Mined Land Reclamation to Restore Forest Land Capability:

Spoil Type and Seeding Effects

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Introduction

The purpose of this study is to investigate differences in tree survivorship and growth among several tree species on different soil/spoil materials on a reclaimed coal surface mine in West Virginia. Trees were planted in various substrates (soil and spoil types) to determine how spoil type and ground cover seeding affects tree survival, tree growth, and emergence of the full plant community. Soil/ spoil treatments were divided such that half of each substrate-treatment plot received either "tree compatible" herbaceous seeding or no seeding. This report describes the study layout and provides initial tree planting and survival data. It is intended as an initial report and documentation of study implementation and design. No substantive conclusions are drawn from these results, as longer time periods will be required to determine how reforestation success may have been affected by the soil and seeding treatments applied.

Methods

Study site and research plot construction

The study site is located near Yolyn, WV on the North Rum permit of the Apogee Coal mining complex. On this site, 16 one acre plots were established which represent 4 replicates of the soil/spoil type treatment blocks. Each block contains four substrate treatment types:

Type 1, Soil: Surface soil and organic matter down to the bedrock (O, A, E, B, C, R). The material included some stumps, roots, litter, but much of this material had been removed from the source area by grubbing prior to retrieval for reclamation. The soil material left after forest clearing was harvested and hauled to the reclamation area without any mixing or other manipulation of the soil layers, other than what occurred during excavation and placement. Because the forest vegetation had been cleared for some time prior to removal, it had become occupied by some non-forest species that had seeded into the area via natural processes.

Type 2, Brown/weathered sandstone: Weathered brown rock, usually found directly underneath the Type 1 Soil. This substrate is primarily sandstone but does contain some weathered siltstone and shale.

Type 3, Mix of weathered sandstone and gray overburden: This is approximately a 50/50 mix of the two general substrate types. The gray overburden is a mix of gray sandstone, siltstone or shale. Materials that should weather to soil-like materials with pH<7 were ideally selected.

Type 4, Gray/unweathered sandstone: This is primarily unweathered sandstone, but does contain some siltstone and shale.

Each block contained one replicate of each substrate treatment; treatments were placed randomly within blocks. Plots were constructed by Apogee Coal in winter 2011/2012 (Figure 1). As shown in Figure 1, Blocks 1-3 contained rectangular plots that were placed on a slope and Block 4 contained square subplots that (with the exception of the gray seeded plot) were placed on the flat, level surface adjacent above the slope. Because of spatial limitations, the gray seeded plot within Block 4 was placed such that approximately half of the plot was on a slope and half was on an upper flat area.

Figure 1. Plot diagram showing the arrangement of the four substrate treatments within the four blocks, the placement of the seeded/unseeded subplots, and the treatment areas (used by Apogee Coal for placement).

Soil and spoil analysis

Soils were sampled in March 2012 by a consulting firm hired by Apogee Coal and shipped to Virginia Tech. Apogee Coal personnel were requested to ensure that at least 10 subsamples, well distributed throughout each experimental plot, were obtained for each soil sample; and that each sub-sample was obtained to a depth of approximately 6 inches using consistent methods. Within Block 4, each of the 8 soil areas was sampled separately. These samples were maintained separately during the analysis, but results for each substrate type within Block 4 were combined by averaging for reporting below.

Samples were air-dried prior to analysis. Coarse fragment composition of substrates was determined by weighing total samples, sieving samples through a 2 mm sieve, and weighing all coarse fragments retained by the sieve. Percent coarse-fragment content was calculated for each sample as a mass ratio of coarse fragments to the full sample. Coarse fragments were then typed as weathered or unweathered sandstone, siltstone or shale, coal or organic fragments (roots, woody debris); and percent composition of each fragment type was calculated from mass.

Chemical analysis of soil fines (<2 mm fragments) was done by the on-site Virginia Tech Soil Testing Lab. Analysis included pH and measurement of extractable P, K, Ca, Mg, Zn, Mn, Cu, Fe, B, soluble salts and organic matter content using the lab's standard procedures developed for natural soils (Maguire and Heckendorn, 2009). Organic matter was determined by the loss-on-ignition method.

Tree planting and seeding of the study site

Each substrate treatment plot was divided into two ½ acre subplots, one of which was left unseeded, and the other hydroseeded with a mix of herbaceous species selected to exhibit low competition with the planted trees (Table 1). During hydroseeding, all subplots received a mix of mulch and fertilizer.

Table 1. Application rates of seeded species and soil amendments within seeded and unseeded subplots.

Species/amendment	Seeded	No seed
	Application rates (lbs/acre)	
Perennial grasses:		
Perennial Ryegrass	13	0
Timothy grass	6.7	0
Annual grasses:		
Annual ryegrass	6.6	0
Legumes (with innoculant):		
Birdsfoot trefoil	6.6	0
White clover	4	0
Fertilizer:		
Nitrogen (N)	17	17
Phosphorus (P)	63	63
Potassium (K)	17	17
Mulch:		
Cellulose fiber	500-670	500-670

Across the entire study site, a mix of tree species was planted in March 2012 by Williams Forestry & Associates using standard mine-site planting procedures (Table 2). Within plots, tree planting microsites were selected to avoid ridges/hummocks and hollows so that trees would not be buried or washed away as the substrate settled and eroded.

Table 2. The tree planting mix prescribed for planting all experimental areas.

Species	Trees per acre
White Oak(WO)	100
Northern Red Oak(RO)	100
Chestnut Oak(CO)	100
Sugar Maple(SM)	100
Black Cherry(BC)	100
Tulip Poplar	50
Shagbark Hickory(SH)	50
Hawthorn(H)	25
Eastern Redbud(RB)	25
Gray Dogwood(GD)	25
Eastern White Pine(EWP)	25

Vegetation sampling

Establishing permanent plots

In June 2012, permanent tree and herbaceous plots were established. Within each of the 32 seeded/unseeded subplots, a transect was established in the direction of the slope directly in the middle of the subplots.

To assess tree survival and growth, we sampled 1/20 acre (1/50 ha) circular subplots to sample approximately 30% of the study site. The entire length of the sloped seeded/unseeded subplots was approximately 300 feet. To insure sampling all key areas of the sloped plots, avoid sampling edge areas, and facilitate finding plots in the future, we established tree plots at 75, 150 and 225 feet from the top of the plot, with tree plots approximately centered within each subplot. At each sampling point, a ½ inch, 4 foot re-bar post was hammered into the ground to mark the center of the plot. The plot radius to achieve 1/50 hectare plots was 8 m.

Within each of the non-sloped subplots (Block 4), three 1/50 ha circular tree plots were established to distribute them evenly throughout the area, Because of spatial limitations, the non-sloped subplots were square-shaped, which required the tree plots to be placed in a triangular arrangement. The location of each of the triangle points was consistent within all of the non-sloped subplots to minimize effects from tree plot placement.

We established four herbaceous plots within each tree plot. Herbaceous plots are 1 m^2 square plots nested within tree plots. Plots were halfway between the plot center and the plot edge (4 m from center) and were placed directly upslope and down-slope of the plot center, as well as to the right and left across the slope of the tree plot.

Vegetation sampling methods

To measure the trees within the plot, an 8 m long rope was attached to the re-bar at the plot center and measuring began at the trees immediately upslope of the tree plot center. The purpose of measuring the trees sequentially was to keep track of individual trees. After tree survival has become fairly constant, trees will be tagged with specific numbers for repeated measures.

Initial measurements in June 2012 were survivorship and "initial" height, which was determined by measuring from the ground up to the base of the current year's new growth. If trees had fallen down, they were picked up and measured as though they were still standing to better assess initial planted height. Dead trees were also recorded and measured. Trees will be measured again at the end of the growing season (October) to determine total annual growth.

The first herbaceous plant sampling occurred in June 2012 when species presence/absence of all seeded and volunteer species was recorded. Herbaceous plots were sampled again in late July 2012. For both sampling dates, a 1 m x 1 m quadrat was centered over the herbaceous plot center, and all herbaceous species within the quadrat were identified and noted. For peak season sampling in July 2012, percent cover of each species was estimated using a visual cover estimate aid. Percent cover was estimated in cover classes (0, 1-10, 11-30, 31 to 50, 51 to 70, 71 to 90 and 91 to 100) to reduce individual bias. Plants of unknown species were collected and are in the process of identification in the Massey Herbarium at Virginia Tech.

Tree Survival Assessment

Tree survival was assessed while measuring initial height and was on a scale from 0 to 1. Values of 0 indicated the tree was dead, values of 1 indicated the tree was alive and healthy, and values of 0.5 were given when trees were alive but appeared unhealthy or dying. Percent survival was calculated by adding up all scaled survival values for each species within each tree plot, dividing the resulting sum by the total number of trees of the same species within that tree plot, and multiplying by 100.

Preliminary Results

Preliminary results are reviewed below. Because results have not been analyzed statistically, all comparisons are nominal at this stage of the project.

Coarse fragment contents were less than 50% for all treatments, and were lowest for the soil treatment. All treatments contained > 50% weathered rock (Tables 3a and 3b).

Soil pH was lowest for the soil treatments. Three of the 4 soil plots had pH's of <5.5, but the 4th had an anomalously high pH of 7.5. Extractable nutrient values must be interpreted cautiously, understanding the acidic extractant used by the Virginia Tech soil testing lab, which is intended for use with natural soils, can release nutrients from unweathered spoils that may not be plant-available in the short term.

Table 3a. Actual structure and general composition of substrate treatments.

Substrate type	Block	Coarse fragment (CF) %	Mean CF %	Weathered rock (W) %	Mean W %	Unweathered rock (UW) %	Mean UW %
Brown	1	43.18	42.65	74.18	69.31	22.74	28.62
Brown	2	44.87		84.76		14.58	
Brown	3	44.79		81.67		16.44	
Brown	4	37.78		36.64		60.74	
Gray	1	47.10	43.40	62.02	63.19	37.57	35.33
Gray	2	31.35		60.64		36.44	
Gray	3	46.91		78.83		20.17	
Gray	4	48.23		51.28		47.14	
Mix	1	43.94	46.06	57.55	66.04	42.07	33.22
Mix	2	47.94		60.96		38.58	
Mix	3	46.95		83.80		15.57	
Mix	4	45.41		61.86		36.67	
Soil	1	33.97	32.78	76.95	70.34	22.48	27.29
Soil	2	38.67		78.85		18.27	
Soil	3	24.59		80.07		17.07	
Soil	4	33.87		45.49		51.33	

Table 3b. Actual rock type composition of substrate treatments.

		Weathered			Unweathered				
Substrate type	**Block**	**Sandstone %**	**Siltstone %**	**Shale %**	**Sandstone %**	**Siltstone %**	**Shale %**	**Coal fragment %**	**Organic fragment (%)**
Brown	1	57.97	12.03	4.17	12.64	5.62	4.48	3.07	0.01
Brown	2	76.12	4.65	4.00	4.33	4.20	6.05	0.66	0.00
Brown	3	68.02	7.19	6.47	1.56	9.83	5.05	1.89	0.00
Brown	4	23.41	6.86	6.37	15.04	20.19	25.52	2.57	0.04
Gray	1	55.45	4.34	2.23	27.22	5.03	5.32	0.41	0.00
Gray	2	49.66	6.00	4.97	9.93	12.70	13.81	2.92	0.00
Gray	3	52.46	14.43	11.94	4.30	8.58	7.29	0.99	0.01
Gray	4	43.21	3.57	4.50	22.28	6.28	18.57	1.56	0.02
Mix	1	48.93	4.27	4.34	9.51	13.80	18.76	0.28	0.10
Mix	2	56.18	2.70	2.08	6.29	16.30	15.99	0.46	0.00
Mix	3	77.46	3.31	3.03	9.21	4.64	1.72	0.63	0.00
Mix	4	51.34	5.37	5.15	11.92	7.91	16.85	1.44	0.02
Soil	1	34.82	7.87	34.26	1.12	8.58	12.78	0.48	0.09
Soil	2	49.05	15.69	14.11	3.76	8.76	5.75	2.88	0.00
Soil	3	53.83	17.65	8.59	1.45	9.15	6.48	2.80	0.06
Soil	4	18.83	13.43	13.23	15.70	18.49	17.15	3.15	0.03

Table 4. Soil, properties, as determined by Virginia Tech Soil Testing Laboratory.

Block	Substrate Type	pH	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B	OM (%)	SS (ppm)	CEC meq/ 100g
			mg/kg											
1	Brown	8.0	40	49	932	206	3	76	2.3	123	0.1	1.0	77	6.5
2	Brown	7.6	44	44	557	212	2	54	1.4	76	0.1	0.8	115	4.6
3	Brown	7.7	40	71	679	243	4	66	3.4	84	0.1	1.1	102	5.6
4	Brown	6.0	23	55	478	168	3	27	3.0	65	0.1	1.2	103	4.2
	Mean	7.3	37	55	661	207	3	56	2.5	87	0.1	1.0	99	5.2
1	Gray	7.8	37	59	1012	268	2	86	1.9	177	0.1	1.1	64	7.4
2	Gray	8.2	41	43	631	184	2	55	2.1	118	0.1	1.0	77	4.8
3	Gray	7.8	39	71	759	226	3	58	2.5	80	0.1	1.4	90	5.8
4	Gray	7.4	39	41	561	153	2	41	1.5	135	0.1	0.9	115	4.2
	Mean	7.8	39	54	741	208	2	60	2.0	127	0.1	1.1	87	5.5
1	Mix	6.8	36	57	615	207	2	58	2.3	121	0.1	1.1	77	4.9
2	Mix	8.0	37	48	690	201	3	68	2.4	114	0.1	0.8	64	5.2
3	Mix	7.2	33	31	460	161	1	29	1.0	45	0.1	0.7	38	3.7
4	Mix	6.3	19	39	336	138	2	33	1.5	61	0.1	0.9	58	2.9
	Mean	7.1	31	44	525	177	2	47	1.8	85	0.1	0.9	59	4.2
1	Soil	5.3	14	46	367	151	2	23	2.2	60	0.1	1.5	26	6.1
2	Soil	7.5	41	62	846	243	2	64	2.4	151	0.1	1.1	166	6.4
3	Soil	5.1	15	68	204	130	2	40	2.4	53	0.1	1.0	51	3.8
4	Soil	5.5	19	65	291	182	4	31	4.4	55	0.1	1.4	64	4.0
	Mean	5.8	22	60	427	177	2	39	2.9	80	0.1	1.3	77	5.1
Grand Mean		7.0	32	53	589	192	2	50	2.3	95	0.1	1.06	80	5.0

Table 5. Actual tree density (trees per acre) observed in research plots. Nominal survival is the ratio of trees observed to trees prescribed.

Species	Trees planting prescription	Trees observed in June 2012	Nominal Survival
White Oak(WO)	100	105.6	106%
Northern Red Oak(RO)	100	80.2	80%
Chestnut Oak(CO)	100	84.2	84%
Sugar Maple(SM)	100	81.7	82%
Black Cherry(BC)	100	89.6	90%
Shagbark Hickory(SH)	50	31.9	64%
Tulip Poplar(TP)	50	41	82%
Hawthorn(H)	25	23.1	92%
Eastern Redbud(RB)	25	24	96%
Gray Dogwood(GD)	25	25	100%
Eastern White Pine(EWP)	25	18.5	74%
Overall	700	604.8	86%

Actual tree density was calculated by dividing the total number of each tree species by the total number of acres surveyed (32 1/20 acre plots, or 4.8 acres). Data are presented in the number of trees observed on average per acre (Table 5, Figure 2). It should be noted that this tree density is based on trees observed in June 2012, but because some trees may have washed away in between planting and sampling, this may be an underestimate of trees actually planted. Furthermore, survivorship is likely skewed, particularly in plots that had more erosion, as these plots lost trees that were unknown and therefore unaccounted for.

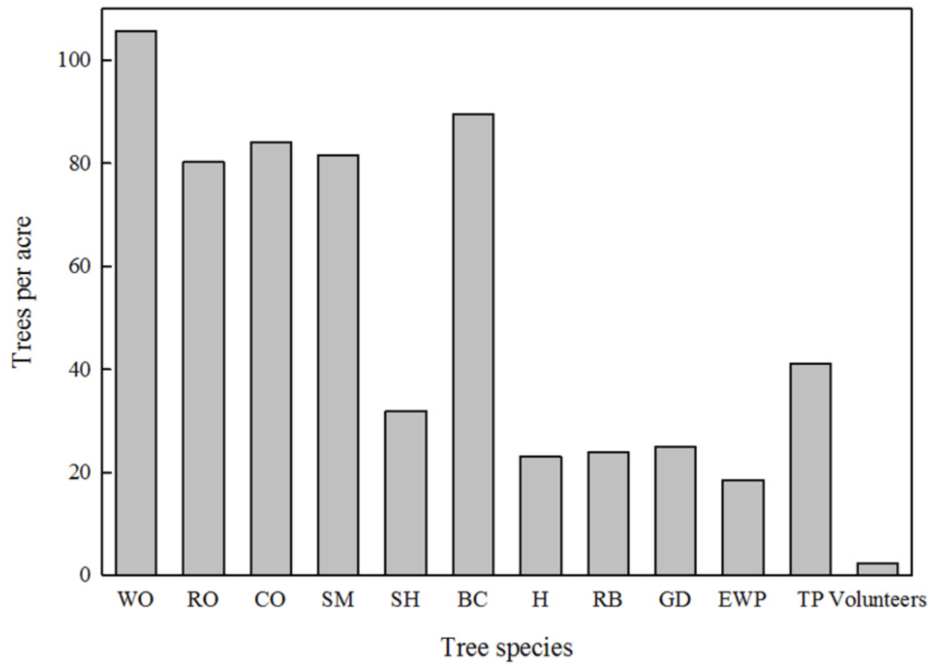

Figure 2. Actual density of each tree species as well as total volunteer trees on the per acre basis.

Observed tree density was generally similar to tree planting prescriptions, with the exception of shagbark hickory (64%) and eastern white pine (74%). Nominal survival for all other tree species exceeded 80%, and averaged 86% across all species. (Table 5). Volunteer species included striped maple, red maple, sycamore, black locust, sweet birch and black oak. The most common volunteer species (5 of 11 volunteer trees) was black locust.

Preliminary analysis found no significant main effects of soil type or seeding treatment on tree survival ($\alpha = 0.05$). Presented here are mean survival data for each planted tree species across all treatments (Figure 3). Eastern white pines had much lower survival than any other species, but this increased mortality was similar across treatments suggesting a possibility of problems with the planting stock as a cause of mortality.

Future tasks

Currently, vegetation samples from the herbaceous sampling periods in June and July 2012 are being identified to species in the Virginia Tech Herbarium. Once all samples are indentified, herbaceous data will be analyzed.

A few plots had much more erosion (observed deep gullies) and had minimal to non-existent vegetation as well as decreased seedling survival. In October 2012, tree plot slope and roughness will be quantified to assess whether these factors are related to decreased establishment of vegetation.

Herbaceous plots will be sampled twice a year, in June and July/August 2013 to capture the diversity of early and late season vegetation. Tree plots will be sampled in October 2012 for survival, total stem height and stem diameter.

Our ability conduct future monitoring of this site over the longer term, as will be required to achieve project goals, is dependent on availability of future funding that can be used for this purpose.

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Reference

Maguire, R., and S. Heckendorn. 2009. Laboratory Procedures: Virginia Tech Soil Testing Laboratory. Virginia Cooperative Extension Publication 452-881.