a 12-year bonding period after final reclamation. Permits not meeting the standards may cause the operators to face a mitigation plan that may require an amount up to twice the remaining bond amount to be paid to the Special Reclamation Fund or require the coal operator to perform an equivalent of in-kind mitigation. Therefore, failure to achieve performance standards could be very costly for large area permit holders that operate mountaintop removal mines that generally seek AOC variances.

Revegetation of surface mines generally occurs concurrently with reclamation to ensure timely bond release. Erosion control and slope stability are important components of an effective reclamation and revegetation plan. Early establishment of tree seedlings in areas that require reforestation is important to ensure that performance standards, both in terms of tree survival and growth, are achieved within the time frame set by the new regulations.

The objective of this research was to assess several factors that influence tree survival and growth on mountaintop surface mines in West Virginia. Evaluating tree survival across many species and among various site and planting conditions may allow coal operators to improve tree establishment and growth, thereby reducing the chance of failure on permits with commercial forestry post-mining land uses.

Study Site

Catenary Coal's Samples Mine in southern WV is the largest surface mine in the eastern U.S. with contiguous permits covering over 7,400 acres. Mountaintop removal is the dominant mining method on this site and several areas have been permitted with commercial forestry as the post-mining land use.

The geology of the area being mined is within the Pennsylvanian System, and the disturbed strata are in the Pottsville, Kanawha, and Allegheny Formations. Seven major coal seams or coal zones (with 14 separate splits) are mined. In descending order, the coal seams are the Freeports, Kittannings, Stockton, Coalburg, and Winifrede. A topsoil substitute has been allowed for use in all permits prior to 2001 with or without an AOC variance. Those areas permitted after 2001 without an AOC variance also may use a topsoil substitute. The areas sampled during the summer of 2002 were reclaimed with a topsoil substitute consisting primarily of strata immediately above the deepest coal seam mined, which contains about 80% fine to medium grained, micaceous, light gray sandstone (unweathered) and 20% of a mix of shales and coal. The pH of the surface material ranged from 6.0 to 8.0. With recent regulation changes in 2002, topsoil substitutes are no longer allowed on commercial forestry sites and 5 feet of the original topsoil combined with weathered brown sandstone is the required growth medium.

The height and diameter of trees in reforestation plots were sampled along transects.

Tree Sampling Methods

The management at Samples has established an aggressive reforestation program where more than 100,000 trees have been transplanted in small blocks during the past five or six years (~20,000 trees per year). These plantations were the focus of this tree survival and growth study.

Tree plantations one to three years of age of various sizes and various tree compositions were mapped and evaluated for seedling survival and growth during the summer of 2002. Belt transects (2.4 m wide and of various lengths based on the size of the plantation) were run through plantations perpendicular to planted rows (Figure 1). Since plantations varied in size, we first mapped each plantation thereby denoting its size, and then we evaluated about 1/10th of the total area of each plantation by running enough belt transects within the plantation to represent the 10% evaluation area. Within transects, each tree was identified by species and its height and basal diameter were measured. In each transect, general site conditions were measured: slope was measured by a clinometer; aspect was determined by compass degree; and groundcover percentage and composition (total and by major species) were visually estimated.

Planting date, slope, aspect, and ground cover were separated into categories for analysis. Statistical analyses were performed using analysis of variance (SAS Institute, 1987) using these factors as main effects on tree survival. Two-way interactions were also tested for their influence on tree survival, but are not shown here.

During 2002, 60 different tree plantations were mapped covering about 50 ha (125 ac) of land area. Of this 50 ha of area, 123 transects were established in these plantations for our tree survival evaluation, which covered 10% of the total area. Most transects were between 60 to 100 m in length, or about 0.020 ha. Based on planting records, stocking densities varied from 1,000 to 5,434 trees/ha (400 to 2,200 trees/ac), with an average of about 1,482 trees/ha (600 trees/ac).

Results and Discussion

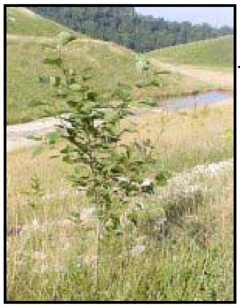
Tree plantations sampled in this study were established in the spring of 1999, spring of 2001, and fall of 2001. No significant difference in survival was found among the three planting dates (varied between 58 to 68% average survival), although as expected the older planting had slightly less survival (Table 1). Tree survival varied from 9% to 98% in transects, and averaged 65% across all ages of plantations. Tree heights and basal diameters also varied slightly, with the largest trees on the older plantings.

Table 1. Average survival, height, diameter, and other parameters of all trees transplanted at three dates at the Samples Mine.

	Spring 1999	Spring 2001	Fall 2001
Ave % Survival	58	68	64
Ave Ht of all trees (cm)	71	47	44
Ave Dia of all trees (mm)	12	8	6
# of Species Encountered*	11	8	8
# of Plantations Sampled	6	23	26

* *Includes invaders.*

We were unable to evaluate the survival of each species because we didn't know exactly how many of any one particular species had been planted in any specific area (we only could determine the general proportion of each species planted during any one year). Tree species and proportions of transplanted trees were calculated based on planting records and included: black alder (7%), sycamore (6%), chestnut oak (5%), bur oak (11%), white oak (24%), sawtooth oak (4%), red oak (1%), white ash (36%), red maple (1%), pitch x loblolly pine (2%), white pine (<1%), dogwood (3%), and black cherry (<1%). Therefore, our assessment was based on the total number of planted trees in a specific plantation because we could identify the spacing of planted trees.



Some of the largest transplanted trees were black alder.

Black alder was the largest tree in all plantations and within each planting date (Figure 2). Other species showing good growth were sycamore, pitch x loblolly pine, white ash, red maple, and black cherry. In comparing growth between spring 2001 and fall 2001, very little difference could be found, suggesting that not much growth had occurred during the 2001 growing season. This also demonstrates that the first growing season is an establishment period rather than a growth period.

Slopes were used as surrogates for compaction. Steeper slopes had less compaction while flatter slopes had more.

Some slopes were less compacted and were only rough graded.

Researchers have studied the negative influence of compaction on survival and growth of trees planted on surface mined land. Compaction, resulting from regrading the topsoil to make it smooth for planting (also referred to as "tracking in"), restricts root growth and retards the establishment and growth of trees (Burger, 1999; Larson and Vimmerstedt, 1983; Torbert et al., 2000). Torbert and Burger (1996) found a significant difference in survival and height growth of commercially valuable trees planted to moderately and intensely graded spoils. Zeleznik and Skousen (1996) found that survival and average height growth of white ash, tulip poplar, and white pine were greater on sites subjected to low grading intensity compared to high grading.

Although no direct measurements of compaction were performed at the time of this paper, the extremes of slope, <30% and >50%, were considered as analogs to conditions of compaction and a surrogate for soil bulk density (Figure 3). The reason behind designating the lower slope class to represent a more compacted condition comes from observations at the site of the use of heavier equipment to regrade flatter slopes, and the use of lighter equipment on steeper slopes, as well as less truck and equipment traffic associated with steeper slopes (Figure 4). Mean survival was highest in areas with steeper slope (75 to 62%), but the difference was not statistically significant (Table 3).

Aspect has been long recognized as a factor that influences species composition and forest site quality in the eastern United States. South and west facing slopes are generally the least productive, while north and east facing slopes are the most productive (Hicks et al, 1982). Soil moisture and energy relationships in native forests have produced environments that favor the establishment and proliferation of certain species. Haynes (1983) found sparser plant communities on drier, south-facing aspects, while northern aspects had more vigorous plant communities, which was related to improved moisture conditions. Recommendations for tree planting suggest that trees adapted to drier site conditions [pines (*Pinus spp*.), black locust *(Robinia pseudo-acacia* L.), and red oak] be established on southern and western aspects. Trees adapted to wetter and cooler climates [black walnut, black cherry, yellow-poplar, cottonwood (*Populus deltoides* Marsh.), green ash (*Fraxinus pennsylvanica* Marsh.), white ash, and sweet gum (*Liquidambar styraciflua* L.)] should be transplanted on northern and eastern aspects.

Table 2. Average height and diameter of trees transplanted at three dates at the Samples Mine.

Species	Spring 1999 Ave Ht.	Spring 1999 Ave Dia.	Spring 2001 Ave Ht.	Spring 2001 Ave Dia.	Fall 2001 Ave Ht.	Fall 2001 Ave Dia.
Black alder	167	29	95	18	124	24
Sycamore	102	19	45	7	45	6
Chestnut oak	23	4	45	8	46	6
Bur oak	61	12	38	8	33	7
White oak	39	6	38	6	42	7
Sawtooth oak	43	5	37	5	39	5
Red oak	29	5	41	6	0	0
White ash	80	12	50	8	46	6
Red maple	77	13	38	6	47	7
Pitch x Loblolly	82	19	25	6	23	5
White pine	64	17	0	0	0	0
Dogwood	36	5	36	5	38	5
Black cherry	63	7	50	5	0	0

Table 3. Average survival of trees transplanted from 1999 – 2001 on three slope classes at the Samples Mine.

Slope Class	Range	Mean Survival (%)	Standard Deviation
1	0 – 30%	67	19.1
2	31 – 50%	62	21.0
3	> 50%	75	11.5

Table 4. Average survival of trees transplanted during 1999-2001 on five aspect classes at the Samples Mine.

Aspect Class	Range (°)	Major Direction	Mean Survival (%)	Standard Deviation
1	316 - 45	NW-NE	66	25.6
2	46 - 135	NE-SE	68	17.8
3	136 - 225	SE-SW	65	17.2
4	226 - 315	SW-NW	59	22.0
5	< 30% slope	All	68	18.3

The effects of aspect were considered in this study (survival varied between 59 and 68%), but no significant differences in tree survival among aspects were found (Table 4). The effect of aspect on soil moisture at Samples may be muted by the fact that the difference in relief of the reclaimed terrain is generally less than 150 feet. More time is probably needed for trees to be exposed to these various aspect conditions for survival differences to show.

The negative effects of abundant and aggressive ground cover on the survival and growth of transplanted trees has long been known. Trees transplanted into introduced, aggressive, annual forages [especially tall fescue (*Festuca arundinacea* L.) and sericea lespedeza (*Lespedeza cuneata* L.)] are often overtopped by the grasses or legumes and are unable to break free through the coverage (Burger and Torbert, 1992; Torbert et al, 1995). The seedlings are pinned to the ground and have little chance for survival.

Trees can be transplanted into areas with no groundcover, and then a tree-compatible, less-aggressive cover can be seeded during the following early spring or late fall before three leaves have emerged.

Trees should be transplanted into soils with no ground cover (Figure 5), and then a tree-compatible ground cover should be seeded afterward that will be less competitive with trees (Figure 6). The tree compatible ground cover should be slow growing, sprawling or low growing, not alleopathic, and not present competition to trees (Burger and Torbert, 1992). Plass (1968) reported that after four growing seasons the height growth of sweetgum and sycamore planted into an established stand of tall fescue on spoil banks was significantly retarded. Andersen et al (1989) found that survival and height growth for red oak and black walnut was significantly greater on sites where ground cover was chemically controlled.

In this study, ground cover varied from 0% to 95%, averaging 71%. Ground cover species included: annual rye, perennial ryegrass, clovers (red, white, and sweet), birdsfoot trefoil, alfalfa, bicolor and sericea lespedeza, orchard grass, K-31 tall fescue, timothy, and redtop. Trees showed a trend of better survival with low amounts of ground cover (74 compared to 62%), but the differences were not significant (Table 5). Again, more time will probably be needed for ground cover to have a significantly negative influence. From our observations, it appears that 0 to 25% ground cover has no influence on tree survival, while there is a slight decrease in tree survival as the ground cover increases to 50%. Above 50%, a more rapid decline in tree survival is apparent.

Summary

During the summer of 2002, we sampled over 50 plantations at the Samples surface mine in West Virginia to determine the effects of planting date, slope, aspect, and ground cover on the survival of transplanted trees. Plantations were established in spring 1999 and spring and fall of 2001.

Table 5. Average survival of trees transplanted during 1999-2001 with three ground cover classes at the Samples Mine.

Ground Cover Class	Range (%)	Mean Survival (%)	Standard Deviation
1	< 50	74	5.5
2	50 – 70	67	7.6
3	> 70	62	8.2

Average tree survival across these three dates and among all tree species was 65%. Black alder was the largest of the transplanted trees, but sycamore, pine, white ash, red maple, and black cherry also showed good growth. Slope was used as a surrogate for soil compaction (steeper slopes had smaller equipment compared to flatter slopes with larger equipment) and tree survival was 75% on slopes >50%, 62% on slopes 31-50%, and 67% on slopes <30%. Tree survival was not different among five aspect classes (ranging from 59% on SW-NW aspects to 68% on NE-SE aspects). Tree survival was highest (75%) in areas with <50% groundcover and lowest (62%) in areas with >70% ground cover. More time is needed to see if these tree survival trends continue with these site factors.

Trees have grown better where the groundcover was seeded after transplanting.

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