Carbon Sequestration on Surface Mine Lands

Quarterly Report

Reporting Period Start Date: 10/01/03

Reporting period End Date: 12/31/03

Principal Authors: Donald H. Graves
Christopher Barton
Richard Sweigard
Richard Warner

Date Report Issued: January 30, 2004

DOE Award Number: DE-FC26-02NT41624

Name and Address of Submitting Organization

University of Kentucky
Department of Forestry
Lexington, Kentucky 40546-0073

DISCLAIMER

“This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents, that its use would not infringe on any privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.”

ABSTRACT

The October – December 2003 Quarter was dedicated to analyzing the first years tree planting activities and evaluation of the results. This included the analyses of the specie success at each of the sites and quantifying the baseline data for future year determination of research levels of mixes. The small mammal colonization study of revegetated surface mines was also initiated and sampling systems initiated.

TABLE OF CONTENTS

Disclaimer	2
Abstract	3
Table of Contents	4
List of Graphical Material	5
Introduction	6
Executive Summary	6
Experimental	6
Results and Discussion	9
Conclusion	11

LIST OF GRAPHICAL MATERIALS

Table 1	Results of initial small mammal trapping on Starfire Mine	9
Table 2	Dry bulk density (pounds per cubic foot) of sediments from seedling survey plots	11
Figure 1	Seedling height at 17 West measured summer 2003	12
Figure 2	Seedling composition at 17 West	13
Figure 3	Leaf area index at 17 West	14
Figure 4	Seedling height at Gilbratar measured summer 2003	15
Figure 5	Seedling composition at Gilbratar	16
Figure 6	Leaf area index at Gibraltar	17
Figure 7	Seedling composition at Vogue	18
Figure 8	Seedling height at Vogue measured summer 2003	19
Figure 9	Leaf area index at Vogue	20
Figure 10	Leaf area index at Big Run	21
Figure 11	Seedling composition at Big Run	22
Figure 12	Leaf area index at Big Run	23

INTRODUCTION

EXECUTIVE SUMMARY

During the first years' activities, 72,760 tree seedlings were planted on 107 acres in eastern Kentucky and 38,760 seedlings were planted on 57 acres in western Kentucky. The quantities of each species was discussed in the first Annual Report. A monitoring program was implemented to measure treatment effects on above and below ground C and nitrogen (N) pools and fluxes. A sampling strategy was devised that will allow for statistical comparisons of the various species within planting conditions and sites.

Seedling heights and diameters were measured for initial status and will be re-measured on an annual basis. Leaves were harvested and leaf area measurements were performed. They were then dried and weighed and analyzed for C and N. Whole trees will be removed later to evaluate C and N levels in all components of the trees. Clip plots were taken to determine herbaceous production and litter was collected in baskets and gathered each month to quantify C & N levels.

Soil samples were collected to determine the chemical and mineralogical characterization of each area. The physical attributes of the soils are also being determined to provide information on the relative level of compaction.

Hydrology and water quality monitoring is being conducted on all areas. Weather data is also being recorded that measures precipitation values, temperature, relative humidity, wind speed and direction and solar radiation.

Detailed studies to address specific questions pertaining to carbon flux are being initiated. The small mammal colonization study was also initiated that will identify and quantify the various mammals that invade as the vegetation develops.

EXPERIMENTAL

The study is taking place in three distinct mining regions in Kentucky's eastern and western coalfields regions. Specific mining sites are located in southeastern Kentucky near the West Virginia border, in southeastern Kentucky near Hazard and in western Kentucky near Central City.

Tree species selections are intended to provide a gradient of tree growth and litter quality. Tree species included white ash, yellow poplar, white pine and other available species. Seedlings of each species were planted randomly in mixed species plots on compacted (control), dozer ripped and Kentucky RAM #124 compliant loose-graded spoil at two of the three mining locations.

A monitoring program was implemented to measure treatment effects on aboveground and belowground C and nitrogen (N) pools and fluxes for the planting areas. Sample plots were established in the mixed species planting areas at the two reforestation sites.

Plots were designed in a manner to both adequately sample each species planted and to account for differences with respect to site preparation activities and micro-topographic variability amongst planting units. As such, multiple 50 x 50 meter plots (8) were set within planting units that exceeded 8 hectares in area. This scenario was replicated within each reforestation site and for the differing reclamation practices employed (ripped vs. uncompacted vs. compacted). In addition, complete seedling inventories were analyzed in several smaller plots (1-2 ha.) that presented unique features in both reforestation areas. The sampling strategy will provide for a minimum of 100 seedlings per species per planting unit, which will allow for statistical comparison of the differing species within the differing planting conditions and sites. These plots will also be utilized for measuring carbon pools within the sites.

Seedling height and diameter were measured within the monitoring plots and will be re-measured annually. Notes were taken on seedling health, vigor, growth form and level of herbivory. Leaf area measurements were performed on a subset of trees from each plot (3 per species per plot). Once measured, individual leaves were collected, dried, weighed and analyzed for C and N. Aboveground seedling biomass production shall be estimated with allometric equations developed from the above information for the individual species. Plots were planted with enough seedlings so that select trees can be later sacrificed to determine whole tree biomass, and evaluate C and N levels in stems, branches and roots. Root biomass will be measured using sequential soil coring over an annual cycle, and through whole tree harvesting. Clip plots were used to measure herbaceous production on the mine soil. Litter was collected from the plots using 0.5 m² plastic litter baskets. The baskets are emptied each month and the litter is dried, weighed and analyzed for C and N.

Soil samples were collected from each plot at 0-5, 5-10, 10-20 and 20-40 cm increments for chemical and mineralogical characterization. Physical attributes of soils on the sites were determined using a recording cone penetrometer and a nuclear density gauge. Both instruments provide information on the relative level of compaction or depth of resistance.

Hydrology and water quality monitoring equipment was installed at the eastern and western Kentucky reforestation sites. Flumes and stilling wells were placed adjacent to the planting areas to measure runoff from rain events. ISCO automatic water samplers were installed to evaluate export of solids and C from the planting areas. Solar panels and liquid level actuators were connected to the ISCO samplers to: 1) provide a constant power source and 2) to initiate sampling only when runoff was detected. Pressure transducers and mini-dataloggers were installed to provide continuous (10 minute interval) stage data for determination of flow rates. Water samples were collected from the ISCOs after each event that produced sample; then, transferred to the University of Kentucky in coolers at 4⁰C where they were analyzed for total and suspended solids, total dissolved solids, particle size analysis, and total organic carbon. A weather station consisting of a tipping bucket style rain gauge was installed to monitor rainfall events at each flume location. Data is recorded at five-minute intervals using HOBO event datalogger. Additional weather stations will be installed at each of the major reforestation

sites to measure precipitation volume, temperature, relative humidity, wind speed and direction and solar radiation. The weather stations will be centrally located among plots within each site.

Detailed studies to address specific questions pertaining to carbon flux are being initiated with the development of additional manipulative plots to examine the influence of spoil depth, mycorrhizae, chemical and mineralogical properties, and use of amendments on forest establishment. Based upon earlier studies by UK and the USDA Forest Service, mycorrhizal fungi have been shown to play a major role in the survival, nutrient uptake and biomass development (above and below ground) of seedlings planted on mined sites and abandoned industrial areas. Given that the current reforestation study intends to examine the potential for enhanced carbon sequestration on mined sites via C accumulation in soil and forest biomass, then efforts to maximize seedling survival and growth should be further examined. As such, a factorial experiment using inoculated vs. non-inoculated species in non-fertilized, fertilized only, amended (organic mulch) only, and fertilized + amended plots will be examined. Seedlings used for the study are being grown at the Kentucky Division of Forestry Nursery. Currently, the Nursery does not inoculate their beds with mycorrhizae, so the mycorrhizal trees used for the study will be initially inoculated in the beds and later treated with root dip applied at the time of transplanting. As such, preparation of seedling beds was performed this year at the Morgan Co. Nursery for the experimental study. Beds were prepared using a tractor drawn-inoculator that places a vegetative inoculum of *Pisolithus tinctorius* (Pt) and *Scleroderma cepa* (Sc) at a depth of approximately 10 cm between the seedling rows. Seedlings were monitored in the beds throughout the summer and an inoculation index was performed in the Fall.

The following reports research activities for past 3 months regarding small mammal colonization and plant succession of reclaimed surface mines. The original intent of this study was to focus on the colonization of small mammals from forest edges to various plots located on reclaimed surface mines. While the creation and monitoring of course woody debris plots and corridors would have provided insight regarding their importance in promoting small mammal colonization on surface mines, several factors would have limited our abilities to meet the stated objectives. Specifically, after further literature review and conversations with small mammal experts, we were concerned that 1.5 years would not be enough time to find measurable differences. Additionally, no species were detected in forest habitats that were not already present in the mined land. This alone would have limited our abilities to infer much about small mammal colonization on reclaimed mine land. As a result of these concerns, we identified new research questions, reexamined the literature, created a study design, and have conducted initial small mammal surveys at new study sites. A brief synopsis of the new study design is provided below.

This project will take place on two strip mines located in eastern (Star Fire Mine, Perry County) and western (Peabody WMA, Muhlenberg County) Kentucky. Specifically, we will compare small mammal communities in research plots created by the University of

Kentucky, Forestry Department to study the impacts of varying degrees of compaction on tree growth.

For the past 7 years, The University of Kentucky, Department of Forestry has been experimenting with altering soil compaction on reclaimed mine lands to enhance tree growth. Research plots obtained from the University of Kentucky Forestry Department will be utilized for quantifying small mammal abundance and specie richness on varying landscapes that differ in degrees of compaction. Trapping grids will be located within the following treatments: (1) loose-dumped spoil with no machine grading; (2) spoil that has been graded to a smooth surface, typical of current mine practices but has been mechanically ripped to depths of 30 inches or more (3) spoil that has been graded to a smooth surface, typical of current mine practices within the state. Each treatment contains 3- 50m x 50 m (0.25 ha) replicates; these replicates will be utilized by this project. A total of 18- 50m x 50m replicates will be examined for this study.

Several trips were made to potential study sites during the past few months. Initially, we were accompanied in the field by Ms. Daphne Marshall (eastern KY) and Ms. Jackie Perkins (western KY) who familiarized us with plot layouts. Once study plots were delineated, we conducted a 1-night trapping session in eastern Kentucky. Initial trapping has not yet been conducted in the western study area. The goal of initial trapping bouts are to familiarize ourselves with the small mammal species we will likely encounter during this study. The identification of some small mammals to the species level can be difficult and time consuming, thus, our initial trapping efforts are intended to save us time when the intensive trapping sessions begin in February. The following is a description of the initial trapping activity.

Our initial trapping session occurred in eastern Kentucky. We focused our trapping efforts solely in ripped plots at the Starfire Mine; two trapping grids were established within traps/grid. The project has currently accumulated 72 trap nights. We recorded a trapping success rate of 40.2 % with *Peromyscus leucopus* as the most frequently trapped species.

Table 1. Results of initial small mammal trapping on Starfire Mine

Grid #1		Grid #2	
<u>Species</u>	<u># trapped</u>	<u>Species</u>	<u># trapped</u>
<i>Peromyscus leucopus</i>		<i>Peromyscus leucopus</i>	
White-footed mice	12	White-footed mice	16
		<i>Microtus pennsylvanicus</i>	
		Meadow vole	1

RESULT AND DISCUSSION

The analyses of the first year data is currently in process. Seedling surveys were completed and compiled this quarter. At the 17 West –Ripped site (Eastern Kentucky), average initial seedling height was between 30 and 50 cm for all species planted except

for black locust which exhibited an average height of over 100 cm (Figure 1). There were 8700 seedlings in the sampling pool at 17 West, of which black locust, white oak, ash and red oak were the dominant species (Figure 2). Of the four dominant species, white oak and red oak exhibited the highest average leaf area index ($>2000 \text{ mm}^2$). Black locust and ash exhibited similar average leaf area indices at 1000 mm^2 (Figure 3). The 17 West site also contained an average herbaceous biomass of $411.5 \pm 167.1 \text{ g/m}^2$ on the seedling plots.

Seedlings at the Gibraltar –Ripped site (Western Kentucky) showed an average initial height between 30 and 60 cm for all species planted (Figure 4). There were 1693 seedlings in the sampling pool at Gibraltar, of which northern red oak, white oak, ash, baldcypress and southern red oak were the dominant species (Figure 5). Of the four dominant species, white oak and both red oaks exhibited an average leaf area index of $\approx 2000 \text{ mm}^2$. Baldcypress exhibited a lower average leaf area index at $<1000 \text{ mm}^2$ (Figure 6). The Gibraltar site contained an average herbaceous biomass of $401.7 \pm 128.7 \text{ g/m}^2$ on the seedling plots.

The Vogue site (Western Kentucky) contained loose graded material and exhibited the lowest species diversity of any site sampled. There were 532 seedlings in the sampling pool at Vogue, with white oak, yellow poplar and southern red oak in the species mix (Figure 7). The three showed an average initial seedling height between 30 and 60 cm (Figure 8). The three species exhibited an average leaf area index of $\approx 3000 \text{ mm}^2$, which was higher than that observed on the ripped sites and may be attributable to better soil rooting conditions (Figure 9). The Vogue site contained an average herbaceous biomass of $44.7 \pm 24.4 \text{ g/m}^2$ on the seedling plots, which was much lower than that observed on the other sites. The lack of herbaceous cover may have also contributed to the increased leaf area at this site as the seedlings did not have to compete as much with the herbaceous biomass for water and nutrient resources.

Seedlings at the Big Run – Control (compacted) site (Western Kentucky) showed an average initial height between 30 and 60 cm for all species planted (Figure 10). There were 836 seedlings in the sampling pool at Big Run, of which northern red oak, black locust, ash, and southern red oak were the dominant species (Figure 11). Of the dominant species, ash exhibited the highest average leaf area index of $\approx 4000 \text{ mm}^2$. Red oak and white oak contained leaf area indices similar to that observed in the ripped areas ($\approx 2000 \text{ mm}^2$), while baldcypress exhibited a lower average leaf area index at $<1000 \text{ mm}^2$ (Figure 12). The Big Run site contained the highest average herbaceous biomass of all sites samples at $657.5 \pm 165.4 \text{ g/m}^2$ on the seedling plots.

Soil and vegetation samples collected during the surveys are currently being processed and analyzed.

Penetration resistance, penetration depth, and bulk density data from the reclamation test cells were analyzed in October – December 2003. The results of this analysis are following. Collected data from the reclamation cells was analyzed from each of the mine sites. The following parameters were identified for each sample from most sites:

- Penetration Depth
- Penetration Resistance Mean
- Penetration Resistance Maximum
- Moisture Content at Depth 12"
- Dry Bulk Density at Depth 12"
- Moisture Content at Depth 6"
- Dry Bulk Density at Depth 6"
- Moisture Content at Depth 2"
- Dry Bulk Density at Depth 2"

Several sites (17 west and Vogue) were deemed too steep for penetration analysis, however, information from the nuclear density probe was available at all sites. Calculated average data will give us opportunity to compare physical parameters of soil with tree data (survival rate and height) annually. Table 2 outlines initial density conditions on the sites.

Table 2. Dry bulk density (pounds per cubic foot) of sediments from seedling survey plots.

Site	Density 5 cm		Density 15 cm		Density 30 cm	
	<u>AVG</u>	<u>STD</u>	<u>AVG</u>	<u>STD</u>	<u>AVG</u>	<u>STD</u>
Gibraltar	89.1	5.6	108.6	8.1	115.3	10
Vogue	107.1	5.4	118.3	8.1		
Big Run	91.5	3.5	108.9	6.5	106	4.3
17 West 1	80.9	6.3	94.6	5.3		
17 West 2	82.6	6.7	92.1	6.6	99.1	8.6
17 West 5	88.6	5.7	100.8	6.8	108.7	5.1

CONCLUSIONS

There are no conclusions at this time. The project is scheduled to continue for two more years.

Seedling Height 2003

17 West - Ripped

Figure 1. Seedling height at 17 West measured summer 2003

Species Samples (%)

17 West – Ripped

8700 Total - 2003

Figure 2. Seedling composition at 17 West

Leaf Area 2003

17 West - Ripped

Figure 3. Leaf area index at 17 West

Seedling Height 2003

Gibraltar - Ripped

Figure 4. Seedling height at Gibraltar measured summer 2003

Species Samples (%)

Gibraltar – Ripped

1693 Total - 2003

Figure 5. Seedling composition at Gibraltar

Leaf Area 2003

Gibraltar - Ripped

Figure 6. Leaf area index at Gibraltar

Species Samples (%)

Vogue – Loose Dumped

532 Total - 2003

Figure 7. Seedling composition at Vogue

Seedling Height –2003

Vogue – Loose Dumped

Figure 8. Seedling height at Vogue measured summer 2003

Leaf Area 2003

Vogue – Loose Dumped

Figure 9. Leaf area index at Vogue

Seedling Height 2003

Big Run - Control

Figure 10: Leaf area index at Big Run

Species Samples (%)

Big Run – Control

836 TOTAL - 2003

Figure 11. Seedling composition at Big Run

Leaf Area 2003

Big Run - Control

Figure 12. Leaf area index at Big Run