Carbon Sequestration on Surface Mine Lands

Quarterly Report

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ABSTRACT

A monitoring program to measure treatment effects on above ground, and below ground carbon and nitrogen pools for the planting areas is being conducted. The collection of soil and tissue samples from both the 2003 and 2004 plantings is complete and are currently being processed in the laboratory. Detailed studies have been initiated to address specific questions pertaining to carbon cycling. Examinations of decomposition and heterotrophic respiration on carbon cycling in the reforestation plots were continued during this reporting period. A whole-tree harvesting method was employed to evaluate carbon accumulation as a function of time on the mined site. The trees were extracted from the sites and separated into the following components: foliage, stems, branches, and roots.

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INTRODUCTION

EXECUTIVE SUMMARY

Field sampling has been completed for the 2004 growing season on all plots established in 2003 and 2004. Density measurements are complete as are the whole tree harvesting that was initiated this year. Hydrologic data is continuing to be monitored as well as weather station data. The analyses of all the data is being processed in preparation of the submission of the annual report in December 2004. The project is attracting much national attention and has been the basis for the formation of the Appalachian Regional Reforestation Initiative. (See appendix 1 pgs. 10-13) The site was visited by the over 100 soil scientists during the 24th Central State Forest Soils Workshop on October 12-14, 2004, in Hazard, Kentucky. Presentation of the project will also be a portion of the gathering to sign the statement of mutual intent at Roanoke West Virginia in December 2004.

EXPERIMENTAL

A monitoring program to measure treatment effects on above ground and below ground carbon (C) and nitrogen (N) pools for the planting areas is currently underway. Sample plots that were established in 2003 are currently being assessed to determine change from previous year (biomass, carbon and nutrients). The plots were designed in a manner to both adequately sample such species planted and to account for differences with respect to site preparation activities and micro-topographic variability amongst planting units. Additional plots were developed this spring/summer to be used to assess the 2004 plantings, and will be monitored in a fashion similar to those plots established in 2003 (Graves et al., 2003). Collection of soil and tissue samples from both the 2003 and 2004 is complete and the samples are currently being processed/analyzed in the laboratory. Results from these activities will be presented in the 2004 Annual Report.

Mineland Reforestation Mycorrhizae Study

Detailed studies to address specific questions pertaining to carbon cycling have been initiated with the development of additional manipulative plots to examine the influence of mycorrhizae, spoil chemical and mineralogical properties, and use of amendments on forest establishment and carbon sequestration. A factorial experiment using inoculated vs. non-inoculated species in non-fertilized, fertilized only, amended (organic mulch) only, and fertilized + amended plots was established in 2004 and described in the 6th Quarter Report (Graves et al., 2004).

The research plots were established on mined sites in Knott and Muhlenberg Counties, KY. Fifty-four 15 x 15 meter plots were delineated on each site. Prior to planting, each site was ripped to a depth of approximately 2-meters using a dozer. Half of the area received an application of 40 tonnes per acre of a wood chip/manure compost mixture (Figures 1-3). The composted areas were subsequently ripped again to incorporate the material into the spoil.

Two tree species; *Pinus taeda* (Loblolly Pine) and *Quercus rubra* (Northern Red Oak), were planted in the plots. Each plot received 100 seedlings spaced at 1.5 meter centers. Each treatment will be examined in triplicate for each species. At 100 trees per plot x 3 plots per treatment x 8 treatments x 2 species, 4,800 seedlings were planted per site. Additional plots with no trees planted were established as controls and to evaluate potential for carbon sequestration on sites planted with grass species. Half of the seedlings from each plot were tagged and measured (height, diameter and leaf area). These trees will be evaluated each year for growth and survival statistics. Soil samples were also collected from the sites during the last reporting period and are currently being analyzed. Whole tree harvesting and tissue samples will be collected from non-tagged seedlings of each treatment in 2005.

Decomposition and Soil CO₂ Efflux

Efforts to examine decomposition and heterotrophic respiration on C cycling in the reforestation plots continued during this reporting period. Litter bag and permeable column installation was completed during this reporting period. Litter bags (20 x 20 cm with 10 g of leaf material) were placed at random in selected plots within the reforestation area and on undisturbed forested sites. Each plot (6 total: 3 mined and 3 natural) received 24 bags which were stapled to the surface soil using steel rods. Three bags from each site will be collected every three months, weighed and analyzed for C and N concentrations. In addition, permeable columns were inserted into the soil at each site (15 cm depth) in close proximity to the litter bags to evaluate carbon change over the same study period. The columns consisted of a homogenized spoil material with known C and N concentrations contained within a nylon bag. The spoil will be influenced by all climatic and biological activities subjected to original material located at the sites, and thus should be a good indicator of changes in soil carbon and nutrient levels. Columns will be removed at the same time and frequency as described for the litter bags. PVC collars that were installed at these sites to evaluate soil CO₂ efflux using a LI-COR LI-8100 Automated Soil CO₂ Flux System were monitored monthly throughout this reporting period. Litter collectors were also placed in the field at each plot during this reporting period and are being collected monthly. Litter from the collectors is removed, dried, weighed, and separated to determine % species present and analyzed for total C and N.

Whole-Tree Harvesting

A chronosequence approach was initiated to evaluate carbon accumulation as a function of time on the mined sites. Since the trees planted during this study are only 1 and 2 years of age, we looked to older stands within the same planting area that used the same reclamation practice to provide information for older sites. We can use this data to project a trajectory that the planted areas may follow with respect to C and biomass accumulation as they grow. A whole-tree harvesting method was employed for this approach where trees were extracted from the sites and separated into the following components: foliage, stem, branches, and roots. Biomass estimates of the various components were obtained in the field and samples from each fraction were collected for chemical analyses. Four tree species (*Platanus occidentalis*: Sycamore, *Fraxinus Americana*: White Ash, *Quercus alba*: White Oak, and

Liriodendron tulipifera: Yellow Poplar) representing 3 age classes (1, 2, and 7 years of age) on loose spoil material were examined. The trees were manually and randomly sampled by using a chain saw and shovels (Figure 1). The root collar diameter (RCD), crown height and width, and seedling height were measured prior to harvest. The trees were then subdivided into the 4 tree components and weighed using a portable analytical scale and a heavy-duty hanging scale. Subsamples of each tree component were taken to the laboratory where leaf area, dry weight, and physical and chemical analyses were, or will be, performed. All samples were washed and rinsed with deionized water, oven-dried, ground in a mill, and prepared for further analyses such as total C, total N, total organic C, pH, EC, nutrients, and trace elements. In addition, bulk and rhizosphere soils were collected for each age class and species sampled and will be analyzed for a similar suite of elements.

a. One-year-old Sycamore b. Two-year-old Sycamore c. Seven-year-old Sycamore

Figure 1. One (a), two (b), and seven-year-old (c) Sycamore were manually and randomly harvested by using a chain saw and shovels.

Water quantity and quality data was monitored and collected during the period. A detailed topographical survey was conducted on the research sites and GPS locations were established for all the installations. Two separate computer programs were developed to process raw data generated from the Mini Troll devices and rain gauges. Those variables monitored and qualified were: turbidity, settleable solids, suspended sediment concentrations, particle size distribution, rain events and run off flow quantities. The Department of Mining Engineering collected penetration resistance, penetration depth and bulk density data from the reclamation test cells. Data was collected from the following areas:

- Gibraltar Mine

Cell 8 (dragline area), 8 sample plots 2500 sq.meters each.

Collected data: 32 samples of penetration resistance, 32 samples of penetration depth, 32 samples of bulk density at 2 inches depth, 32 samples at 6 inches depth, and 32 samples at 12 inches depth. (See appendix 2, pg. 14)

Cell 12 (Nelson)

Collected data: 48 samples of bulk density at 2 inches depth, 48 samples at 6 inches depth, and 48 samples at 12 inches depth for horse manure plots. 48 samples of bulk density at 2 inches depth, 48 samples at 6 inches depth, and 48 samples at 12 inches depth for non-manure plots. (See appendices 3 & 4 pgs. 15-16)

- Laurel Fork:

Mycorrhizae Plots

Collected data: 32 samples of bulk density at 2 inches depth, 32 samples at 6 inches depth, and 32 samples at 12 inches depth for horse manure plots. 32 samples of bulk density at 2 inches depth, 32 samples at 6 inches depth, and 32 samples at 12 inches depth for non-manure plots. (See Appendices 5-6, pgs. 17-18)

Analysis data is currently in progress. The results of this analysis will be available for the next quarterly report.

RESULTS AND DISCUSSIONS

As a result of this research, the U.S. Office of Surface Mining has recently started a federal reforestation effort called the “Appalachian Regional Reforestation Initiative”. The APRI is a partnership between OSM and the State of Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia whose purpose is to promote and encourage the restoration of coal mined lands on a regional level. (See Appendix 1, pgs. 10-13)

The members of the Appalachian Regional Reforestation Institute will be meeting in Roanoke, West Virginia on December 14, 15, 16, 2004 to sign a Statement of Mutual Intent stating that they desire to work together to promote and encourage planting more trees on active and abandoned coal mine lands. This event will take place at the Stonewall Resort in Roanoke, West Virginia during the afternoon of December 15, 2004. This is a major event that marks the beginning of an era of mutual agreement that has not existed in a number of years.

CONCLUSIONS

No conclusions can be drawn at this time since one third of the project has not been completed.

STATEMENT OF MUTUAL INTENT

for the

APPALACHIAN REGIONAL REFORESTATION INITIATIVE

The States of Appalachia including the Regulatory Authorities in Kentucky, Maryland, Ohio, Pennsylvania, Virginia, and West Virginia; the Office of Surface Mining, including the Tennessee Federal Program; and all other parties of this Statement of Mutual Intent desire to work together to promote and encourage planting more trees on active and abandoned coal mined lands. We will increase efforts, cooperate and partner among ourselves to plant economically viable trees, while using current Forestry Reclamation Approach (FRA) technology. This technology will increase survival rates and growth rates of crop trees, increase overall productivity, and promote natural invasion and succession of plant and animal communities.

FRA technology is a five-step reclamation process that has been proven by forestry research to increase tree survival and tree productivity. The five steps in the FRA are:

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 substitutes established in step one to create a non-compacted growth medium.
3. Use native and non-competitive 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.

Reforestation of coal mined land using the FRA will provide multiple environmental and economic benefits:

Environmental Benefits of Reforestation

- Increased diversity of plant succession
- Natural succession of native forest plants
- Reduced potential for establishment of invasive species

- Enhanced wildlife habitat
- Soil and water conservation
- Recovery of the hydrologic balance
- Improvement of overall water quality
- Carbon sequestration

Economic Benefits of Reforestation

- Increased timber value
- Landowner tax reduction
- Recreational areas
- Jobs for the local economy
- Local tax revenue
- Reforestation provides an economically viable post mining land use option for both the landowner and the mining company

I. OBJECTIVES

- Establish and implement a reforestation program within each of the seven Appalachian Region States that promotes the FRA during reclamation of active coal mining operations and abandoned mined lands projects.
- Raise the awareness level of government agencies, private organizations, and general public on economic and environmental benefits associated with planting quality trees using FRA technology.
- Work with Federal, State, and local government agencies, mining companies, environmental groups, industry groups, academia and other public and private organizations to identify landowners and mining companies that will utilize the current FRA technology in reclamation.
- Provide a forum to transfer technology and other information concerning the creation of highly productive forestland and related environmental assets and cooperate as a clearinghouse to share data and information as it relates to current FRA technology.
- Apply FRA technology for growing quality trees while supporting the development of new technologies.
- Prepare periodic reports to describe the current status, success and increased productive tree planting efforts of projects using the FRA technology by all parties to the Statement of Mutual Intent.
- Promote the establishment of native forest species.

II. ACCOMPLISHMENTS (or SUCCESSES)

- Provide FRA training to State and Federal regulatory personnel for active and abandoned coal mined lands.
- Achieve public outreach and FRA training to the coal industry located in the States represented by this Statement of Mutual Intent.
- Achieve public outreach and FRA training to all other interested parties located in the States represented by this Statement of Mutual Intent.
- Increase the number of trees planted using FRA technology in the States represented by this Statement of Mutual Intent.
- Identify incentives to promote reforestation on coal mined lands.

III. GENERAL PROVISIONS

- A. We will carry out all activities in this Statement of Mutual Intent in full compliance with applicable State and Federal laws and regulations.
- B. Any party may withdraw from this Statement of Mutual Intent by notifying the other parties in writing.

IV. SIGNATURES

STATEMENT OF MUTUAL INTENT
APPALACHIAN REGIONAL
REFORESTATION INITIATIVE
December 15, 2004

(Signature)

{ _____
(Print Name)

(Affiliation)

(Address)

(Signature)

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(Print Name)

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(Print Name)

(Affiliation)

(Address)

Appendix 2

SPOIL COMPACTION FIELD DATA <i>Gibraltar Mine - dragline area</i> (8 sample tests x 4 corners)									
Collection Dates: 07/07/2004									
Sample	Density @ 12" Penetration Depth (pcf)			Density@6" Depth (pcf)			Density@2" Depth (pcf)		
Number	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density
1	123	21.3	101.7	120.6	20.6	100	100.8	22.8	78
2	138.5	22.4	116.1	124.1	11.9	112.2	111.6	15.2	96.4
3	133.7	22.9	110.8	121	12.5	108.5	112.7	11.4	101.3
4	141.9	17.6	124.3	124.4	22	102.4	105	11.7	93.3
5	134.8	22.4	112.4	130.3	15	115.3	111.7	12.1	99.6
6	130.4	25.5	104.9	123.5	13.7	109.8	115.5	14.3	101.2
7	131.4	22	109.4	116.6	12	104.6	107.8	12	95.8
8	127.3	18.6	108.7	122.6	20.6	102	124.9	25.6	99.3
9	127.2	15.3	111.9	123.8	22.9	100.9	124.5	28.1	96.4
10	126.4	21.5	104.9	128.7	26.3	102.4	113.9	23.2	90.7
11	132	18.2	113.8	120.1	15	105.1	118.3	18.7	99.6
12	128.7	17.9	110.8	125.2	16.3	108.9	102.9	17.4	85.5
13	121.3	14.3	107	124.4	19.2	105.2	111.3	18.2	93.1
14	123.9	13.3	110.6	127	14.5	112.5	107	9.8	97.2
15	114.8	17	97.8	128.3	11.9	116.4	100.6	10.6	90
16	133.7	15.8	117.9	120.6	23.3	97.3	115.5	15.8	99.7
17	132	17.7	114.3	115.2	15.4	99.8	102.3	11	91.3
18	125.9	14.6	111.3	127.9	12.8	115.1	99.8	10.1	89.7
19	134.2	19.5	114.7	119.5	16.7	102.8	113.6	17.3	96.3
20	130.1	11.2	118.9	126.4	12.4	114	98.4	10.3	88.1
21	125.5	22	103.5	125.6	27.7	97.9	117.5	25.1	92.4
22	128.9	14.8	114.1	120.3	20.7	99.6	99.8	19.1	80.7
23	132.6	13.1	119.5	115.9	28.6	87.3	107.6	26.2	81.4
24	133.4	16.1	117.3	128.5	16.5	112	109.5	11.8	97.7
25	130.8	22.4	108.4	123.1	14.8	108.3	112.2	9.6	102.6
26	131.7	14.5	117.2	136.6	22.3	114.3	107.8	15.7	92.1
27	128.5	16.4	112.1	120.4	18.2	102.2	115	13.4	101.6
28	129.7	21.2	108.5	133.7	28.3	105.4	126	27.4	98.6
29	134.6	14.6	120	128.5	14.1	114.4	105.3	19	86.3
30	128.1	12.1	116	130	19	111	112.7	18.5	94.2
31	128.5	14	114.5	124.7	16.9	107.8	102.4	13.2	89.2
32	133.3	23.2	110.1	119.8	19.4	100.4	107.6	15.1	92.5
AV			112.0			106.1			93.5
Std.dev			5.8			6.7			6.4

Appendix 3

SPOIL COMPACTION FIELD DATA										
Gibraltar Mine - Nelson Creek										
Non-Mycorrhizae Plots										
Collection Dates: 07/23/2004										
Plot	Sample	Density @ 12" Penetration Depth (pcf)			Density@6" Depth (pcf)			Density@2" Depth (pcf)		
#	#	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density
1	1	123	15.9	107.1	117.6	16.3	101.3	102.7	15	87.7
	2	114.9	20.2	94.7	111	20.5	90.5	103.1	20.1	83
2	1	124	12.6	111.4	113.3	12.1	101.2	94.9	11.4	83.5
	2	115.8	13.9	101.9	112.1	13.6	98.5	99.6	14.3	85.3
3	1	134.8	22.9	111.9	125.7	23.5	102.2	114	21.9	92.1
	2	122.8	13.4	109.4	105.6	14.1	91.5	100.2	14.2	86
4	1	120.5	13	107.5	106.9	13.7	93.2	91.3	13.7	77.6
	2	113.1	12.4	100.7	106.5	12.4	94.1	87.8	12.6	75.2
5	1	121.8	18.7	103.1	114.5	19.4	95.1	111	20.4	90.6
	2	112.5	20.6	91.9	111	20.1	90.9	100.5	21.3	79.2
6	1	116.9	19.3	97.6	110.3	19.5	90.8	104.9	18.3	86.6
	2	107.3	12.5	94.8	97.8	12.6	85.2	95.3	12.3	83
7	1	119	11.8	107.2	107	13	94	107.4	17.4	90
	2	123.2	18.4	104.8	115.6	18.4	97.2	111.4	19.1	92.3
8	1	116.9	15.6	101.3	100.4	15.3	85.1	92.5	15.4	77.1
	2	121.6	16.7	104.9	107	16.6	90.4	93.1	16.5	76.6
9	1	118	12.8	105.2	112	13.3	98.7	105.6	14.6	91
	2	126.5	15.5	111	120.7	16.6	104.1	110.3	15.4	94.9
19	1	95.9	14.5	81.4	88.6	14.3	74.3	89.4	15.6	73.8
	2	104.9	19.8	85.1	95.6	20.9	74.7	86	18.9	67.1
20	1	118.2	16.2	102	115.8	16.4	99.4	105.4	15.4	90
	2	104.2	12.9	91.3	99.5	12.2	87.3	104.1	13.4	90.7
21	1	95.9	7.4	88.5	86.3	7.1	79.2	84.4	7.1	77.3
	2	129.6	9.5	120.1	112.1	10.6	101.5	95	10.2	84.8
22	1	114.3	11.8	102.5	113.5	10.9	102.6	96.4	12.4	84
	2	109	7.1	101.9	97.6	8	89.6	97.7	7.4	90.3
23	1	128.4	12.6	115.8	118.1	12.6	105.5	101.7	13.5	88.2
	2	126.9	13.1	113.8	123.3	12.5	110.8	107.6	11.4	96.2
24	1	106.3	10	96.3	100.6	12.1	88.5	92.3	11.3	81
	2	103.7	9.4	94.3	98	9.5	88.5	102.2	9.8	92.4
31	1	121.4	11.3	110.1	116.1	11.3	104.8	103.0	12.5	90.5
	2	109.2	8	101.2	102.9	7.5	95.4	80.4	7.9	72.5
32	1	103.5	8.6	94.9	96.8	8.4	88.4	91.4	8.9	82.5
	2	107.5	9.5	98	101.9	10.3	91.6	95	9.6	85.4
33	1	129.9	9.9	120	122.2	12.1	110.1	107.1	12.5	94.6
	2	116.9	10.2	106.7	104.6	11.2	93.4	107.4	11	96.4
34	1	119.5	7.8	111.7	105.8	8.1	97.7	92.8	8	84.8
	2	107	8.4	98.6	109.7	8.4	101.3	98.1	8.1	90
35	1	108	10.8	97.2	105	12	93	93.8	11.2	82.6
	2	118.7	10.4	108.3	112.1	11.2	100.9	95.8	10.9	84.9
36	1	130.8	9	121.8	120.7	9.2	111.5	109.1	9.4	99.7
	2	106.5	8.7	97.8	92.6	9.7	82.9	91.5	8.6	82.9
37	1	110.1	10.1	100	98.4	9.4	89	94.5	9.9	84.6
	2	107.8	13.7	94.1	102.3	13	89.3	95	13.9	81.1
38	1	105.2	5.5	99.7	110	6.5	103.5	105.6	6.3	99.3
	2	120.4	8.2	112.2	105.3	9	96.3	97.6	8.5	89.1
39	1	102.7	7.2	95.5	94.6	7.3	87.3	84.3	8.1	76.2
	2	117.5	9.4	108.1	97.9	9.5	88.4	91	9.8	81.2
AV				102.8			94.4			85.5
Std.dev				8.9			8.5			7.2

Appendix 4

SPOIL COMPACTION FIELD DATA <i>Gibraltar Mine - Nelson Creek</i> <i>Mycorrhizae Plots</i>										
Collection Dates: 07/23/2004										
Plot	Sample	Density @ 12" Penetration Depth (pcf)			Density@6" Depth (pcf)			Density@2" Depth (pcf)		
		Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density
10	1	123.2	25.5	97.7	118	24.5	93.5	103.7	25.3	78.4
	2	123.1	23.4	99.7	104.7	23.5	81.2	80.6	25	55.6
11	1	125.6	19.7	105.9	115.1	21.2	93.9	94.4	20.1	74.3
	2	123	23.9	99.1	112.1	24	88.1	92.9	22.7	70.2
12	1	123.6	23.6	100	115.6	23.6	92	83.1	22.3	60.8
	2	120.9	20.9	100	109.5	21.8	87.7	74.1	20.7	53.4
13	1	126.1	20.6	105.5	120.9	22.2	98.7	95.2	21	74.2
	2	126.9	23.3	103.6	119.2	22.5	96.7	95.8	23.2	72.6
14	1	115	11.2	103.8	100.7	14.4	86.3	70.6	13.7	56.9
	2	110.5	10.3	100.2	102.7	10.5	92.2	79.7	11.4	68.3
15	1	105.6	16	89.6	88.2	15.9	72.3	73.9	16	57.9
	2	123.6	18.8	104.8	105.8	17.6	88.2	79.3	19.4	59.9
16	1	112.2	21.4	90.8	94.7	22	72.7	72.9	21.1	51.8
	2	124	19.1	104.9	113.6	20.2	93.4	94.8	17.4	77.4
17	1	111.2	18.1	93.1	108	18.4	89.6	84.9	17.3	67.6
	2	126.5	18	108.5	114.8	20	94.8	84.5	18.9	65.6
18	1	110	11.8	98.2	104.3	12.5	91.8	89.8	13.1	76.7
	2	102.1	13.9	88.2	89.5	14.2	75.3	76.3	12.8	63.5
25	1	131.4	13.5	117.9	121.4	15.9	105.5	100	16.5	83.5
	2	108.4	6.4	102	92.7	5.7	87	82.8	5.7	77.1
26	1	105	8	97	92	6.3	85.7	81.5	6.4	75.1
	2	97.6	8.1	89.5	93.3	7.8	85.5	85.1	8.5	76.6
27	1	107.1	10.7	96.4	100.4	9.8	90.6	91.8	10.2	81.6
	2	108.7	14.4	94.3	99.7	10.2	89.5	91.7	14.4	77.3
28	1	111.9	13.5	98.4	107.1	12.1	95	94.7	15.4	79.3
	2	115.1	19.5	95.6	107.6	19.5	88.1	95.1	18.7	76.4
29	1	109.6	11.3	98.3	99.6	11.4	88.2	78.9	12.2	66.7
	2	121.6	21.1	100.5	115.6	21.7	93.9	97.2	21.8	75.4
30	1	124.6	16.7	107.9	109.1	17.9	91.2	68	18	50
	2	117.3	13.2	104.1	106.9	11.1	95.8	95.6	11.4	84.2
40	1	91.6	10	81.6	68.7	9.7	59	67.7	9.2	58.5
	2	92.4	11.5	80.9	85.5	11.2	74.3	63.2	11.9	51.3
41	1	99.8	11.6	88.2	92.2	11.1	81.1	76.6	11.8	64.8
	2	97.4	12.5	84.9	76.5	12.5	64	69.5	12.8	56.7
42	1	107.1	6.8	100.3	95.9	8	87.9	81.5	8.7	72.8
	2	105.2	13.2	92	108.8	15.7	93.1	86.4	15.3	71.1
43	1	116.1	19.6	96.5	108.3	21.1	87.2	88.1	20.3	67.8
	2	95.9	9	86.9	84.9	8.3	76.6	64.8	8.5	56.3
44	1	103.9	7.5	96.4	94.1	7.2	86.9	92.7	7.1	85.6
	2	120.4	14.2	106.2	113	16.6	96.4	94	15.9	78.1
45	1	105.9	7.5	98.4	88.4	8.8	79.6	93.6	8	85.6
	2	124	14.8	109.2	109.9	13.6	96.3	88.1	12.7	75.4
46	1	90.3	10.7	79.6	78.7	10.7	68	79.2	11.9	67.3
	2	108.4	8.1	100.3	102.8	6.9	95.9	94.3	7.1	87.2
47	1	125.6	18.1	107.5	115.8	19.2	96.6	93.8	19	74.8
	2	116.6	14.6	102	94.4	13.9	80.5	82.1	13.9	68.2
48	1	103.8	11.4	92.4	92.9	11.1	81.8	83.9	11.8	72.1
	2	90.5	6.4	84.1	82	6.3	75.7	88.9	6.8	82.1
AV				97.6			86.8			70.1
Std.dev				8.2			9.5			10.1

Appendix 5

SPOIL COMPACTION FIELD DATA <i>Laurel Fork Mine</i> <i>Non-Mycorrhizae Plots</i>									
Collection Dates: 08/11/2004									
Sample #	Density @ 12" Penetration Depth (pcf)			Density@6" Depth (pcf)			Density@2" Depth (pcf)		
	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density
1	102.4	6.2	96.2	93.1	4.7	88.4	81.4	4.4	77
2	92.1	9.8	82.3	80.5	4.3	76.2	84.9	5	79.9
3	108	6.3	101.7	73.7	5.5	68.2	82.7	6.1	76.6
4	103.7	8.2	95.5	92.7	6.7	86	79	7.7	71.3
5	97.6	2.6	95	104.7	6.1	98.6	95.1	7.1	88
6	114.9	5.3	109.6	97.8	3.3	94.5	95.9	4.1	91.8
7	111.9	7.8	104.1	105.5	5.6	99.9	87.1	5.8	81.3
8	104.3	5.4	98.9	91	6.8	84.2	76.3	6.5	69.8
9	109.1	6	103.1	94.2	6.1	88.1	80.5	5.8	74.7
10	110.4	8.4	102	82.2	4.8	77.4	81.2	10.8	70.4
11	107.7	6.3	101.4	91.5	8.6	82.9	79.1	9	70.1
12	112.5	7.1	105.4	100	8.6	91.4	76.3	8.9	67.4
13	119.2	7	112.2	96	7.8	88.2	82.4	8.1	74.3
14	111.6	6.2	105.4	107.7	5.5	102.2	102.7	6.4	96.3
15	112.9	7.3	105.6	96.1	9.3	86.8	83.7	9.2	74.5
16	106.8	8.6	98.2	97.3	8.7	88.6	76.8	8.3	68.5
17	109.5	7.7	101.8	89.3	4.7	84.6	82.3	8	74.3
18	106.7	6	100.7	94.5	6.2	88.3	89.4	8.1	81.3
19	113.2	9.3	103.9	99.6	6	93.6	86.7	7.9	78.8
20	117.9	11.2	106.7	91.4	4.9	86.5	79.1	6	73.1
21	106.3	7.3	99	94.3	6.1	88.2	85.7	8.5	77.2
22	108	6.8	101.2	100.6	7.3	93.3	70.3	8	62.3
23	111.1	7.6	103.5	92.7	7.6	85.1	88.5	7.4	81.1
24	109.6	8.3	101.3	89.7	8.8	80.9	83.2	8.3	74.9
25	104.8	5.5	99.3	92.4	5.3	87.1	82	5	77
26	107.6	7.3	100.3	100	9	91	91.5	8.6	82.9
27	109.5	8.4	101.1	93.8	7.5	86.3	84.8	7.2	77.6
28	106.3	6.1	100.2	96.9	5.9	91	90.7	5.5	85.2
29	110.9	7	103.9	94.5	6.2	88.3	86.3	6.1	80.2
30	104.2	7.2	97	94	9.8	84.2	83.4	9.2	74.2
31	105.4	6.7	98.7	88.9	5.8	83.1	81.2	6.8	74.4
32	104.9	6.9	98	95.1	6.1	89	82.7	5.9	76.8
AV			101.0			87.6			77.0
St.Dev.			5.1			6.7			7.0

Appendix 6

SPOIL COMPACTION FIELD DATA <i>Laurel Fork Mine</i> <i>Mycorrhizae Plots</i>									
Collection Dates: 08/11/2004									
Sample #	Density @ 12" Depth (pcf)			Density@6" Depth (pcf)			Density@2" Depth (pcf)		
	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density	Wet Density	Moisture C-t	Dry Density
1	101	29.5	71.5	71.2	19.6	51.6	86.3	29	57.3
2	117.5	22.9	94.6	98.1	22.7	75.4	80.6	23.4	57.2
3	102.2	17.3	84.9	74.9	6.6	68.3	61.4	6.2	55.2
4	112.1	32.8	79.3	95.7	22	73.7	72.4	22.1	50.3
5	98.7	15.5	83.2	88.5	15.4	73.1	75	16.1	58.9
6	112.6	17.1	95.5	69.4	8.2	61.2	80.1	8.2	71.9
7	111.6	9.3	102.3	97.5	5.4	92.1	60.8	4.1	56.7
8	108.2	12.8	95.4	83.3	4.6	78.7	89	3.8	85.2
9	107.3	18.5	88.8	88.3	21.2	67.1	66.9	19.9	47
10	111.3	13.4	97.9	90	15.7	74.3	62.7	15.9	46.8
11	96.2	15.7	80.5	88.4	3.8	84.6	70	4.1	65.9
12	104.9	11.1	93.8	99.5	10.9	88.6	77.3	4.7	72.6
13	94.5	3.4	91.1	90.9	3.3	87.6	79.2	3.5	75.7
14	77	3.8	73.2	82.8	2.4	80.4	79.7	2.7	77
15	103.8	12.2	91.6	93.4	7.9	85.5	73.8	5.8	68
16	106.1	20.4	85.7	92.1	11	81.1	78.4	6.3	72.1
17	102.2	14.3	87.9	78.3	12.5	65.8	70.6	6.5	64.1
18	100.4	12.2	88.2	84.5	10.4	74.1	74.3	5.4	68.9
19	94.3	7.9	86.4	88.9	5.2	83.7	71.3	6.8	64.5
20	105.8	11.8	94	97.2	7.8	89.4	66.5	4.4	62.1
21	99.1	13.5	85.6	90.3	10.8	79.5	69.7	3.8	65.9
22	99	14.8	84.2	86.8	12.5	74.3	72.4	8.9	63.5
23	92.5	9.5	83	80	7.7	72.3	67.5	5.3	62.2
24	104.6	11.1	93.5	90.4	9	81.4	80.1	7.1	73
25	101.9	10	91.9	78.9	6.9	72	69.9	5.8	64.1
26	102.7	13.7	89	92.1	10.9	81.2	74.3	6	68.3
27	100.4	15.6	84.8	85.5	12.1	73.4	67.7	9.1	58.6
28	103	12.8	90.2	85	10.3	74.7	75	9.4	65.6
29	95.5	11.3	84.2	90.4	9.9	80.5	71.1	9.3	61.8
30	89.7	9.5	80.2	87.8	8.2	79.6	67.6	6.5	61.1
31	107.8	9.6	98.2	79.3	7.6	71.7	69.3	8.4	60.9
32	102.5	12.6	89.9	80.6	10.4	70.2	70.4	9.9	60.5
AV			88.1			76.5			63.8
St.Dev.			7.0			8.6			8.4