First-Year Response of Mixed Hardwoods and Improved American Chestnuts to Compaction and Hydroseed Treatments on Reclaimed Mine Land[1]

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Abstract

There is increasing interest in the restoration of native Appalachian hardwood forests using the Forestry Reclamation Approach (FRA) on sites that are being reclaimed following surface mining for coal. Additionally, much interest has developed in the deployment of American chestnut trees that have been improved through breeding to have both blight resistance and timber tree stature. Including chestnuts in planting mixes for the FRA is one potential method to efficiently re-introduce them in the central Appalachian region, but the viability of this method needs to be assessed. There are further questions regarding how choices of herbaceous vegetation and grading practices affect tree survival and growth and plant succession on reforested mine sites. A new experiment combining components of the FRA with plantings of American chestnut trees was begun in the spring of 2008 on active coal-mining sites in Virginia with the goal of directly assessing the effects of grading and groundcover treatments on reforestation success, using a planting mix that includes American chestnut. On each of the three sites, half of the experimental area was smooth-graded and tracked-in as per common reclamation practice, and the other half was loose-graded as recommended using the FRA. Within each grading treatment plot, one-third of the area was hydroseeded with a conventional herbaceous vegetation mix, one-third was seeded with a tree-compatible herbaceous mix, and one-third was seeded with annual ryegrass. All treatments were planted with a mix of native hardwood trees. The loose-graded sections were also planted with six genotypes of chestnut, including pure American, Chinese, and American x Chinese crosses. Tree survival and growth, groundcover, and native plant volunteers were measured. After one growing season, tree survival was not affected by any of the experimental treatments. The tree-compatible mix and the conventional mix provided significantly more ground cover by August than did the annual rye. Loose grading reduced soil loss compared to smooth grading. Chestnut trees grown from planted nuts were competitive with other species' survival rates.

Introduction

Successful rehabilitation of mined land is necessary in order to prevent mining from degrading the land base of agricultural and forest systems and the ecological services those systems provide. Land base degradation makes no sense in a world of growing human populations and ongoing desire for sustainable economic development. Coal surface mining in Appalachia will go on as long as it is economically and politically feasible, and there is a logical imperative to employ the best land reclamation and rehabilitation practices in the course of inevitable mining operations.

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Background

Since 1980, shortly after the implementation of the SMCRA, researchers with the Powell River Project at Virginia Tech have been developing reforestation practices called the Forestry Reclamation Approach (FRA) (Burger and Zipper 2002). A cooperative effort called the Appalachian Regional Reforestation Initiative (ARRI) was formed in December of 2005 to specifically advocate the use of the FRA for proper restoration of native forests on sites reclaimed following coal mining in the eastern United States. ARRI goals are to encourage planting of more hardwood trees of high value, using methods that increase the planted trees' survival and growth, and to accelerate forest succession to establish forest habitat (Angel et al. 2005).

The Forestry Reclamation Approach is a mine reclamation method that has been developed through scientific research and field experience to achieve these goals and has been approved by regulatory agencies. The FRA can be implemented by coal mining operators more cost-effectively than traditional mine reforestation approaches, which entail heavy grading and vigorous herbaceous vegetation (Burger and Zipper 2002). The FRA is intended to restore ecosystem services such as clean water, carbon sequestration, clean air, and habitat for wildlife and other plants (Angel et al. 2005).

The ARRI is needed in order to correct key problems created by common reclamation practices under the SMCRA that hindered restoration of productive native forests on mined land. These key problems, meant to stabilize land and prevent erosion, were the compaction of soil during re-grading and the planting of aggressive herbaceous vegetation (Angel et al. 2005). The ARRI seeks to inform operators of the steps necessary to avoid and/or mitigate these key problems and demonstrate the value of native forests. The FRA can achieve the requirement in the SMCRA that land be restored to equal or higher use and productivity (Angel et al. 2005). Five steps summarize the FRA process (Burger et al. 2005):

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 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 succession species for wildlife and soil stability, and commercially valuable crop trees.
5. Use proper tree planting techniques.

The FRA is intended to allow full compliance with federal regulations through cost-effective practices by mine operators while successfully re-establishing native forest species. The FRA can be modified to accommodate other forest land uses such as woody biomass production, fruit orchards, or ornamentals (Burger et al. 2005).

Low-compaction grading helps planters plant trees correctly, allows rain water to infiltrate the soil rather than moving off in erosive surface flow, allows the soil to hold more water and air that supports tree growth and soil life, and allows roots to grow more freely. Low-compaction grading is also less expensive than traditional grading practices because it involves fewer machine hours to make fewer grading passes over reclaimed sites (Sweigard et al. 2007).

Tree survival and growth are generally higher on loose-graded mine sites than on compacted and tracked-in mine sites. Numerous experimental studies have demonstrated that high soil bulk density, which occurs as a result of excessive soil compaction, has a negative effect on tree growth (Jones et al. 2005, Rodrigue and Burger 2004, Andrews et al. 1998, Torbert and Burger 2000, Torbert and Burger 1990).

Reforestation practices are meant to accelerate natural forest succession with direct tree planting. Simultaneously, grasses, legumes, nurse shrubs, nurse trees, and crop trees are established, and these perform their functions of stabilizing land and accumulating nutrients before yielding to other plant types in the process of succession. Under Virginia regulations implementing SMCRA (4VAC25-130-816.116. Revegetation; standards for success), lands reclaimed to support a commercial forest post-mining land use are required to have at least 400 trees/ac of commercial value and at least 40 additional trees/ac of wildlife value at bond release. Non-commercial forests have a 400-tree/ac stocking requirement, but it is not required that the trees used be of commercial value. Given the normal survival rates achieved when appropriate reclamation practices are used, planting 550 crop trees and 60 to 100 wildlife or nurse trees per acre can usually achieve these stocking requirements (Burger and Zipper 2002).

Natural mountain forest landscapes in the Appalachians are uneven with many rocks, boulders and rough, loose soils. That is a very different environment than the smooth-graded, compacted soils sought by reclamation specialists in the past. The SMCRA only requires compaction where it is needed to ensure stability. There is, therefore, little reason to compact reclaimed sites when stability can be otherwise achieved, especially on areas that are level or have only gentle, short slopes.

Species of forage often used for hayland/pasture are not compatible with trees. These species include Kentucky-31 tall fescue, red clover, and sweet clover. Legumes can provide up to 50 lbs/ac/yr of nitrogen to the soil in conjunction with *Rhizobium* bacteria. Favorable legumes include birdsfoot trefoil (*Lotus corniculatus*) and white or ladino clover (*Trifolium repens*). Favorable annual grasses include foxtail millet (*Setaria italica*) and annual ryegrass (*Lolium multiflorum* Lam.). Favorable perennial grasses include perennial ryegrass (*Lolium perenne*), timothy *(Phleum pratense)* and, for steep slopes, orchardgrass (*Dactylis glomerata*). Weeping lovegrass (*Eragrostis curvla*) is a tall grass that is useful on acid sites at low seeding rates (Burger and Zipper 2002). Favorable groundcovers are low-growing to allow light to reach young trees growing among them and do not create a continuous sod, which would compete vigorously with trees for water resources.

Goal and Objectives

The goal of this study is to assess the effects of grading and herbaceous vegetation practices on the survival and growth of native hardwoods, including the American chestnut, when these practices are deployed on an active mining operation at a full operational scale.

We tested the following hypotheses:

1. Increased levels of grading and tracking by mining equipment:
   - depress the growth and survival of planted native hardwood trees;
   - accelerate soil loss.

2. Increased levels of herbaceous groundcover:
   - depress the growth and survival of planted native hardwood trees;
   - have a negative effect on recruitment of native vegetation.

Finding or failing to find experimental support for these hypotheses will test some of the assumptions of the FRA and provide insight into how it might be improved in theory and in practice.

Methods and Materials

Overview of Treatments and Design

Three experimental sites (blocks) were established by cooperating mining firms on active mining sites in southwestern Virginia (Fig. 1). The sites shared similar topographical characteristics with steep, long slopes. Blocks 1 and 2 were near Norton, Virginia (Fig. 2) and Block 3 was near Carbo, Virginia (Fig. 3). Block 1 is also referred to as the "Red River Coal" site (Fig. 4), Block 2 as the "Powell River Project" site (Fig. 5) and Block 3 as the "Carrie Ridge" site (Fig. 6). At each site, two grading treatments and three vegetation treatments were installed as a 2x3 factorial randomized block design.

The two grading treatments were (1) smooth grading with tracking-in and (2) loose grading with a single pass. It took approximately 3 to 3.5 extra machine hours per acre to achieve the heavier grading. Three one-acre groundcover treatments were sown on each grading treatment plot: (1) a conventional mix of species intended to create the highest rate of groundcover (Fig. 7); (2) a tree-compatible mix (Powell River Project mix) intended to create a moderate rate of groundcover (Fig. 8); and (3) a native invasion mix intended to create the lowest rate of groundcover (Fig. 9, Table 2). Block 1 was hydroseeded in the fall of 2007, Block 2 in the winter of 2007-2008, and Block 3 in the early spring of 2008. All sites were planted with the same mix of native trees (Table 1) by a commercial tree-planting contractor in mid-January of 2008.

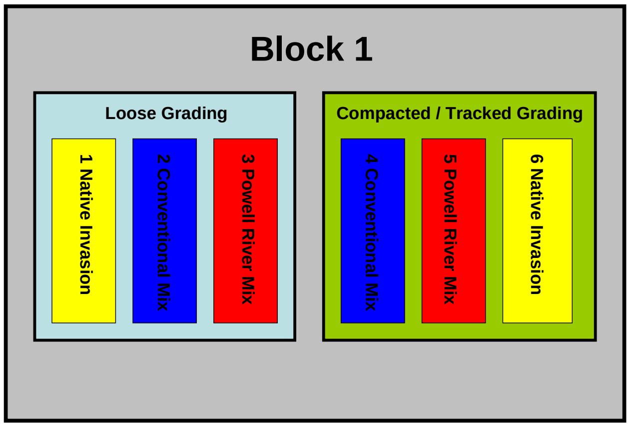

Figure 1. Conceptual map of the layout of experimental blocks using Block 1, Red River Coal site, as an example.

Figure 2. Location of Blocks 1 and 2 near Norton, Virginia.

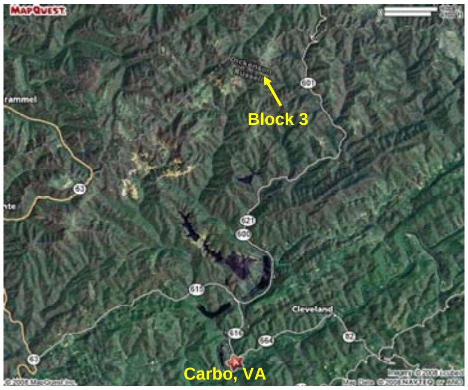

Figure 3. Location of Block 3 near Carbo, Virginia.

Figure 4. Block 1, winter 2007-2008.

Figure 5. Block 2, winter 2007-2008.

Figure 6. Block 3, winter 2007-2008.

Figure 7. Conventional mix, August 2008.

Figure 8. Powell River Project mix, August 2008.

Figure 9. Native invasion mix, August 2008.

Table 1. Tree planting prescription for all experimental plots.

Species	Trees Planted/Acre
yellow poplar (*Liriodendron tulipifera*)	50
white oak (*Quercus alba*)	83
chestnut oak (*Quercus prinus*)	83
black oak (*Qurecus velutina*)	83
red oak (*Quercus rubra*)	83
sugar maple (*Acer saccharum*)	83
black cherry (*Prunus serotina*)	83
white ash (*Fraxinus allegheniensis*)	83
shagbark hickory (*Carya ovata*)	25
white pine (*Pinus strobus*)	37
redbud (*Cercis canadensis*)	22
gray dogwood (*Cornus racemosa*)	22
red mulberry (*Morus rubra*)	10
Total	**747**

Table 2. Seed, fertilizer and mulch mixtures for groundcover treatments.

Mixture	Rate (lbs/ac)
Native Plant Invasion Mix	
Seed Mix:	
Annual ryegrass (*Lolium multiflorum*)	20
Diammonium Phosphate 18-46-0	300
Wood Cellulose Fiber	1500
Powell River Project Mix	
Seed Mix:	
Annual ryegrass (*Lolium multiflorum*)	20
Perennial ryegrass (*Lolium perenne*)	10
Timothy (*Phleum pretense*)	5
Birdsfoot trefoil (*Lotus corniculatus*)	5
Ladino clover (*Trifolium repens*)	3
Weeping Lovegrass (*Eragrostis curvula*)	2
Diammonium phosphate 18-46-0	300
Wood Cellulose Fiber	1500
Conventional Mix	
Seed Mix:	
Rye grain (*Secale cereale*)	30
Orchardgrass (*Dactylis glomerata*)	20
Perennial ryegrass (*Lolium perenne*)	10
Korean lespedeza (*Lespedeza cuneata*)	5
Birdsfoot trefoil (*Lotus corniculatus)*	5
Ladino clover (*Trifolium repens*)	5
Redtop (*Agrostis gigantea)*	3
Weeping lovegrass (*Eragrostis curvula*)	2
16-27-14	400
Wood Cellulose Fiber	1500

Erosion and Sedimentation

Erosion pins made of half-inch steel rebar were used to estimate loss and accumulation of surface soil. Twelve erosion pins were installed in each of the 18 treatment plots of the experiment (Fig. 10).

Once installed, the pins were measured in height to the nearest millimeter on the uphill side. Thereafter, the pins were measured before the growing season in early April and after the growing season in late October.

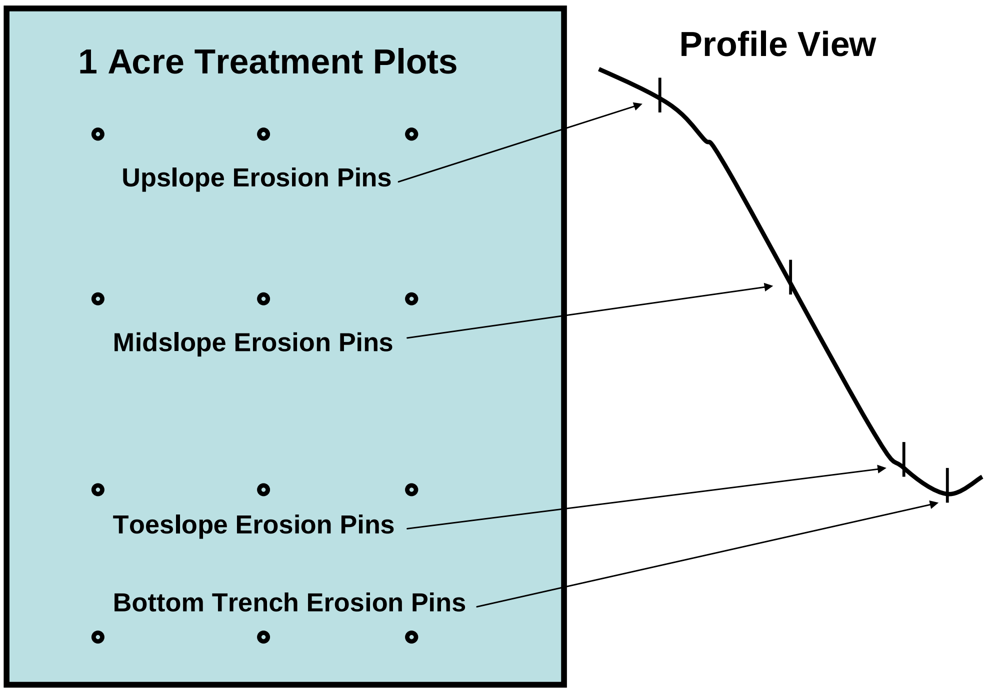

Figure 10. Conceptual map of erosion pin layout on all 18 treatment plots. Soil samples were taken 1 m to the right of each erosion pin, facing uphill.

Soil Sampling and Testing

Soil samples were gathered for each of the 18 plots. Samples were composed of nine subsamples taken within each plot 1 m from the erosion pins. The surface 2 inches of soil were removed in order to discard hydroseeding materials from the sample, and soil was collected from a depth of 2-6 inches for each subsample. The subsamples were combined and mixed for a single composite sample per plot. Soil samples were air-dried, then sieved through a #10 screen to separate the coarse and fine fractions. Samples were analyzed for pH, extractable cations, cation exchange capacity, soluble salts, and organic carbon content (Table 3). No significant differences in these chemical properties were found among treatment plots within blocks.

Table 3. Soil physical and chemical properties at onset of experiment, spring 2008.

Block	Grading	Cover Type	% Fines	pH	P (ppm)	K	Ca	Mn	Fe	CEC (meq/100g)	Acidity (%)	BS	OM	SS (ppm)
1	Loose	Native Invasion Mix	47	5.96	36	62	823	46.2	62.6	6.0	2.0	98.0	1.3	269
1	Loose	Conventional Mix	55	5.52	32	59	928	33.7	49.8	7.5	7.9	92.1	1.2	602
1	Loose	Powell River Project Mix	47	5.51	46	62	1284	42.5	79.7	9.6	6.2	93.8	1.2	909
1	Compact	Conventional Mix	50	4.59	27	50	774	44.2	73.7	7.6	24.3	75.7	1.2	563
1	Compact	Powell River Project Mix	40	5.80	70	62	1447	60.7	86.6	10.1	2.4	97.6	1.2	973
1	Compact	Native Invasion Mix	48	6.93	49	75	977	63.9	73.6	7.2	0.1	99.9	1.5	115
2	Loose	Native Invasion Mix	27	7.93	47	74	2617	135.3	197	17.4	N/A	100.0	1.6	218
2	Loose	Conventional Mix	29	8.10	22	66	3009	160.7	122.5	19.6	N/A	100.0	1.4	218
2	Loose	Powell River Project Mix	45	7.46	78	63	1309	86.4	77.3	9.6	N/A	100.0	2.0	230
2	Compact	Conventional Mix	42	7.21	75	60	1466	80.7	71.2	10.3	N/A	100.0	1.8	627
2	Compact	Powell River Project Mix	39	7.20	77	64	1122	69.4	68.7	8.4	N/A	100.0	2.3	218
2	Compact	Native Invasion Mix	36	6.76	70	66	1120	58.7	65.8	8.1	0.1	99.9	1.8	384
3	Loose	Powell River Project Mix	45	7.19	28	44	910	35.8	42.5	6.3	N/A	100.0	0.9	51
3	Loose	Native Invasion Mix	30	6.76	41	48	740	43.6	54.9	5.7	0.5	99.5	0.9	51
3	Loose	Conventional Mix	41	7.20	48	51	1036	54.6	66.8	7.7	N/A	100.0	0.8	77
3	Compact	Conventional Mix	32	6.23	46	47	846	37.5	45	6.9	0.9	99.1	0.9	64
3	Compact	Powell River Project Mix	37	7.02	52	50	1088	44.4	49.7	8.4	N/A	100.0	0.9	51
3	Compact	Native Invasion Mix	42	6.95	43	49	949	43.4	53.4	7.3	N/A	100.0	0.9	64

American Chestnut Planting

Six genotypes of American chestnuts, provided by the American Chestnut Foundation, were planted on all of the loose-graded plots from March 14-17, 2008. Chestnut seeds were planted and protected using procedures developed by the American Chestnut Foundation (Fig. 11). These procedures involved digging a 4-inch wide x 8-inch deep hole, filling it with a mix of potting soil, native forest topsoil for biotic inoculation, and on-site mine soil. Seeds were then placed on top of this medium and covered with an additional 1-inch layer of soil medium. Tree tubes (15 inches tall) were then placed 1 inch deep into the ground around the seed and planting medium and staked with a piece of 3/8-inch rebar. Rocks were piled around the base of each tube to the height of a few inches. Planting was performed in late March and germination was first checked in early May. Thereafter, survival, tree height to the highest live bud, canopy diameter, and stem diameter at the height of the top of the tree tube were measured in late October to early November at the conclusion of the growing season.

Figure 11. Photo of chestnut planting method taken in March 2008.

Vegetation Sampling

Five 1/20-ac circular woody plant measurement plots were established on each treatment plot (Fig. 12).

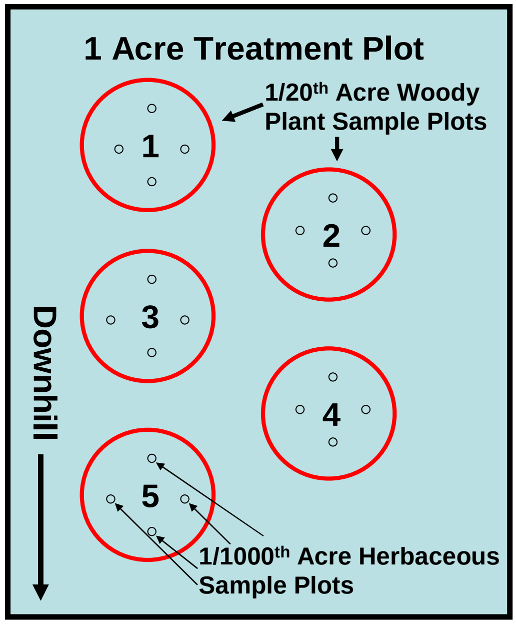

Figure 12. Conceptual diagram of vegetation sampling plots for all 18 treatment plots.

Groundline diameter and tree height to the highest live bud were measured for all trees within measurement plots. Groundline diameter measurements were not taken for chestnut trees as they were still contained in tree tubes. Additionally, four 1/1000-ac herbaceous plant measurement plots were nested inside of each woody plant measuring plot. Within each measuring plot, total groundcover was estimated using an ocular method by comparing observed ground coverage with diagrams of various coverages typically used for determining percent mottling in soils. Percent groundcover by species was estimated in the same way. Plant samples of all species encountered were collected for identification. Pictures of each herbaceous plot were taken.

Statistical Analysis

Data were analyzed using JMP 7.0 (SAS Institute Inc., Cary NC). Differences in performance characteristics among treatments were determined using a randomized block ANOVA. Tukey-Kramer HSD was used for mean separations ($P < 0.05$ and $P < 0.10$). Multi-factor analysis was also performed to analyze treatment interactions and block effects.

Results

Compaction had no significant impact on survival of mixed hardwood trees or on the percent groundcover of herbaceous vegetation (Table 4). The conventional groundcover mix and the Powell River Project mix both produced significantly more groundcover than the native invasion mix. Groundcover type had no effect on tree survival, although the native invasion mix does appear to have nominally better survival than the other two mixes (Fig. 13).

The exposed height of erosion pins actually decreased over the time frame between erosion pin measurements, as indicated by positive soil surface change (Table 5), an unexpected result that was attributed to soil expansion caused by compression rebound, freeze-thaw processes, mineral slaking, moisture swell, and rooting expansion. Hence, these measurements are expressed as "surface change," a relative measurement computed from the exposed heights of the erosion pins. Visual observations indicated that soil was being lost even at sites where measured surface change was positive. Surfaces in upslope positions eroded more (i.e., less positive surface change) than those in mid- and toeslope positions, and the tree-noncompetitive groundcover mixes (PRP and native invasion) eroded less than the conventional mix. Loose grading caused significantly less erosion than smooth and tracked-in grading (Fig. 14). There were no significant effects of groundcover type or landscape position on erosion.

Table 4. Treatment and block effects on groundcover rates and surviving trees per acre (TPA) with significant differences (Tukey HSD) by alpha (α) level.

	Groundcover	**α = 0.05**	**α = 0.10**	**Survival (TPA)**	**α = 0.05**	**α = 0.10**
Grading						
Compact	0.59	a	a	320	a	a
Loose	0.55	a	a	269	a	a
Block						
1 – RRC (Fall Seed)	0.81	a	a	296	a	a
3 – CR (Spring Seed)	0.62	a	b	272	a	a
2 – PRP (Winter Seed)	0.28	b	c	316	a	a
Groundcover						
Conventional	0.66	a	a	268	a	a
Powell River Project	0.61	a	a	252	a	a
Native Invasion	0.44	b	b	364	a	a

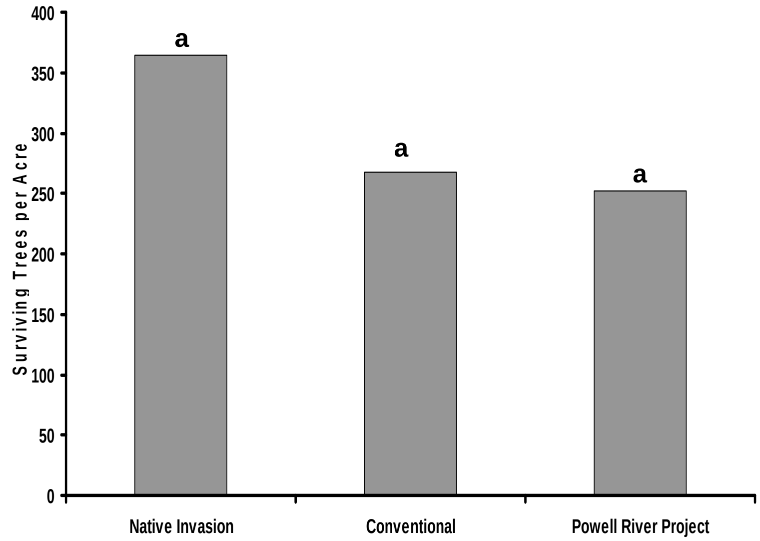

Figure 13. Trees per acre by groundcover treatment surviving the first growing season with significant differences at the α = 0.10 level indicated by different letters.

Table 5. Treatment and block effects on soil depth change over 230 days spanning the 2008 growing season with significant differences by alpha level.

	Soil Depth Change (mm)	$\alpha = 0.05$	$\alpha = 0.10$
Grading			
Loose	17	a	a
Compact	3	b	b
Block			
1 - RRC	9	a	a
2 - PRP	15	a	a
3 - CR	6	a	a
Groundcover			
Conventional	8	a	a
Powell River Project	11	a	a
Native Invasion	12	a	a
Landscape Position			
Upslope	7	a	a
Midslope	11	a	a
Toeslope	13	a	a

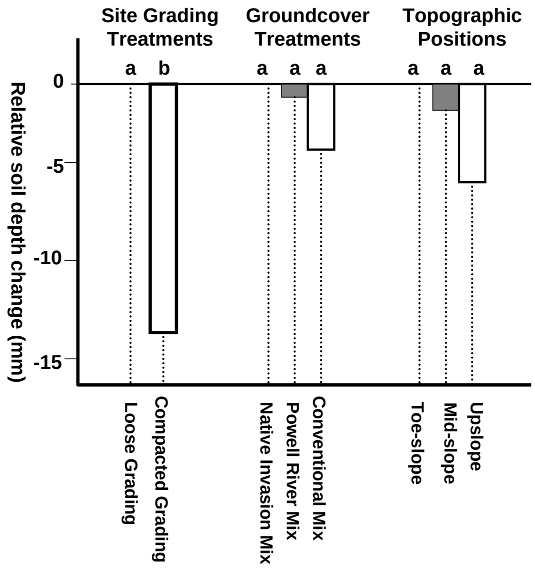

Figure 14. Relative change in soil surface among treatments. The treatment experiencing the least soil erosion was set as the baseline. Significance differences (α= 0.10 level) are shown by by different letters within treatment categories (grading, groundcover and topographic position).

Groundcover type had no significant effect on chestnut survival or growth (Table 6). There were significant differences in the performance of the genotypes. The Chinese chestnuts and hybrids with the highest proportion of Chinese genes grew fastest. Chinese chestnut had higher survival than one genotype of hybrid chestnut.

Table 6. Treatment, block and genotype effects on survival and growth of chestnut trees with significant differences by alpha level.

	Survival	α = 0.05	α = 0.10	Ht (mm)	α = 0.05	α = 0.10
Groundcover						
Native Invasion	0.75	a	a	247	a	a
Powell River Project	0.74	a	a	259	a	a
Conventional	0.63	a	a	233	a	a
Block						
2 - Powell River	0.80	a	a	236	a	a
1 - Red River Coal	0.70	ab	ab	253	a	a
3 - Carrie Ridge	0.63	b	b	250	a	a
Genotype						
2	0.88	a	a	331	a	a
3	0.80	ab	ab	303	a	ab
5	0.73	ab	ab	220	b	c
1A	0.69	ab	ab	202	b	c
1B	0.64	ab	ab	197	b	c
4	0.57	b	b	220	b	c
X	0.57	ab	ab	262	ab	bc

* Genotype Key: 1A = All-American; 1B = All-American; 2 = All-Chinese; 3 = ¾ American B1F3; 4 = 7/8 American B2F3; 5 = 15/16 American B3F2; X = genotype label lost.

Groundcover treatment and grading treatment had no effect on number of volunteer herbaceous species; however, there was a significant block effect (Table 7).

No significant interaction effects between groundcover type and grading type were found for tree survival, tree growth and erosion rates.

Table 7. Treatment and block effects on count of established volunteer species.

	Avg. Count of Volunteer Spp.	α = 0.05	α = 0.10
Groundcover			
Native Invasion	3.8	a	a
Powell River Project	3.0	a	a
Conventional	1.0	a	a
Block			
2 - PRP (Winter Hydroseed)	5.7	a	a
3 - CR (Spring Hydroseed)	1.8	ab	b
1 - RRC (Fall Hydroseed)	0.3	b	b
Grading			
Loose	2.8	a	a
Compact	2.4	a	a

Discussion

Different compaction levels did not result in significantly different groundcover rates or rates of tree survival after this first growing season (Table 4). It remains to be seen how the vegetation will respond when it becomes more fully established.

There were significant differences in the groundcover rates achieved by the different groundcover treatments (Table 4). Nominally, the conventional mix of grasses and legumes grew more coverage than the Powell River Project mix that is designed to be less competitive with trees. Statistically, the native invasion treatment grew less groundcover than the other two treatments. We hypothesized that this would occur and that having less groundcover will allow these treatment plots to accumulate more volunteer vegetation, thus facilitating succession.

Groundcover type did have significant effects on surviving tree counts, and thus on apparent survival, a result that supported the research hypothesis. The native invasion treatment allowed higher tree survival than the Powell River Project or conventional treatments (Table 4). Therefore, annual rye alone may be a viable alternative groundcover in terms of promoting tree survival while achieving other reclamation goals (Groninger et al. 2007).

We hypothesized that the three experimental groundcover treatments would perform equally well at controlling erosion, and this hypothesis is supported (Fig. 16, Table 5). One implication of these data is that if one of these groundcover treatments exhibits superior performance characteristics in other categories besides erosion control, such as improving tree survival or increasing the rate of volunteer plant succession, then it might be favored for those other purposes. All treatments performed equally well at accomplishing the primary reclamation goal of erosion control. Continued monitoring of these plots is important, however, because the native invasion mix is specifically designed to fade out after the first year and yield to whatever naturally comes on to the site. Depending on what arrives and how much ground it covers, the erosion effects could change. Groundcover rates are thought to be connected to erosion rates, and that is supported by the fact that there were no significant differences in soil depth changes (erosion/deposition) or groundcover rates across the three groundcover treatments.

We hypothesized that higher levels of compaction would lead to higher levels of surface erosion, possibly due to an inability of water to infiltrate as quickly through compacted materials lacking macroporosity. This hypothesis is supported (Table 5). As no significant effect of compaction on groundcover was expected or found, the differing rates in soil erosion may have occurred due to the direct physical effects of compaction on soil rather than the indirect effects of compaction through promoting or inhibiting vegetation.

We expected that more net soil surface would be lost from upslope positions than from midslope and toeslope positions and that more net soil depth would be lost by midslope positions than by toeslope positions due to the deposition of eroded material into lower positions and the tendency of lower concave surfaces to accumulate more material than convex surfaces above. The data in Table 5 show no significant differences in rates of soil change among the landscape positions, although the hypothesis is nominally supported. Revegetation strategies might be improved by adapting them to topographic features and it is the goal of this aspect of the study to gather some relevant information on that issue while confirming whether the erosion pins are functioning as expected. Because of the stratified layout of the vegetative sampling plots along topographic gradients, it will be possible to also look at the effects of topographic position on the survival and growth of various woody and herbaceous species in this study.

We expected that the planted chestnut trees would respond to the three groundcover treatments the same as the other hardwoods. There were no significant differences in survival or height growth of chestnuts planted on the three different groundcover treatments (Table 6). The chestnuts were planted in tree tubes, giving them a degree of separation from herbaceous competition, so it stands to reason that they would express less responsiveness to groundcover type at this early growth stage than the other unsheltered mixed hardwoods.

The all-Chinese chestnut genotype is demonstrating significantly higher survival rates than the 7/8 American-1/8 Chinese (Table 6), but all other hybrids were the same. We expected the genotypes with the highest proportion of Chinese genes to have higher survival rates than the all-American and more strongly American genotypes, and this was confirmed nominally, though only partially statistically. The all-Chinese genotype is also demonstrating significantly more height growth than most of the mixed genotypes and all of the all-American genotypes (Table 6). No significant differences in survival or growth have been observed yet among the American or hybrid genotypes, suggesting that either there are not strong differences in genetic potential between these genotypes or that potential differences have not yet expressed themselves.

The inability to control the size of tree seedlings planted confounds the growth data of the mixed hardwoods other than chestnut for the first year. Measurements of height and groundline diameter for the mixed hardwoods were taken at the end of the 2008 growing season; however, these data will not be useful until the data from 2009 are available with which to make a comparison of actual growth. Survival data is also premature for the mixed hardwoods, as the exact number planted in the beginning of the 2008 growing season is unknown.

The native invasion groundcover treatment did have the highest nominal number of volunteer herbaceous species per treatment plot at the end of the first growing season (Table 8). We hypothesized that the lower rate of groundcover as well as the annual lifecycle of annual rye would allow for faster rates of volunteer plant recruitment and succession. It may take multiple growing seasons to differentiate, if at all. If it does, that will indicate that planting annual rye only is a faster path of natural succession. A further research question is whether the lack of legumes will reduce the productivity of the system in the long term by reducing the accumulation of nitrogen. If it does, then choices would have to be made between the desire for faster succession and accumulation of volunteer plant species versus long-term forest productivity effects of the legume-accumulated nitrogen.

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