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Technical Progress Report

**“Restoring Sustainable Forests on Appalachian Mined Lands for Wood Products,
Renewable Energy, Carbon Sequestration, and Other Ecosystem Services”**

Quarterly Report

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ABSTRACT

The overall purpose of this project is to evaluate the biological and economic feasibility of restoring high-quality forests on mined land, and to measure carbon sequestration and wood production benefits that would be achieved from forest restoration procedures. We are currently estimating the acreage of lands in VA, WV, KY, OH, and PA mined under SMCRA and reclaimed to non-forested post-mining land uses that are not currently under active management, and therefore can be considered as available for carbon sequestration. To determine actual sequestration under different forest management scenarios, a field study was installed as a 3 x 3 factorial in a random complete block design with three replications at each of three locations, Ohio (Figure 1), West Virginia (Figure 2), and Virginia (Figure 3). The treatments included three forest types (white pine, hybrid poplar, mixed hardwood) and three silvicultural regimes (competition control, competition control plus tillage, competition control plus tillage plus fertilization). Each individual treatment plot is 0.5 acres. Each block of nine plots requires 4.5 acres, and the complete installation at each site requires 13.5 acres. The plots at all three locations have been installed and the plot corners marked with PVC stakes. GPS coordinates of each plot have been collected. Soil samples were collected from each plot to characterize the sites prior to treatment. Baseline soil carbon was determined for each of the eighty-one plots. Fertility analysis of soil samples was completed and these data were used to prepare fertilizer prescriptions and the pre-designated plots were fertilized. We also evaluated economic-based policy instruments that are designed to mitigate the reforestation burden borne by the owner of reclaimed mined land. Results suggest that although profitability of reforestation of these previously reclaimed mine lands may be achievable on better sites under lower interest rates, substantial payments would be required to reach “profitability” under many conditions.

TABLE OF CONTENTS

Title Page	1
Disclaimer	2
Abstract	3
List of Graphical Materials	4
Introduction	6
Executive Summary	7
Task 1 Report	11
Task 2 Report	18
Task 3 Report	20
Task 4 Report	22
Task 5 Report	33
Project Timetable	35

LIST OF GRAPHICAL MATERIALS

Figure 1. Map of field sites in Lawrence County, Ohio	8
Figure 2. Map of field sites in Nicholas County, West Virginia	9
Figure 3. Map of field sites in Wise County, Virginia	10
Figure 4. General location of the three study sites in the Appalachian coalfields	12
Figure 5. Soil sampling scheme for estimating the baseline carbon content in the topsoil (TS) and subsoil (SS) layers of a hypothetical study site	13
Table 1. Baseline carbon content results (% by weight) at two soil profile depths for all experimental plots of our three-state project study sites (OH – Ohio, WV – West Virginia, VA – Virginia); 1,2,3 indicate the treatment block number at each site	14
Table 2. Approximate classification scheme based on measurable soil and site properties that separate land area into productivity classes for white pine	19
Table 3. Land expectation values of mixed Appalachian hardwood reforestation of reclaimed mine sites when landowner or mine operator pay establishment costs, by site class, reforestation intensity, and discount rate—60-year rotation (\$/hectare)	27
Table 4. Land expectation values of white pine reforestation of reclaimed mine sites when landowner or mine operator pay establishment costs, by site class, reforestation intensity, and discount rate—30-year rotation (\$/hectare)	28
Table 5. Lump-sum payment required at reforestation inception to provide minimal profitability ($LEV \geq 0$) for landowner of reclaimed mine land, by site class, reforestation intensity, and discount rate (\$/hectare)	29

Table 6.	Lump-sum payment required at reforestation inception to provide full reimbursement of forest conversion costs to landowner of reclaimed mine land, reforestation intensity, and discount rate (\$/hectare)	30
Table 7.	Annual payment required over one rotation to allow minimal profitability ($LEV \geq 0$) for landowner of reclaimed mine land, by site class, reforestation intensity, and discount rate (\$/hectare/year)	31
Table 8.	Annual payment required over one rotation to provide full reimbursement of forest conversion costs to landowner of reclaimed mine land, reforestation intensity, and discount rate (\$/hectare/year)	32

INTRODUCTION

Public Law 95-87 mandates that mined land be reclaimed in a fashion that renders the land at least as productive after mining as it was before (Torbert et al. 1995). Research has shown that restored forests on mined lands can be equally as or more productive than the native forests removed by mining (Burger and Zipper 2002). Given that most land surface-mined for coal in the Appalachians was originally forested, forestry is a logical land use for most of the reclaimed mined land in the region (Torbert and Burger 1990). However, since implementation of the SMCRA, fewer forests are being restored in the eastern and Midwestern coalfield regions (Burger et al. 1998). In several states, most notably Virginia, the majority of mined land is now being restored to forests. Over eighty percent of Virginia's mined land has been reclaimed to forested post-mining land uses since 1991. However, region-wide, the majority of mined land that was originally forested is not being reclaimed in a way that favors tree establishment, timber production, carbon sequestration, and long-term forest productivity (Torbert and Burger 1990).

We believe that these reclaimed mined lands are producing timber and sequestering carbon at rates far below their potential for reasons that include poor mine soil quality, inadequate stocking of trees, lack of reforestation incentives, and regulatory disincentives for planting trees on previously forested land (Boyce 1999, Burger and Maxey 1998). A number of these problems can be ameliorated simply through intensive silvicultural management. Through established site preparation techniques such as ripping, weed control, fertilizing, and liming, the quality of a given site can be improved. Other management and silvicultural techniques such as site-species matching, correct planting techniques, employing optimal planting densities, post-planting weed control, and thinning can also improve normal development of forest stands, and improve timber production and carbon sequestration.

Similar to the much-debated topic of converting agricultural land to forests, the conversion of reclaimed mined lands to forests carries with it many economic implications. The primary difference between converting agricultural lands to forests and converting reclaimed mined lands to forests is the absence of any obvious extrinsic opportunity cost in the latter scenario; this, of course, assumes that the reclaimed mined land has been abandoned and is not being utilized for any economically beneficial purpose.

A fair amount of research has been conducted regarding the amounts and values of timber produced on reclaimed mined lands. The effect that a carbon market may have on decisions pertaining to the reclamation of mined lands has also been researched. According to previous research, it appears that mined lands are capable of sequestering carbon and producing harvest volumes of equal or greater magnitude to similar non-mined lands. This fact alone, however, does not render afforestation of mined lands economically profitable or feasible in all cases. There is a lack of research pertaining specifically to the conversion of reclaimed mined lands from their current uses to forests and the economic implications of such a land use conversion. Furthermore, the potential for an incentive scheme aimed at promoting the conversion of reclaimed mined lands to forests has yet to be explored in depth.

This study ultimately addresses the potential for increasing carbon sequestration on surface-mined land. The overall research objective of this study is to determine the economic feasibility of carbon sequestration through converting reclaimed mined lands to forests using high-value tree species, and to demonstrate the economic and decision-making implications of an incentive scheme on such a land use conversion.

EXECUTIVE SUMMARY

The purpose of this project is to evaluate the biological and economic feasibility of restoring high-quality forests on abandoned mined land, and to measure carbon sequestration and wood production benefits that would be achieved from forest restoration procedures. During the second quarter of 2004 significant progress was made on all tasks. Soil carbon analyses were completed for baseline carbon determinations for all the experimental plots. The field study is a 3 x 3 factorial in a random complete block design with three replications at each of three locations, Ohio (Figure 1), West Virginia (Figure 2), and Virginia (Figure 3). The treatments included three forest types (white pine, hybrid poplar, mixed hardwood) and three silvicultural regimes (competition control, competition control plus tillage, competition control plus tillage plus fertilization). Each individual treatment plot is 0.5 acres. Each block of nine plots is 4.5 acres, and the complete installation at each site is 13.5 acres. Traditional dry combustion techniques were used for carbon analyses. Investigations are under way to refine these soil carbon estimates by discriminating between geogenic carbon (carbon associated with fossilized coal) and pedogenic carbon (carbon associated with plant-derived organic matter). A study on the influence of coarse fragments in mine soils on the accurate determination of soil carbon is also under way. Traditional soil sampling of mine soils will invariably cause overestimation of soil carbon because of the size and amount of coarse fragments. Adjustment factors are being calculated to correct this bias. Preliminary classification and inventory criteria and procedures for mined land were developed. We achieved our task of identifying groups of plots with similar soil properties within each plot but differing soil properties between the groups of plots. These criteria are being validated on sites with existing tree stands. Upon validation, the classification criteria will be used to assign forest productivity ratings to each of the experimental plots. Carbon sequestration is a function of forest productivity. Mapping mine soil productivity is a critical step towards estimating carbon sequestration across the minescape. All plots were planted as prescribed. Deer fencing was installed at the sites in Ohio and West Virginia to prevent browse damage to the newly planted seedlings. All trees at all sites with the exception of one block of the study at the Virginia site were treated with a spot spray herbicide application to control competing vegetation. The block that was excluded at the Virginia site was devoid of competing vegetation and therefore not treated. This treatment was carried out by shielding each tree and applying a 2.5% glyphosate herbicide around the base of each tree. Economic-based policy instruments that are designed to mitigate the reforestation burden borne by the landowner were evaluated. Results suggest that although profitability of reforestation of these previously reclaimed mine lands may be achievable on better sites under lower interest rates, substantial payments would be required to reach “profitability” under many conditions. Lump-sum payments of up to almost \$2400 per hectare in mixed hardwoods and up to \$2080 per hectare in white pine management may be required to make reforestation minimally profitable in some circumstances (low productivity sites under high interest rates), while one-time payments of up to \$2469 for hardwoods and \$2358 for pine would be required for a full reimbursement of reforestation expenses.

Figure 1. Map of field sites in Lawrence County, Ohio.

Figure 2. Map of field sites in Nicholas County, West Virginia.

VIRGINIA site locations. DOE project.
 Coordinates are UTM (z17) meters in NAD'83
 Prepared by Beyhan Amichev.12/08/2003.

Figure 3. Map of field sites in Wise County, Virginia.

TASK 1: Estimate forest productivity and carbon sequestration potential on mined lands supporting abandoned grasslands. (Burger et al.)

Executive Summary

Baseline total soil carbon content estimates were produced for each experimental plot on all study site locations. These results will be partitioned into geogenic and pedogenic carbon using a unique soil combustion-microscopy technique (Soil-CMT). We designed the Soil-CMT technique to be used for most minesoils with various amounts of coal in the soil.

Experimental

Subtask 1.1:

We identified and located three project sites in the Appalachian Coalfields. All selected sites were on coal-mined land that has been reclaimed to grassland/hayland/pastureland in the period after 1978. At each study site we established three replications (blocks) of the nine treatments proposed for this project. An extensive description of the experimental treatments was included in previous project progress quarterly reports.

We established 27 treatment plots (50 x 50 m size) at each study site: (1) near the town of Jackson, Jackson County, Ohio; (2) near the town of Leivasy, Nicholas County, West Virginia; (3) near the town of Norton, Wise County, Virginia (Figure 4). In addition to the treatment plots, two control plots (control and herbicide-control) were established on each block of each study site. A total of 99 plots, including treatment and control plots, were established in three states, Ohio, West Virginia, and Virginia.

The plots on each site were divided into three blocks of nine, which were selected according to field measures of site acidity, pH (acidic, neutral, and alkaline), and site accessibility. The two main criteria in choosing plot locations per research block were (i) to locate all plots on relatively flat sites with slopes less than 8-10%, and (ii) to keep the plots adjacent to each other forming as contiguous of matrix as possible. These criteria were chosen in order to minimize equipment transportation between plots, fencing, and other associated costs, and to increase work efficiency.

We collected soil samples at five locations on each plot (Figure 5) to two sampling depths, 0-10 cm and 10-30 cm. All soil samples were stored in paper bags, or open plastic bags in a well-ventilated area, and were air- or oven-dried at 50-60°C in order to shorten the drying time. We sieved the soil samples through sieve No. 10 (< 2 mm) in order to separate the fine earth fraction from the coarse rock fragments in this soil. Then the fine earth component of each soil sample (< 2 mm) was used for soil carbon content estimation. Total soil carbon was determined with carbon-nitrogen auto-analyzer (Vario MAX CNS analyzer, elemental, Hanau, Germany). Total soil carbon content estimates were reported as percent carbon, grams of C per grams of soil (Table 1).

Figure 4. General location of the three study sites in the Appalachian coalfield.

Figure 5. Soil sampling scheme for estimating the baseline carbon content in the topsoil (TS) and subsoil (SS) layers of a hypothetical study site.

Subtask 1.2:

We designed a technique that will allow differentiation between pedogenic and geogenic carbon in mineland soil samples. Soil samples with known amounts of coal and plant residue were combusted at 800 °C and 300 °C (1,472 °F and 572 °F). The micro particles (ranging from 10 µm to 50 µm) that were emitted from the soil sample due to the combustion process were captured with a temperature-resistant quartz fiber filter. Then each filter, containing coal and plant micro particles on its surface, was prepared for high magnification scanning microscopy analysis.

By analyzing the surface of the filters under high magnification (x5000) using a scanning microscope, we will be able to observe and to measure the volume ratio between clearly observable coal and plant particles. The latter ratio will be used to partition the total soil carbon content measured with the carbon-nitrogen auto-analyzer into carbon derived from coal particles (geogenic carbon) and carbon sequestered by plants (pedogenic carbon).

Results and Discussion

Subtask 1.1:

Table 1. Baseline carbon content results (% by weight) at two soil profile depths for all experimental plots of our three-state project study sites (OH – Ohio, WV – West Virginia, VA – Virginia); 1,2,3 indicate the treatment block number at each site.

Site	Depth	Plot #	C, %	StDev [C, %]	Site	Depth	Plot #	C, %	StDev [C, %]
OH1	Topsoil (0-10cm)	1	1.597	0.411	OH1	Subsoil (10-30cm)	1	0.550	0.268
		2	1.532	0.351			2	0.330	0.186
		3	1.595	0.504			3	0.301	0.027
		4	1.723	0.460			4	0.531	0.214
		5	1.270	0.422			5	0.820	0.314
		6	1.669	0.341			6	2.570	2.051
		7	1.280	0.196			7	0.942	0.222
		8	1.761	0.714			8	1.479	1.050
		9	1.829	0.412			9	0.487	0.294
	Average		1.584	0.424	Average		0.890	0.514	
OH2	Topsoil (0-10cm)	1	1.572	0.358	OH2	Subsoil (10-30cm)	1	0.487	0.246
		2	1.392	0.562			2	0.735	0.545
		3	2.071	1.506			3	0.406	0.186
		4	1.632	0.439			4	0.441	0.052
		5	1.251	0.365			5	0.450	0.288
		6	1.172	0.369			6	0.502	0.154
		7	1.209	0.411			7	0.896	0.611
		8	1.283	0.378			8	3.772	5.248
		9	1.211	0.371			9	0.595	0.441
	Average		1.421	0.529	Average		0.920	0.863	
OH3	Topsoil (0-10cm)	1	1.629	0.485	OH3	Subsoil (10-30cm)	1	0.502	0.153
		2	1.616	0.530			2	0.663	0.134
		3	1.870	0.600			3	0.709	0.195
		4	1.287	0.168			4	0.507	0.232
		5	1.380	0.452			5	0.380	0.060
		6	1.681	0.659			6	0.349	0.113
		7	1.272	0.420			7	0.547	0.349
		8	1.216	0.181			8	0.459	0.078
		9	1.213	0.489			9	0.337	0.087
	Average		1.463	0.443	Average		0.495	0.156	
Grand Average		1.489	0.465			0.768	0.511		

Table 1 (continued).

Site	Depth	Plot #	C, %	StDev [C, %]	Site	Depth	Plot #	C, %	StDev [C, %]
WV1	Topsoil (0-10cm)	1	3.878	1.152	WV1	Subsoil (10-30cm)	1	1.840	1.460
		2	4.673	1.843			2	2.857	2.145
		3	3.400	0.675			3	1.883	0.622
		4	5.036	1.806			4	2.310	0.749
		5	4.159	1.737			5	1.582	0.385
	Topsoil (0-10cm)	6	2.744	0.152		Subsoil (10-30cm)	6	1.376	0.204
		7	2.910	0.666			7	1.820	0.369
		8	2.775	0.736			8	1.526	0.328
		9	3.363	0.415			9	1.809	0.285
	Average		3.660	1.020		Average		1.889	0.727
WV2	Topsoil (0-10cm)	1	2.739	0.203	WV2	Subsoil (10-30cm)	1	1.150	0.129
		2	2.637	0.548			2	1.470	0.382
		3	2.588	0.366			3	1.243	0.096
		4	3.376	0.798			4	1.312	0.139
		5	2.634	1.481			5	1.319	0.284
	Topsoil (0-10cm)	6	2.641	0.665		Subsoil (10-30cm)	6	1.320	0.157
		7	3.835	1.191			7	1.112	0.174
		8	3.853	0.861			8	1.512	0.263
		9	3.235	0.767			9	1.426	0.197
	Average		3.060	0.764		Average		1.318	0.202
WV3	Topsoil (0-10cm)	1	3.020	0.764	WV3	Subsoil (10-30cm)	1	1.295	0.290
		2	4.177	0.657			2	1.650	0.255
		3	3.791	0.706			3	1.474	0.441
		4	3.486	0.623			4	1.024	0.122
		5	3.293	1.634			5	1.203	0.320
	Topsoil (0-10cm)	6	2.763	0.598		Subsoil (10-30cm)	6	1.181	0.266
		7	3.880	0.927			7	1.752	0.242
		8	3.616	1.255			8	1.361	0.371
		9	3.381	0.777			9	1.241	0.202
	Average		3.490	0.882		Average		1.353	0.279
Grand Average			3.403	0.889				1.520	0.403

Table 1 (continued).

Site	Depth	Plot #	C, %	StDev [C, %]	Site	Depth	Plot #	C, %	StDev [C, %]
VA1	Topsoil (0-10cm)	1	1.424	0.543	VA1	Subsoil (10-30cm)	1	1.299	0.263
		2	0.945	0.544			2	1.892	0.652
		3	0.657	0.152			3	2.719	1.482
		4	0.767	0.362			4	1.989	0.275
		5	1.347	0.471			5	1.990	1.012
		6	1.150	0.462			6	1.299	0.421
		7	1.077	0.460			7	1.768	0.590
		8	1.548	0.210			8	1.501	0.463
		9	1.454	0.308			9	1.368	0.391
	Average		1.152	0.390		Average		1.758	0.617
VA2	Topsoil (0-10cm)	1	1.842	0.284	VA2	Subsoil (10-30cm)	1	2.315	0.983
		2	3.033	1.093			2	3.550	1.453
		3	2.710	0.475			3	3.579	2.457
		4	2.724	0.153			4	2.770	0.581
		5	2.535	0.549			5	2.786	0.320
		6	2.329	0.491			6	2.531	0.916
		7	2.184	0.471			7	3.194	1.033
		8	1.968	0.520			8	2.116	1.213
		9	2.519	0.491			9	3.294	1.065
	Average		2.427	0.503		Average		2.904	1.113
VA3	Topsoil (0-10cm)	1	0.996	0.173	VA3	Subsoil (10-30cm)	1	0.703	0.371
		2	0.971	0.444			2	0.809	0.458
		3	1.855	0.696			3	1.446	0.810
		4	2.085	1.250			4	1.880	1.499
		5	2.720	1.103			5	1.992	0.734
		6	2.287	1.173			6	1.626	0.469
		7	2.614	1.585			7	2.246	1.314
		8	2.377	0.721			8	2.327	1.172
		9	2.712	1.253			9	1.710	0.396
	Average		2.069	0.933		Average		1.638	0.803
Grand Average			1.883	0.609				2.100	0.844

Subtask 1.2:

Because coal particles, infinitely small to grain size, are expected to contaminate some of the mine soil samples, it is a priority to develop a method and practical mechanism for C content partitioning to C from coal (geogenic C) and C from plants (pedogenic C). Pedogenic C can be found in the form of soil organic matter and/or plant residues. Unfortunately, there is no existing method in the literature that may be of use for such analysis.

The soil combustion-microscopy technique (Soil-CMT) that was previously described was adapted from pollution-source determination studies at the Center for Great Lakes Studies, University of Wisconsin-Milwaukee. In these studies sources of pollution in Lake Erie (Kralovec et al. 2002) and Lake Michigan (Karls and Christensen 1998) were inferred from sediment core samples that were analyzed for presence of particles from incomplete combustion of fossil fuels, such as coal and oil, and wood. The authors in both studies used the same methods for carbon content and carbon source partitioning analysis of sediment samples that appeared useful and applicable to soil C partitioning in our current project.

Conclusions

Subtask 1.1:

Due to the nature of soil carbon measuring using dry combustion techniques we suspect that the present carbon content results include plant derived carbon as well as carbon from coal. We determined that the content of carbonates in our soil samples is insignificant. In any rate, there are existing techniques for eliminating carbonates from soil samples that are commonly used for pre-treating minesoils with high shale component.

The amount and size of coal particles currently residing in the soil may vary greatly across space and down the soil profile. Therefore in order to produce accurate minesoil carbon content results we will partition our estimates into geogenic and pedogenic carbon estimates.

Subtask 1.2:

The Soil-CMT technique is still under exploration and we will be performing more extensive testing in order to determine its accuracy and applicability for this project. We believe that the Soil-CMT technique will yield accurate carbon partitioning results that will prove to be practical in future carbon sequestration projects.

References

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- Kralovec, A.C., E.R. Christensen, and R.P. Van Camp. 2002. Fossil Fuel and wood combustion as recorded by carbon particles in Lake Erie sediments 1850-1998. *Environmental Science and Technology* 36(7):1405-1413

TASK 2: Develop classification and inventory criteria and procedures for mined land. (Galbraith et al.)

Executive Summary

During the reporting period (April-June 2004), we have continued a literature search about classification criteria for reforestation on mine soils, and continued lab analysis on field samples collected in earlier reporting periods. A classification scheme has been developed and verification of its accuracy has begun.

Experimental

During the reporting period (April-June 2004), continued lab analysis was performed on previously collected samples. Lab analysis was conducted using the same materials and methods as described in the previous reporting period. Planted trees were measured for initial height and diameter. A classification scheme has been designed for the use on all abandoned surface mined lands that were reclaimed following guidelines enacted by the 1977-SMCRA. Use of the classification scheme is being correlated with actual tree growth data.

Results and Discussion

Results of the individual plot laboratory analysis previously reported have been updated. The results indicate that we achieved our task of identifying groups of plots with similar soil properties within each plot but differing soil properties between the groups of plots. The results have not been compared statistically because the data were used only to provide background information to assess the validity of our plot layout at each study site. Results of analysis at the 2-m deep soil pit description and sampling sites have been completed. Statistical analysis has not been conducted on any of the soil information because it will be used as background site information and cannot be compared to tree growth until the seedlings have grown. Table 2 contains an approximate classification scheme that separates land area into productivity classes for white pine. A separate set of criteria is being developed for hardwood productivity. It is difficult to scientifically validate a hardwood scheme due to the lack of planted hardwoods on surface mines that could be used for actual tree growth data. However, based on the literature a fairly accurate projection can be made and validated at a later date. The method of designating a point system or other simplistic ratings is in constant revision. An example of one such system is given. Data points are continually being collected and tree growth data is being correlated with total number of points designated to an area. Table1 will continue to be revised during the study.

Conclusion

The classification scheme has been produced and validation points are being collected. Revisions of the point system and classification criteria will lead to accurate methods of classifying post-SMCRA abandoned mined lands into productivity classes for pines and hardwoods.

References

The references for the literature review will be updated continuously during the study. No new references have been added since the previous reporting period.

Table 2. Approximate classification scheme based on measurable soil and site properties that separate land area into productivity classes for white pine.

	I	II	III	IV	V
pH	4.5 - 5.8	4.0 - 4.4 or 5.9 - 6.2	3.5 - 3.9 or 6.3 - 7.0	3.0 - 3.4 or 7.1 - 8.0	<3.0 or >8.0
EC (millimhos/cm)	<0.5	0.5 - 0.7	0.8 - 1.0	1.1 - 1.5	>1.5
Aspect	0 - 90	330 - 360 or 90 - 120	290 - 330 or 120 - 160 flat	270 - 290 or 160 - 180	180 - 270
Texture	SL, SCL	L, SiL	SC, CL, LS	SiCL	SiC, C, S, Si
Color	5/4, 4/6	5/3, 4/4, 3/6	4/3, 3/4, 3/3	4/2, 3/2, 2/2	all colors greyer
CF %	<35%	35% - 50%	50% - 65%	65% - 80%	>80%
Rock Type	>80%	60% - 80%	40% - 60%	20% - 40%	<20%
Compaction	great	good	average	bad	terrible

Need to determine approximate depth to root restricting layer.

>75 cm depth = no correction

50 - 75 cm depth = WF of 0.9

35 - <50 cm depth = WF of 0.8

>25 - <35 cm depth = WF 0.7

20 - 25 cm depth = WF of 0.6

15 - <20 cm depth = WF of 0.5

10 - <15 cm depth = WF of 0.4

<10 cm depth = WF of 0.3

	I	II	III	IV	V
pH	8	6	4	2	0
EC (millimhos/cm)	8	6	4	2	0
Aspect	10	8	6	4	2
Texture	20	15	10	5	0
Color	10	8	6	4	2
CF %	20	15	10	5	0
Rock Type	10	8	6	4	2
Compaction	20	15	10	5	0

additive

93-106

68-93

43-68

18-43

6 to 18

(A+B+C+D+E+F+G+H) * WF

TASK 3: Develop reforestation methods and procedures for mined land. (Fox et al.)

Executive Summary

Fertilization was performed at each of the three study sites on the appropriate plots. Fencing to exclude deer was set up at the West Virginia site. All trees at all three sites were spot sprayed to control competing vegetation.

Experimental

There are three separate field locations in the study. The first site is located in Lawrence County, Ohio, on land owned by The Nature Conservancy. This site was previously owned by MeadWestvaco Corporation. A meeting took place in June 2004 with The Nature Conservancy to discuss its participation as a partner in the project and to ensure continued access to the site. A research permit was granted by The Nature Conservancy to Virginia Tech to continue the project at this site. The second site is located in Nicholas, County, West Virginia, on land owned by Plum Creek Timber Company. The third site is located in Wise County, Virginia, on land owned by PennVirginia Company.

The study was installed as a 3 x 3 factorial in a random complete block design with three replications at each location. The treatments include three forest types (white pine, hybrid poplar, mixed hardwood) and three silvicultural regimes (competition control, competition control plus tillage, competition control plus tillage plus fertilization). Each individual treatment plot is 0.5 acres. Each block of 9 plots requires 4.5 acres, and the complete installation at each site requires 13.5 acres. The plots at all three locations have been installed and the plot corners marked with PVC stakes. GPS coordinates of each plot have been collected from which plot location maps of each site have been made.

Soil samples were collected from each plot to characterize the sites prior to treatment. Analysis of soil samples was completed and these data were used to prepare the fertilizer prescriptions for each site. Fertilizer prescriptions were applied in May 2004. The fertilizer prescription was the same for all sites and consisted of the following:

1. Diammonium phosphate banded along the rows at a rate of 250 lbs/ac;
2. Muriate of potash applied to the base of each tree at a rate of 80 lbs/ac; and
3. Micronutrient mix applied to the base of each tree at a rate of 18 lbs/ac.

Deer fencing was installed at the sites in Ohio and West Virginia to prevent browse damage to the newly planted seedlings.

All trees at all sites with the exception of one block of the study at the Virginia site were treated with a spot spray herbicide application to control competing vegetation. The block that was excluded at the Virginia site was devoid of competing vegetation and therefore was not treated. This treatment was carried out by shielding each tree and applying a 2.5% glyphosate herbicide around the base of each tree.

Results and Discussion

None to date. The installation phase of the project has just been completed.

Conclusions

None to date.

References

None.

TASK 4: Conduct economic analyses of reforestation and forest management activities for carbon sequestration and a variety of forest products and services. (Amacher and Sullivan)

Executive Summary

In this quarter, Task 4 progress focused on economic-based policy instruments that are designed to mitigate the reforestation burden borne by the landowner. Results suggest that although profitability of reforestation of these previously reclaimed mine lands may be achievable on better sites under lower interest rates, substantial payments would be required to reach “profitability” under many conditions. Lump-sum payments of up to almost \$2400 per hectare in mixed hardwoods and up to \$2080 per hectare in white pine management may be required to make reforestation minimally profitable in some circumstances (low productivity sites under high interest rates), while one-time payments of up to \$2469 for hardwoods and \$2358 for pine would be required for a full reimbursement of reforestation expenses.

Experimental

Land expectation value (LEV) has previously been calculated under Task 4 for three silvicultural options on five site classes of reclaimed mine lands that address incompatible ground cover, soil compaction, and site productivity. In addition, the burden that forest landowners bear when they have to pay the costs of returning the land to a forested condition has been considered. In the preceding quarter, we extended this analysis to examine potential policy instruments for alleviating landowner burden of reforesting reclaimed mine lands.

A variety of policy instruments could be designed to remove the burden of forest conversion costs from the landowner, and thereby encourage reforestation. Examples include: lump-sum payments to landowners at the time of conversion, annual payments throughout the rotation, encouraging/establishing carbon markets in these areas, or tax policies that give specific breaks for reforestation or allow full expensing of reforestation costs, rather than capitalizing them at the end of the rotation. In our continued analysis, we have examined the lump-sum and annual payment options further. We consider both payments that allow the landowners to achieve a minimum level of profitability (i.e., $LEV \geq 0$), and those that provide full reimbursement of reforestation expenses.

Recall that our analysis is based on an idealized model of a forest landowner who is facing the decision to reforest previously reclaimed mine land that was reclaimed into grass cover.¹ Suppose that in the absence of a reforestation option, the landowner possesses an *indirect* utility function given by,

$$V(r, I, L_0) = V[r(L_0), I] + \phi(L_0) \quad (1)$$

where $V()$ is indirect utility, r is the revenue generated from the property (which could be considered land rents, and consequently include the market value of the land), I is exogenous landowner income, L_0 is the current condition of the property, ϕ measures non-market benefits (utility) derived from owning the land. The utility function indicates that land condition may be

¹ Owners of reclaimed mine lands are quite diverse, including mine operators, land-holding companies, and small private owners. Our representative landowner model is intended to be only a generalized depiction, and all elements of the model may not be applicable to a given owner.

important to utility in multiple ways, including financial returns (first term on the RHS) and amenities that the landowner derives from the condition of the land (second term on the RHS). Moreover, each component of the indirect utility function could without loss be expressed as a stream of rents generated from using the land from grazing or hunting, or production of non-market benefits. That is, we could define discounted annual revenues and non-market benefits from the reclaimed land as follows:

$$r(L_0) = \int_0^{\infty} a[L_0(z)]e^{-iz} dz; \quad \phi(L_0) = \int_0^{\infty} b[L_0(z)]e^{-iz} dz \quad (2)$$

where i is the interest rate, $a(\cdot)$ are annual revenues generated from the land (perhaps grazing or hunting leases), $b(\cdot)$ are non-market benefits derived from owning land each period, z is a variable of integration representing time periods $1, \dots, t$, and $L_0(z)$ is land condition at each point in time.

Suppose now that the landowner represented by (1) is offered the opportunity to reforest previously mined land that was reclaimed into grass cover. Not only will the reforestation provide potential harvest revenues when the timber matures, but the stream of non-market benefits may also be different than those identified in (2) above. Thus, the new indirect utility function can be written

$$V(r, I, L_f) = V[r(L_f), I] + \phi(L_f) \quad (3)$$

where L_f is the condition of the land after reforestation, and discounted revenues and non-market benefits are calculated as follows:

$$r(L_f) = \frac{pQ_f(t)e^{-it} - c_f e^{it}}{(1 - e^{-it})} - c_0 + \int_0^{\infty} a[L_f(z)]e^{-iz} dz \quad (4)$$

and

$$\phi(L_f) = \int_0^{\infty} b[L_f(z)]e^{-iz} dz \quad (5)$$

where p is the unit price of timber, Q_f is the volume of timber produced from reforested land at age t , c_f is regular reforestation costs after timber harvest, and c_0 is initial reforestation costs incurred when converting grassland into forest². This formulation is similar to the standard Hartman (1976) model of a forest with amenities that is used commonly in forest landowner analyses (e.g., Amacher et al. 2003, Sullivan et al. 2004).

² Note that this representation of the problem is slightly simplified for presentation, depicting reforestation cost as a single, one-time expense. In actuality, there may be multiple costs associated with site conversion (especially the control of established, competing vegetation) that occur over the first few years of initial forest stand establishment, which we address in our empirical analysis.

Reforestation of the reclaimed land involves a welfare improvement only if:

$$V(r, I, L_f) > V(r, I, L_0) \Leftrightarrow \quad (6)$$

$$V[r(L_f), I] - V[r(L_0), I] + \phi(L_f) - \phi(L_0) > 0$$

or

$$V \left[\frac{pQ_f(t)e^{-it} - c_f e^{it}}{(1 - e^{-it})} - c_0 + \int_0^\infty a[L_f(z)]e^{-iz} dz, I \right] - V \left[\int_0^\infty a[L_0(z)]e^{-iz} dz, I \right] \quad (7)$$

$$+ \int_0^\infty b[L_f(z)]e^{-iz} dz - \int_0^\infty b[L_0(z)]e^{-iz} dz > 0$$

Net discounted revenues of timber harvesting in this calculation could be positive or negative, depending on conversion and regular reforestation costs, prices, interest rates and timber volumes produced. Annual revenues and non-market benefits may differ from pre-forestation values, due to differing land attributes (L_f v. L_0), though it is difficult to imagine these annual values not increasing when the land is reforested. It should be noted that a major component of our calculation is the conversion cost c_0 in (4) and (7) above. This undiscounted cost must be paid up front, at the time of reforestation, without any offsetting revenues until the timber reaches maturity in t years. Hence, it is likely to play a major role in determining landowner welfare and, ultimately, the likelihood of reforestation occurring.

Using this framework, a first potential policy option considered for encouraging reforestation of previously reclaimed surface mine sites is to provide a lump-sum payment to the landowner at the time of conversion. In this case, a payment could be established that provided the minimum level of profitability, in which case the payment would be set at the absolute value of those LEVs that are less than zero (Tables 3 and 4). This payment would vary by site quality and regeneration intensity, and would be zero for cases where LEV is already greater than or equal to zero:

$$\text{Minimum profitability payment} = |LEV_{jk}| \forall LEV_{jk} \leq 0, \text{ and } 0 \text{ otherwise}, \quad (8)$$

where LEV_{jk} is land expectation value for site class j and regeneration intensity k prior to any payments made to encourage reforestation.

Alternatively, a payment level could also be established to provide full reimbursement of reforestation expenses, in which case the payment would be set at the present value of the initial reforestation costs, which varies by regeneration intensity, but not by site class:

$$\text{Full reimbursement payment} = \sum_{t=0}^R c_{0kt} / (1+i)^t \quad (9)$$

where c_{0kt} is reforestation cost for regeneration intensity k occurring at time t , and R is the time at which reforestation is fully established and bond release is achieved. Calculated full reimbursement payments do not vary in our study by site class, because costs do not vary across site classes for a given forest type and regeneration intensity level. Higher intensity regeneration simply costs more, and improved growth is not a factor in this payment option.

In our work under Task 4 in the preceding quarter, we have examined the magnitude of these potential payments that would be required to mitigate the landowner burden of reforestation expenses on reclaimed mine sites, under a range of site conditions and reforestation options.

Results and Discussion

Calculated minimum profitability lump-sum payments (Table 5) vary between zero, for those scenarios with estimated LEVs already greater than zero in which interest rates are low and site productivity is high, and almost \$2400 per hectare for mixed hardwood scenarios with high interest rates and low site productivity. By adjusting regeneration intensity as appropriate for site productivity and market situation, the payment required for minimum profitability can be reduced somewhat, as compared with some of the highest payment scenarios. As expected, our results illustrate that smaller investments typically should be made in sites with poor productivity where improved growth does not offset the additional cost, or in situations where high alternative rates of return result in greater discounting of the future benefits of those investments.

Lump-sum payments required for full reimbursement of forest conversion expenses range from \$1527 per hectare for white pine under a high ARR and low reforestation intensity, up to nearly \$2460 per hectare for mixed hardwoods under a low ARR and high intensity reforestation (Table 6). The fact that reforestation cost is higher for hardwoods than for pines, and that it increases with increasing intensity, is evident in the uniformly higher payment required for hardwood conversion compared with pine conversion, and in the higher payment required for reimbursement of higher intensity effort. With regard to the lower payments occurring under a higher ARR, these results seem counterintuitive. However, the costs occurring in the later years of reforestation (i.e., second and third years) are discounted to a greater degree at higher interest rates, therefore requiring a lower payment in the first year than in situations with a lower ARR. Recall that under this scheme, productivity and growth do not matter, because the payment is based only on recovery of the cost of reforesting.

The one-time, lump-sum payments discussed above are also converted to annual payments made over the life of the stand, for both the minimum profitability level (Table 7) and the full cost reimbursement level (Table 8), as follows:

$$a = \frac{P \cdot i \cdot (1+i)^t}{(1+i)^t - 1} \quad (10)$$

where P is the lump-sum payment. Our analysis is based on the assumption that this payment would begin at the time of reforestation and conclude at the time of harvest at the end of the first rotation of timber.

In the case of annualized, minimum profitability payments (Table 7), the required payments range from zero to almost \$182 per hectare per year, but now some hardwood payments are close to, or even lower than, annual payments required to make white pine conversion profitable. This finding is in contrast to many of the lump-sum payments required to make reforestation of these previously reclaimed mine lands minimally profitable, a result of the longer rotation lengths over which the annual hardwood payments are amortized. In the case of annualized, full cost reimbursement payments (Table 8), payments range from \$66 per hectare per year to nearly \$200 per hectare per year, and in every scenario the required mixed hardwood payment is lower than its white pine counterpart—again due to the longer rotation length for hardwoods.

Conclusions

Based on our work in the preceding quarter, it appears that substantial payments would be required to reach “profitability” under the present circumstances. Even though the payments that we examine could generate positive LEVs or even provide full reimbursement of grassland to forest conversion costs, there is no guarantee that the payments will actually cause landowners to reforest in practice. Equation (7) indicates that it is landowner *utility* associated with forestland profitability that will be the determining factor in actual conversion—utility that likely would include cash flow timing, amenities, and even the credit position of the landowner. Our calculated values could be viewed as the minimum levels of payments required to cause grassland to forest conversion on reclaimed mine lands in the Appalachian mine region.

Further, it should be noted that we do not determine whether any of these types of reforestation payments should come from the mine operators or the government. Some would interpret the provisions of SMCRA to require mine operators to go back and pay the costs of making these lands truly productive, including the establishment of commercial forests where appropriate. However, others would argue that regulatory agencies in the past have not readily accepted or been able to judge the suitability of forest establishment for securing bond release on these reclaimed sites.

References

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Table 3. Land expectation values of mixed Appalachian hardwood reforestation of reclaimed mine sites when landowner or mine operator pay establishment costs, by site class, reforestation intensity, and discount rate—60-year rotation (\$/hectare).

Landowner Pays to Reforest				Mine Operator Pays to Reforest			
5% ARR, low prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1532.35	-1814.41	-2316.93		107.36	121.82	129.10
IV	-1501.11	-1778.30	-2248.79		138.60	157.93	197.24
III	-1465.01	-1710.16	-2196.42		174.70	226.07	249.61
III	-1401.70	-1663.37	-2173.24		238.01	272.86	272.79
I	-1350.08	-1634.61	-2173.24		289.63	301.62	272.79
5% ARR, high prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1146.60	-1368.46	-1801.39		493.11	567.77	644.64
IV	-1055.17	-1262.75	-1590.06		584.54	673.48	855.97
III	-949.46	-1051.43	-1434.87		690.25	884.80	1011.16
III	-752.45	-912.79	-1366.22		887.26	1023.44	1079.81
I	-599.50	-827.59	-1366.22		1040.21	1108.64	1079.81
3.5% ARR, low prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1372.05	-1631.40	-2129.71		274.93	312.10	329.88
IV	-1291.77	-1538.59	-1954.57		355.21	404.91	505.02
III	-1198.96	-1363.46	-1819.94		448.02	580.04	639.65
III	-1036.24	-1243.19	-1760.38		610.74	700.31	699.21
I	-903.55	-1169.27	-1760.38		743.43	774.23	699.21
3.5% ARR, high prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-380.55	-485.16	-804.57		1266.43	1458.34	1655.02
IV	-145.53	-213.46	-261.39		1501.45	1730.04	2198.20
III	126.17	329.73	137.50		1773.15	2273.23	2597.09
III	632.56	686.07	313.97		2279.54	2629.57	2773.56
I	1025.70	905.08	313.97		2672.68	2848.58	2773.56
7.5% ARR, low prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1602.96	-1896.10	-2394.16		25.23	28.61	30.45
IV	-1595.66	-1887.66	-2378.24		32.53	37.05	46.37
III	-1587.22	-1871.74	-2366.00		40.97	52.97	58.61
III	-1572.43	-1860.80	-2360.58		55.76	63.91	64.03
I	-1560.36	-1854.08	-2360.58		67.83	70.63	64.03
7.5% ARR, high prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1512.81	-1791.88	-2273.68		115.38	132.83	150.93
IV	-1491.44	-1767.18	-2224.29		136.75	157.53	200.32
III	-1466.74	-1717.79	-2188.03		161.45	206.92	236.58
III	-1420.70	-1685.39	-2171.98		207.49	239.32	252.63
I	-1384.96	-1665.48	-2171.98		243.23	259.23	252.63

Table 4. Land expectation values of white pine reforestation of reclaimed mine sites when landowner or mine operator pay establishment costs, by site class, reforestation intensity, and discount rate—30-year rotation (\$/hectare).

Landowner Pays to Reforest				Operator Pays to Reforest			
5% ARR, low prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1125.97	-1318.31	-1747.07		412.92	517.10	598.14
IV	-914.67	-1062.16	-979.31		624.22	773.25	1365.90
III	-676.38	-316.06	-532.05		862.51	1519.35	1813.16
III	36.19	90.56	-39.10		1575.08	1925.97	2306.11
I	476.35	624.15	268.78		2015.24	2459.56	2613.99
5% ARR, high prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-926.98	-1077.09	-1454.64		611.91	758.32	890.57
IV	-669.54	-764.99	-584.94		869.35	1070.42	1760.27
III	-379.21	78.32	-53.95		1159.68	1913.73	2291.26
III	424.29	561.05	531.27		1963.18	2396.46	2876.48
I	946.83	1194.52	896.78		2485.72	3029.93	3241.99
3.5% ARR, low prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-768.42	-873.41	-1243.99		777.74	969.27	1114.78
IV	-379.93	-402.45	167.60		1166.23	1440.23	2526.37
III	58.18	969.32	989.94		1604.34	2812.00	3348.71
III	1368.31	1716.93	1896.26		2914.47	3559.61	4255.03
I	2177.56	2697.98	2462.32		3723.72	4540.66	4821.09
3.5% ARR, high prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-402.58	-429.90	-706.32		1143.58	1412.78	1652.45
IV	70.75	143.91	892.69		1616.91	1986.59	3251.46
III	604.55	1694.41	1868.97		2150.71	3537.09	4227.74
III	2081.86	2581.96	2944.93		3628.02	4424.64	5303.70
I	3042.59	3746.65	3616.95		4588.75	5589.33	5975.72
7.5% ARR, low prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1364.38	-1616.28	-2080.18		162.99	207.61	243.61
IV	-1273.87	-1506.55	-1751.30		253.50	317.34	572.49
III	-1171.80	-1186.95	-1559.71		355.57	636.94	764.08
III	-866.56	-1012.77	-1348.55		660.81	811.12	975.24
I	-678.01	-784.20	-1216.67		849.36	1039.69	1107.12
7.5% ARR, high prices							
Site/Intensity	Low	Medium	High		Low	Medium	High
V	-1279.15	-1512.95	-1954.91		248.22	310.94	368.88
IV	-1168.87	-1379.26	-1582.37		358.50	444.63	741.42
III	-1044.50	-1018.01	-1354.91		482.87	805.88	968.88
III	-700.31	-811.23	-1104.23		827.06	1012.66	1219.56
I	-476.47	-539.87	-947.65		1050.90	1284.02	1376.14

Table 5. Lump-sum payment required at reforestation inception to provide minimal profitability (LEV ≥ 0) for landowner of reclaimed mine land, by site class, reforestation intensity, and discount rate (\$/hectare).

Mixed Hardwoods (60-year rotation)				White Pine (30-year rotation)		
5% ARR, low prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	1532.35	1814.41	2316.93	1125.97	1318.31	1747.07
IV	1501.11	1778.30	2248.79	914.67	1062.16	979.31
III	1465.01	1710.16	2196.42	676.38	316.06	532.05
III	1401.70	1663.37	2173.24	*	*	39.10
I	1350.08	1634.61	2173.24	*	*	*
5% ARR, high prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	1146.60	1368.46	1801.39	926.98	1077.09	1454.64
IV	1055.17	1262.75	1590.06	669.54	764.99	584.94
III	949.46	1051.43	1434.87	379.21	*	53.95
III	752.45	912.79	1366.22	*	*	*
I	599.50	827.59	1366.22	*	*	*
3.5% ARR, low prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	1372.05	1631.40	2129.71	768.42	873.41	1243.99
IV	1291.77	1538.59	1954.57	379.93	402.45	*
III	1198.96	1363.46	1819.94	*	*	*
III	1036.24	1243.19	1760.38	*	*	*
I	903.55	1169.27	1760.38	*	*	*
3.5% ARR, high prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	380.55	485.16	804.57	402.58	429.90	706.32
IV	145.53	213.46	261.39	*	*	*
III	*	*	*	*	*	*
III	*	*	*	*	*	*
I	*	*	*	*	*	*
7.5% ARR, low prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	1602.96	1896.10	2394.16	1364.38	1616.28	2080.18
IV	1595.66	1887.66	2378.24	1273.87	1506.55	1751.30
III	1587.22	1871.74	2366.00	1171.80	1186.95	1559.71
III	1572.43	1860.80	2360.58	866.56	1012.77	1348.55
I	1560.36	1854.08	2360.58	678.01	784.20	1216.67
7.5% ARR, high prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	1512.81	1791.88	2273.68	1279.15	1512.95	1954.91
IV	1491.44	1767.18	2224.29	1168.87	1379.26	1582.37
III	1466.74	1717.79	2188.03	1044.50	1018.01	1354.91
III	1420.70	1685.39	2171.98	700.31	811.23	1104.23
I	1384.96	1665.48	2171.98	476.47	539.87	947.65

* indicates LEV is positive without additional payments

Table 6. Lump-sum payment required at reforestation inception to provide full reimbursement of forest conversion costs to landowner of reclaimed mine land, reforestation intensity, and discount rate (\$/hectare).

Forest Type/Intensity	Low	Medium	High
	5% ARR		
mixed hardwoods (60-year rotation)	1639.71	1936.23	2446.03
white pine (30-year rotation)	1538.89	1835.41	2345.21
	3.5% ARR		
mixed hardwoods	1646.98	1943.50	2459.59
white pine	1546.16	1842.68	2358.77
	7.5% ARR		
mixed hardwoods	1628.19	1924.71	2424.61
white pine	1527.37	1823.89	2323.79

Table 7. Annual payment required over one rotation to allow minimal profitability ($LEV \geq 0$) for landowner of reclaimed mine land, by site class, reforestation intensity, and discount rate (\$/hectare/year).

Mixed Hardwoods (60-year rotation)				White Pine (30-year rotation)		
5% ARR, low prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	80.95	95.85	122.40	73.25	85.76	113.65
IV	79.30	93.94	118.80	59.50	69.10	63.71
III	77.39	90.34	116.03	44.00	20.56	34.61
III	74.05	87.87	114.81	*	*	2.54
I	71.32	86.35	114.81	*	*	*
5% ARR, high prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	60.57	72.29	95.16	60.30	70.07	94.63
IV	55.74	66.71	84.00	43.55	49.76	38.05
III	50.16	55.55	75.80	24.67	*	3.51
III	39.75	48.22	72.17	*	*	*
I	31.67	43.72	72.17	*	*	*
3.5% ARR, low prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	55.00	65.40	85.38	41.78	47.49	67.64
IV	51.79	61.68	78.36	20.66	21.88	*
III	48.06	54.66	72.96	*	*	*
III	41.54	49.84	70.57	*	*	*
I	36.22	46.87	70.57	*	*	*
3.5% ARR, high prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	15.26	19.45	32.25	21.89	23.37	38.40
IV	5.83	8.56	10.48	*	*	*
III	*	*	*	*	*	*
III	*	*	*	*	*	*
I	*	*	*	*	*	*
7.5% ARR, low prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	121.81	144.09	181.94	115.52	136.85	176.13
IV	121.26	143.45	180.73	107.86	127.56	148.28
III	120.62	142.24	179.80	99.22	100.50	132.06
III	119.49	141.40	179.38	73.37	85.75	114.18
I	118.57	140.89	179.38	57.41	66.40	103.02
7.5% ARR, high prices						
Site/Intensity	Low	Medium	High	Low	Medium	High
V	114.96	136.17	172.78	108.31	128.10	165.52
IV	113.34	134.29	169.03	98.97	116.78	133.98
III	111.46	130.54	166.27	88.44	86.20	114.72
III	107.96	128.08	165.05	59.30	68.69	93.50
I	105.25	126.56	165.05	40.34	45.71	80.24

* indicates LEV is positive without additional payments.

Table 8. Annual payment required over one rotation to provide full reimbursement of forest conversion costs to landowner of reclaimed mine land, reforestation intensity, and discount rate (\$/hectare/year).

Forest Type/Intensity	Low	Medium	High
5% ARR			
mixed hardwoods (60-year rotation)	86.62	102.29	129.22
White pine (30-year rotation)	100.11	119.40	152.56
3.5% ARR			
mixed hardwoods	66.03	77.91	98.60
white pine	84.07	100.19	128.25
7.5% ARR			
mixed hardwoods	123.73	146.26	184.25
white pine	129.32	154.43	196.76

TASK 5: Determine the potential of large-scale SMCRA grassland restoration to sequester carbon and create other societal benefits. (Zipper et al.)

Executive Summary

During the second quarter of 2004, a post-doctoral research associate (Dr. Joshua McGrath) began work co-supported by NASA funds (Wynne et al., 2003; 2004) compiling a database describing the total land area of post-SMCRA, bond released mined lands that would be available for reforestation. We have been working with the government agencies in each state responsible for surface mine regulation, compiling data collected through their mine permitting processes. We have found that the proposed protocol will be inadequate to estimate mined land acreages available for reforestation, and are in the process of developing and applying an alternative protocol that will utilize medium resolution multispectral images from the Landsat Thematic Mapper (TM) and/or Enhanced Thematic Mapper Plus (ETM+) in combination with ancillary data sources including digital orthophotography, spatial mine-permit data available from mining agencies, and geologic data defining coal reserves suitable for surface mining to estimate post-SMCRA grassland acreages available for reforestation.

Experimental

1. Estimate the acreage of lands in Virginia, West Virginia, Kentucky, Ohio, and Pennsylvania mined under SMCRA and reclaimed to non-forested post-mining land uses that are not currently under active management, and therefore can be considered as available for carbon sequestration.

During the past quarter, mining agencies in four of the five states (Virginia, West Virginia, Kentucky, and Ohio) were contacted and preliminary data were obtained. Agencies in Virginia and Kentucky were visited, and the Ohio agency is scheduled for visitation in early August. Our focus for this activity is Phase III bond-released acreages (i.e., lands that have been released from all SMCRA-permitting obligations). We have not yet contacted Pennsylvania, pending resolution of outstanding issues being addressed with the other four states.

Agency records will not be adequate to quantify non-forested post-mining acreages. The agencies maintain mine-permit data in a variety of formats. In some states (e.g., Kentucky), all data on mine permits completed since SMCRA are available electronically, while other states maintain these data as both electronic files (more recent) and as paper archives (for older mines). In all states, acreages reclaimed to various post-mining land uses are not discriminated for individual mining permits. Thus, a permitting record will state the total number of permit acres and the post-mining land use(s) to which those lands were reclaimed, but when multiple post-mining land uses are present, the record will not quantify how the total permit acreage is distributed among those land uses. In all states, the majority of mine permits describe multiple land uses. Although these data can be obtained from individual mine permits, accessing enough permits to estimate post-mining land use acreages in aggregate would be time-prohibitive.

As an alternative to this procedure, we are in the process of applying and advancing a protocol used by The Nature Conservancy (Kant and Kreps, 2004) that utilizes remote sensed data to identify non-forested acreages in southwestern Virginia's Clinch and Powell watersheds. We intend to apply this protocol over part or all of the study region in order to classify images of the study area to determine the spatial extent of mined areas available for reforestation, mined

areas unavailable for reforestation, and un-mined areas. We expect the procedure to include the following steps:

- a. Define the geographical extent of surface coal mining within each state using mine-permit spatial data files obtained from mining agencies, digital orthophotography, and geologic mapping (where available).
- b. Qualitatively identify spatial trends (i.e. shape, area, and position of mined lands relative to topographic features) that correlate with reclaimed surface mined areas and might be useful for the classification.
- c. Using the stratum defined in Step A, create a stratified random sample of 600 points, 300 for each of the mined and un-mined strata.
- d. Obtain one or more Landsat TM or ETM+ scenes of the VA coal region, preferably a path mosaic.
- e. Classify a path mosaic of Landsat TM or ETM+ scenes covering the study area using multiple techniques and ancillary data sources.
- f. Assess the accuracy of the resulting classifications using a random sub-sample of the points interpreted from the VBMP data.

From what we know of agency records available in VA, WV, and KY, we expect that the above procedures will be necessary to estimate mined acreages in these states.

2. Determine the distribution of soil properties influencing reforestation and carbon sequestration potentials over the Appalachian coal fields.

This activity will be conducted by selecting a random sample of the non-forested, reclaimed mine sites identified under activity 1, and sampling those sites to describe their physical and chemical properties. During the past quarter, we began the process of defining statistical and physical sampling protocols, but no sampling was conducted.

3. Estimate the potential for carbon sequestration on post-SMCRA mined lands reclaimed to non-forested land uses in the Appalachian coal fields.

This activity will be conducted by applying the models defined by other investigators to the results of our analyses conducted under Tasks 1 and 2. During the past quarter, no activity was conducted.

Results

There are no results to report at this time.

References

- Wynne, R., J. Campbell, C. Zipper, and L. Watson. 2003. Remote sensing for forest productivity, carbon management and monitoring. Grant application to National Aeronautics and Space Administration / George Mason University. (10/03 – 9/04, funded).
- Wynne, R., J. Campbell, C. Zipper. 2004. Remote sensing for forest productivity, carbon management and monitoring. Grant application to National Aeronautics and Space Administration / George Mason University. (10/04 – 9/05, pending). Kant, Z. and B. Kreps. 2004. Carbon sequestration and reforestation of mined lands in the Clinch and Powell River Valleys: Feasibility Study. The Nature Conservancy. Topical Report: Task 5. DOE Award Number: DE-FC-26-01NT41151.

PROJECT TIMETABLE

						Planned		Completed				
Year:	2002	2003				2004				2005		
Quarter:	4th	1st	2nd	3rd	4 th	1st	2nd	3rd	4th	1st	2nd	3rd
Task 1												
Subtask 1.1	Baseline Carbon Sequestration Potential											
Subtask 1.2	Mine Soil Productivity											
Subtask 1.3						Carbon Sequestration by Forest Practice						
Subtask 1.4						Accounting Procedures						
Task 2												
Subtask 2.1	Classification Criteria											
Subtask 2.2				GIS Mapping								
Subtask 2.3				Test Remote Sensing								
Subtask 2.4						Experimental Plots						
Subtask 2.5						Soil Analyses						
Subtask 2.6											Validate classification criteria	
Task 3												
Subtask 3.1	Locate sites											
Subtask 3.2			Establish experiment									
Subtask 3.3			Silvicultural recommendations									
Subtask 3.4						Reforestation costs						
Subtask 3.5						Evaluate survival & growth						
Subtask 3.6						Estimate growth potential						
Subtask 3.7						Estimate timber & carbon value						
Task 4	Economic feasibility											
Subtask 4.1						Evaluation						
Subtask 4.2								Government policies				
Subtask 4.3												
Task 5												
Subtask 5.1			Identify SMCRA grassland									
Subtask 5.2				Use characteristics of permits								
Subtask 5.3						Soil properties by permit						
Subtask 5.4								Est. quantity grassland				
Subtask 5.5								Est. C sequ. by site quality class				
Subtask 5.6											Est. C sequ. by policy scenario	