2008
POWELL RIVER PROJECT
RESEARCH AND EDUCATION
PROGRAM REPORTS

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Influence of cattle grazing alone and with goats on forage biomass, botanical composition and browse species on reclaimed mine land

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Reclaimed mined-lands have been successfully used for forage production in the Appalachian region. However, the encroachment of undesirable invasive plant species reduces the utilization of these pasturelands by cattle and conventional control methods are not cost-effective. An experiment was initiated in spring 2006 in Virginia to determine the effects of mixed grazing goats with cattle on forage biomass, botanical composition and browse species. The three treatments were a no grazing control, cattle alone grazing, and mixed grazing goats with cattle. Treatments were arranged in a randomized complete block design with 3 replications of each grazing treatments and 2 of the untreated control. The treatment with cattle alone had three crossbred steers while the mixed grazing treatment utilized three crossbred steers and 15 young intact male goats. Forage biomass yield was determined in spring, summer and fall by clipping 8-0.25m² square quadrants per grazing treatment and 4-0.25m² in the control treatment to a 2.5 cm height. Prior to clipping, botanical composition and groundcover were assessed visually. Autumn olive (*Elaeagnus umbellata* Thunb.) measurements included branch length, shrub height, and shrub survival. Eight shrubs were randomly identified and tagged with a letter in each treatment replication while four shrubs were used in the control treatment.

Mixed grazing of goats with cattle can have positive influences on botanical composition and invasive plant species control on reclaimed coal-mined lands in the Appalachian region. When compared to control and cattle alone grazing, forage availability was lower for mixed grazing over the entire grazing season. Groundcover percentage tended to be lowest for mixed grazing particularly during the summer season. Goats showed a clear preference for browse species and forbs such as sericea lespedeza. The grazing behavior of goats influenced the growth pattern of sericea lespedeza from an erect, woody, less leafy plant to a shorter, more palatable, and more leafy plant. The shorter and leafier sericea lespedeza was more acceptable and thus was readily grazed by cattle. In 2006, grazed treatments resulted in a reduction in undesirable weedy species. Furthermore, by the end of the 2007 grazing season, the grazing treatments reduced the weed percentages below 30% (Tables 1 and 2). By the end of the two grazing seasons, the grass component of the grazed pastures increased while legumes particularly clovers declined (Tables 1 and 2). The change in botanical composition of the pastures due to grazing can be attributed to the grazing pattern and diet preference of the grazing animals. The grazing behavior and diet selection of goats greatly differs from cattle. This makes the mixed grazing of cattle and goats an alternative management technique for managing diverse pasture swards.

Goat browsing had negative impact on autumn olive shrubbery. In 2006, branch length was negatively impacted by goat browsing but not in 2007. Differences in autumn olive height showed differences in summer-fall period 2006 and spring-summer period 2007 but no differences in shrub height at the end of the growing seasons were noted. Shrub survival was lower in mixed grazing (up to 80%, Figure 3)) by the end of the experiment compared to the other treatments. Standing on their hind legs and placing their weight on branches resulted in the development of a browse line, broken, and dead branches. Bark stripping and girdling further crippled autumn olive shrub vigor.

Mixed grazing goats with cattle is a viable practice on reclaimed coal-mined lands. It resulted in greater utilization of pasture resources mainly due to the different grazing habit of goats and cattle offering opportunities for complementary pasture use. Goats provided biological control for invasive plant species, such as autumn olive. Therefore, goats could have a major role in low-input farm enterprises in the Appalachian coal-mining region. These results suggest that goats and cattle grazing together in botanically diverse pastures could maximize the efficiency of utilization of both herbaceous and woody species.

Table 1. Effect of control, cattle alone, and mixed grazing treatments on botanical composition -2006.

	Treatments		
Component	Control	Cattle	Mixed
………………………Spring………………………			
Groundcover	81.0a	84.2a	69.5b
Grass	44.0a	40.2a	36.8a
Legume	18.0b*	32.8a*	5.2c*
Weed	38.0b	27.0b	58.0a
..................................Summer……………………...			
Groundcover	91.0a	85.0a	63.5b
Grass	25.0b	48.8a	55.0a
Legume	18.0ba	27.7a	9.2b
Weed	57.0a	23.5b	35.8b
…………..……………Fall………………………...			
Groundcover	80.0a	79.7a	66.2b
Grass	52.0c*	63.7b*	76.3a*
Legume	4.5b	27.5a	7.0b
Weed	43.5a	8.8b	16.7b

Values followed by capital letter signify significance within row
*indicates significant differences at P = 0.10

Table 2. Effect of control, cattle alone, and mixed grazing treatments on botanical composition – 2007.

Component	Control	Treatments Cattle	Mixed
	………………………Spring………………………		
Groundcover	67.5ba	75.2a	55.2b
Grass	72.0a	72.5a	52.7b
Legume	0.5b	19.5a	16.7a
Weed	27.5a	8.0b	30.7a
	..................................Summer……………………..		
Groundcover	63.0a	61.5a	57.8b
Grass	41.0b	77.3a	70.7a
Legume	0.0c*	8.2b*	16.5a*
Weed	59.0a	14.5b	12.8b
	…………..……………Fall………………………....		
Groundcover	83.5b	75.7a	59.7b
Grass	49.0b	83.3a	72.8a
Legume	0.0a	5.8a	5.5a
Weed	51.0a	10.9b	21.7b

Values followed by capital letter signify significance within row.
*indicates significant differences at P = 0.10

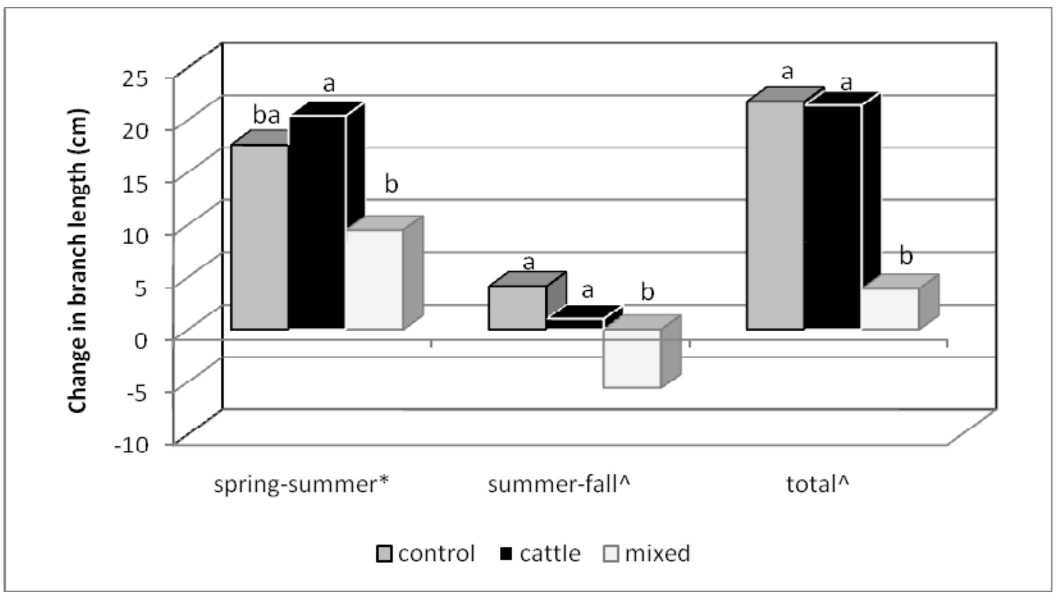

Figure 3. Influence of cattle alone and mixed grazing vs. no grazing control on seasonal and total change of branch length (cm) of autumn olive for 2006
(values within season followed by the same letters not significant at P = 0.05).

Project Coal to Electricity
2008 Summer Teacher Education Program

Barbara Altizer
Eastern Coal Council

Jon Rockett
Powell River Project Research & Education Center

Project Summary

This week-long summer session offered eleven teachers in grades 3-6 and earth science a unique opportunity to learn about Virginia's coalfields and their economic impact on the State's economy. The teachers were from Virginia Beach, Chesapeake, Lexington, South Boston, Dublin, Luray, and Spanishburg and Huntington, WV. We also had two guests for industry, Hannah Murrell with Natural Resource Partners and Cathy Coffey with Americans for Balanced Energy Choices.

The program is designed to address the natural resource and earth science standards of learning, the session provided a first hand field experience covering the extraction, preparation, transportation and utilization of coal. In addition, the Virginia regulatory requirements and global issues associated with coal were also examined.

Why Each Teacher Decided to Attend

Great opportunity (3). Looked informative, hadn't seen all aspects of coal to electricity. I wanted to learn more about coal as a natural resource and how it is mined in VA. Wanted to know more about coal to energy. I knew nothing about the coal industry, and I teach electricity & natural resources of VA. SOL coverage. Opportunity to tour generating plant & coal mines

Field Trips & Presentations

- Flag Rock & Powell River Project Research & Education Center: Tony Scales, Geologist, Virginia DMME, local geologic structure and its impact on history & coal mining. Jon Rockett, Powell River Project Research & Education Center, post-mining land use opportunities for economic development
- Coal Surface Mining Operations: Mike Thomas and Eddie Clapp, Red River Coal Co, Coal
- Virginia's Coal Regulatory Program: Mike Abbott, Virginia Department Mines Minerals & Energy
- Underground Coal Mining Operations: Dickenson/Russell Deep Mine #36 Coal Benefaction: Moss #3 Preparation Plant and Spectrum Laboratory
- Wine Tasting & Dinner, MountainRose Vineyard (Reclaimed Mine Site)
- Coal Rail Transportation Guest Speaker: Tom Rappold, Norfolk Southern Corporation
- Gas Production: CNX Gas (Coalbed Methane Gas

- Longwall Underground Coal Mining: Consol Energy Buchanan Mine
- Air Quality Standards: Dallas Sizemore, Virginia Department Environmental Quality
- Coke Production: Jewell Smokeless Coke Ovens
- Breaks Interstate Park: Jon Rockett, Powell River Project Research & Education Center.
- Guest Speaker: The Honorable Phillip Puckett, Virginia Senate
- Coal-fired Electricity Generation: Appalachian Power, Carbo Plant/Waste Water Treatment/Ash Fill
- Virginia City Hybrid Plant: Herbert Wheary, Dominion Energy
- Cultural Enrichment: Outdoor Drama -- Trail of the Lonesome Pine and Natural Tunnel State Park
- Technology in the Workplace: Joy Mining Machinery Re-build Facility
- Coal Gasification: Eastman Chemical Company

Teachers received 40 hours of Professional Development credit for attending the program and provided the following evaluation:

Overall, how appropriate were the field trip activities?
(11) Very Appropriate (0) Appropriate (0) Not Very Appropriate

Please rate each field trip (max value 4.00)

A.	Flag Rock – geology & land use	3.82
B.	Powell River Project Research & Ed Ctr	3.91
C.	Red River's surface mine	4.00
D.	D/R Mine # 36	4.00
E.	Moss 3 prep plant	4.00
F.	Spectrum Lab	3.73
G.	CNX Gas	3.73
H.	Consol longwall mine	4.00
I.	Jewell Smokeless coke ovens	4.00
J.	Appalachian Power plant	3.91
K.	Joy Mining rebuild facility	3.91
L.	Eastman Chemical coal gasification	3.36

Overall, how appropriate were the evening programs?
(11) Very Appropriate (0) Appropriate (0) Not Very Appropriate

Please rate each evening program (max value 4.00)

A.	Mike Abbott, DMME	3.73
B.	MountainRose Vineyard	3.82
C.	Tom Rappold, Norfolk Southern	3.91
D.	Dallas Sizemore, DEQ	3.64
E.	Breaks Interstate Park	3.91
F.	Phillip Puckett, VA Senate	3.91
G.	John Fox House	4.00

H.	Herbert Wheary, Dominion Energy	4.00
I.	Trail of the Lonesome Pine	3.91
J.	Natural Tunnel SP	4.00

As a result of this program, to what extent do you believe students will increase their understanding of the impact of coal on the Virginia economy?
(9) To A Great Extent (2) To Some Extent (0) Not Much (0) Not At All

As a result of this program, to what extent do you believe students will increase their understanding of the coal industry's future impact on the Virginia economy?
(6) To A Great Extent (5) To Some Extent (0) Not Much (0) Not At All

To what extent will you incorporate the information gained during this program into lesson plans?
Adapt material to existing lesson plans: Never (0) Seldom (0) Often (5) Almost always (4)
Use material to create new lesson plans: Never (0) Seldom (0): Often (3) Almost always (6)

What will be done differently regarding teaching as a result of participating in the program?

- More in depth, more examples, more practicality.
- I will make the coal mining industry a very cool thing to do!
- Wow, this requires a lot of thought. Everything will be done differently as a result of the knowledge I have gained.
- Make a event based problem solving unit about energy
- Incorporating newly learned knowledge & personal experience of going into the mines & plants
- I will use correct terminology and provide a first hand experience instead of book facts
- Help the students to understand how much is involved (jobs, etc) with mining. Also, the resource of coal , what are uses, & safety
- Educating students about coal and its impact on energy and the US and the entire world
- Greater emphasis explanation electrical generation

Has your ability to implement grade level Standards of Learning with SW VA coalfield examples improved as a result of your participating in the program?
(10) Yes (0) No
If Yes, to what extent?
(9) To a Great Extent (1) To Some Extent (0) Not Much (0) Not At All
I learned so much about the industry this week.

Do you believe this will result in students gaining a better understanding of the world around them than would be the case if this program were not offered?

(10) Yes (0) No

Explain:

- Gives us a much better understanding so we can pass it along to others
- Kids will listen to anything a teacher says with regards to something neat to do. I will impress the kids that coal mining is a great place to get a job when they are older.
- They will get info from me about everything I learned – especially energy!
- By participating in this program I can better relate how coal becomes electricity and try to have students use it wisely particularly when I can personally relate to a coal miners life (or plant worker)
- I have a better understanding of my own state, and I feel that the students will benefit from that as I teach and carry it over to a more global perspective.
- I have a better understanding and I will be able to better present the information
- Not only info from our immediate area but the entire world

Additional comments/impressions/thoughts

- I will send you both my thoughts via email once I have given the thought process the time needed to show my great appreciation for the program.
- My objective was to learn different aspects of coal fired electricity so I can educate reporters, elected officials and public. Thanks for the opportunity
- Everything was great! This was a wonderful experience! Want to come back! Food was awesome, too!
- This was the best professional development program I have attended. It was very informative & comprehensive.
- Fabulous, thanks!
- If you had to eliminate anything to cut it shorted you could eliminate *Trail of the Lonesome Pine*, but hen we'd miss the local flavor which is important tool
- You all did a wonderful job – I can't wait to become proactive!
- I'm looking forward to the advanced class!! I have absolutely nothing negative to say.
- This is a great program. I never knew so much was involved in the production or how clean it is. Great program!
- Project Coal to Electricity – one of the greatest classes I've taken for some time. (So much information is given to us.)
- I liked the busy schedule and recommend keeping the program exactly as it is. Wonderful week! Jon and Barbara, thanks for the personal attention. You all must be exhausted.

REFORESTATION OF MINED LAND FOR PRODUCTIVE LAND USES AND ENVIRONMENTAL QUALITY

James Burger, Beyhan Amichev, and Chris Fields-Johnson
Department of Forestry, Virginia Tech

PROGRESS REPORT (2007-2008)

The Powell River Project Forestry Reclamation Approach

Most mined land in the Appalachian Coalfields that was previously forested is now being returned to forests. Forestry is a logical land use because of its traditional economic importance to the region, and because of the many services it provides the public such as flood control, water quality, habitat, carbon sequestration, and aesthetic environments. After the implementation of the SMCRA in 1978, highly-graded mined landscapes covered with agricultural grasses and legumes were common. However, landowners and coal operators are now commonly reclaiming with trees for forestry post-mining land uses. To reclaim mined land with trees, a Forestry Reclamation Approach (FRA) is needed to ensure tree survival and productivity. The approach requires five straightforward steps: (1) select the best soil or mine spoil for trees and apply about 4 feet for the final surface material; (2) grade it lightly or not at all to leave it loose and uncompacted; (3) employ a professional tree planter who guarantees his work; (4) have him plant a mix of commercially valuable native hardwoods (oaks, black cherry, sugar maple, ash, etc., at a rate of 600 trees/acre) along with a lesser amount of wildlife or nurse trees (dogwood, redbud, hawthorn, hickory, crabapple, etc., at a rate of 100 trees/acre); (5) after the trees are planted in winter, hydroseed a tree-compatible ground cover the following spring. More specific recommendations for the FRA can be found in Virginia Cooperative Extension Bulletin 460-123 at http://www.ext.vt.edu/pubs/mines/460-123/460-123.html.

The foundation for the Forestry Reclamation Approach is our ongoing Powell River Project reforestation research program consisting of many forestry research sites in Virginia and adjacent states. The results from these research sites allow us to develop reforestation guidelines for reclaiming mined land, and they allow us to demonstrate the value of reclaimed forests. Because forestry is a long-term enterprise, we maintain and monitor our field sites over time. The older these research sites become, the more valuable they are, because they show how reclamation treatments will ultimately affect the success and value of the restored forest. As we collect data from these older sites, we adjust our guidelines and recommendations in ways that will improve reclamation for better long-term forestry land uses.

Research Reports

This year we did research on several steps of the Forestry Reclamation Approach. Herbaceous ground covers used for erosion control can be very competitive and detrimental to tree survival and growth. This was demonstrated in a six-year study that showed that native hardwoods can grow at three times the rate when ground cover is reduced to 60 to 80% while still controlling erosion. We summarized the results of this and other long-term studies in a Powell River Project Virginia Cooperative Extension Publication that is currently available from the Powell River Project website: http://www.ext.vt.edu/pubs/mines/460-124/460-124.html

Another major mined land reforestation research effort this year was determining the reforestation potential of bond released compacted mined land. Many lands reclaimed since the passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) have dense ground covers and compacted soil materials, in some cases associated with unfavorable soil chemical properties. To address these concerns, three previously reclaimed mined sites were located in Ohio, Virginia, and West Virginia. At each site, eastern white pine, hybrid poplar, and mixed Appalachian hardwoods were planted at three levels of silvicultural intensity (weed control only, weed control with subsoil ripping, and weed control with subsoil ripping and fertilization). Each combination of species and treatment was repeated three times in each of the three states. All species achieved their highest biomass values for this study on the West Virginia shale-based spoils and their highest survival rates on the Virginia sandstone-dominated spoils. When restoring forest vegetation to previously reclaimed mine sites with unfavorable soil and vegetation properties, the use of weed control and subsoil ripping, with or without fertilization, greatly improves survival and growth.

The full paper presenting the results of this work is attached to this report.

Ongoing Research Activities

Our ongoing Powell River Project reforestation research program is dedicated to: (1) helping coal operators meet their reclamation requirements; (2) helping landowners maximize the value of their reclaimed mined land; and (3) helping mining communities meet their socio-economic needs. The following studies are being conducted to meet these goals:

1. *Use of herbicides for weed control to improve native hardwood establishment.*

- This PRP project is in its seventh growing season. The results after three years were published this year in the proceedings of the American Society for Mining and Reclamation.

Burger, J. A., D. O. Mitchem, C. E. Zipper, and R. Williams. 2008. Hardwood reforestation for Phase III bond release: Need for reduced ground cover. In: R. I. Barnhisel (ed.). Proc., 25th Mtg., Amer. Soc. for Mining and Reclamation. July 14-19, 2008, Richmond, VA. ASMR, 3234 Montavesta Rd., Lexington, KY.

2. *Hardwood establishment field trials:*

- This is a large study with 10 three-acre sites located in three states. We completed tree, ground cover, and site measurements for eight continuous years. A preliminary analysis of this project was presented and published at the annual meeting of the American Society of Mining and Reclamation in Breckenridge, Colorado, in June, 2005. A final report will be completed winter, 2009.

Auch, W. T., J. A. Burger, and D. O. Mitchem. 2005. Hardwood stocking after five years on reclaimed mined land in the Central Appalachians. In: R. I. Barnhisel (ed.). Proc., 22nd Mtg., Amer. Soc. for Mining and Reclamation. June 18-24, 2005, Breckenridge, CO. ASMR, 3234 Montavesta Rd., Lexington, KY.

3. *White oak response to different mine soil types:*

- We continue to monitor an 80-acre native hardwood planting on Rapoca Coal Company land. This cooperative effort between Rapoca, Virginia Tech, and the Virginia DMME serves as a model for the application of Powell River Project reforestation guidelines.

We recently completed a study of white oak response to mine soil types on this field site. The results of this work were published in Spring, 2007.

Showalter, J. M., J. A. Burger, C. E. Zipper, J. M. Galbraith, and P. F. Donovan. 2007. Influence of mine soil properties on white oak seedling growth: A proposed mine soil classification model. *Southern Journal of Applied Forestry* 31(2):99-107.

4. *Reforestation and carbon sequestration by forests and soils on mined land:*

- This project was funded by the Appalachian Regional Commission, Virginia Department of Mines, Minerals and Energy, The Nature Conservancy, the U.S. Department of Energy, and the Powell River Project. The project is directed toward reforestation of compacted mined land reclaimed prior to the implementation of the Forestry Reclamation Approach. It compares survival and growth of three forest types (hybrid poplar plantations, white pine plantations, and mixed native hardwoods) growing on mined land subjected to forest practices (weed control, tillage, and fertilization). This 3x3 factorial experiment is replicated three times in each of three states (Virginia, West Virginia, and Ohio). As part of the requirements for an undergraduate research project, fourth-year survival and growth was measured and presented by Chris Fields-Johnson, a forestry senior, at the annual meeting of the American Society for Mining and Reclamation in June, 2008 (Chris received a best paper award for his presentation). His published paper is attached to this progress report.
- The second objective of this study is to measure the potential of restored forests to sequester large amounts of atmospheric carbon, which is associated with the greenhouse effect and climate change. Much of the elevated level of CO_2 in the atmosphere is attributed to land use change and the burning of coal and other fossil fuels. This project will help determine the benefits of reforesting mined land for sequestering carbon from the atmosphere. Beyhan Amichev recently completed his Ph.D. dissertation in 2007 and published one of his papers in the journal *Forest Ecology and Management*.

Amichev, Beyhan Y. 2007. Biogeochemistry of carbon on disturbed forest landscapes. Ph.D. Dissertation. Virginia Polytechnic Institute and State University. 371 p.

Amichev, B., J. A. Burger, and J. A. Rodrigue. 2008. Carbon sequestration empirical models for forests and soils on mined lands in the eastern U. S. coalfields. *Forest Ecology and Management*. In press.

5. *Establishing hardwood forests with American chestnut using the Forestry Reclamation Approach: Effects of grading practices and ground cover:*

- This project compares the relative success of reforestation established using three different types of ground covers on both compacted and uncompacted mined soils. In the winter of 2008, a native hardwood mix was planted across all sites along with 5 varieties of American chestnut hybrids. This project will demonstrate the benefits of using the Forestry Reclamation Approach, and it will test the viability of American chestnut hybrids as a species component in reclaimed native forests. This research trial was established with the cooperation of Red River Coal Co. (two study sites) and Paramont Coal Co. (one study site). It was funded by an OSM Applied Science Grant and the Powell River Project.

6. Bioenergy feedstock production potentials of reclaimed coal mines:

- This project was installed with co-PI Carl Zipper in winter 2008 on three sites in Virginia. The purpose of this project is to determine the feasibility of using otherwise unproductive, reclaimed mined land for feedstock production for raw materials for conversion to biobased fuels and biobased products. We will determine the response of hybrid poplar planted on mined land of different quality to a range of silvicultural treatments, including weed control, tillage, and fertilization; determine biomass production and optimum harvest cycles of short rotation woody trees, including hybrid poplar, tulip poplar, and black locust; and we will conduct an economic analysis of the biomass system to both optimize the silvicutural system and provide feedstock costs to make comparisons with other current energy sources. The project was funded by Alpha Natural Resources.

Outreach Activities

We conducted a tour of forestry research sites during the Powell River Project field day in September, 2007, and supported Arbor Day events conducted by DMME.

Two Extension Bulletins on forestry topics were published:

Burger, J. A., C. E. Zipper, and J. Skousen. 2008. Establishing ground cover for forestry post-mining land uses. Virginia Cooperative Extension Bull. 460-124.

Zipper, C. E., and J. A. Burger. 2008. Coal-resource contracting terms for productive postmining forests. Virginia Cooperative Extension Bull. 460-143.

We participated in the 2nd Annual Appalachian Regional Reforestation Conference in Logan, West Virginia, August 4-6, 2008, and made the following presentations at the conference:

Zipper, C. E. “Overview of ARRI-Forestry Reclamation Approach advisory update.”

Burger, J. A. “Forestry Reclamation Approach Step 2: Grading and compaction.”

What Are the Benefits of This Reforestation Research?

Our work has provided the foundation for the Forestry Reclamation Approach used by many coal operators in Virginia and adjacent states. It is currently being promoted by the Office of Surface Mining’s Appalachian Regional Reforestation Initiative. Economic analyses have shown that the return on mined land reclaimed according to guidelines based on PRP research can be several times higher than on land currently reclaimed to unmanaged land uses. While improving the value of mined land for the landowner, coal operators benefit through more timely and successful recovery of performance bonds, and local communities benefit from land reclamation that improves water quality, reduces flooding potential, is more aesthetically pleasing, and is more valuable for a diversifying economy.

Fourth-Year Tree Response to Three Levels of Silvicultural Input on Mined Lands[1]

C. Fields-Johnson, C. E. Zipper, D. Evans, T.R. Fox, J.A. Burger

Introduction

Across Appalachia, hundreds of thousands of hectares have been mined for coal under the Surface Mining Control and Reclamation Act. Many of these areas have been left in an unproductive state. Effective reforestation of these lands can produce many benefits. These include economic and aesthetic benefits to the landowner, environmental benefits such as restoration of pre-mining vegetative cover and habitat, watershed protection, sequestration of atmospheric carbon, and production of woody biomass for industrial use. However, restoration of forest vegetation on these sites requires financial expenditures. Landowners or agencies choosing to reforest post-SMCRA mine sites face choices regarding the level of silvicultural inputs to be applied in reestablishing the native forest, and thus the level of establishment cost to be borne. Understanding the significant effect and cost differences between available silvicultural treatments is therefore important for realizing economically and biologically sound reforestation. Three common site limitations for trees on reclaimed mine sites are herbaceous competition, soil compaction and low levels of essential nutrients. There are also many options of tree species to use for reforestation based on reclamation goals and post-mining use objectives. This study examined both silvicultural and species factors.

The objective of this study was to evaluate the effects of silvicultural treatments on the survival and early growth of two tree species and a speices mix with potential for use in the reforestation of reclaimed surface mine lands in the Appalachians.

Methods and Materials

Background

This experiment employed a 3 x 3 x 3 factorial combination of silvicultural treatments, species and state location using a randomized complete block design (Fig. 1). The three silvicultural treatments studied were herbaceous weed control using herbicide, subsoil ripping, and fertilization. Experimental plots were established in Ohio, Virginia, and West Virginia on three separate sites in each state, providing three repetition blocks for each treatment-species-state combination. Species groups included Eastern white pine (*Pinus strobus*), hybrid poplar (*Populus* spp.) and a mix of native Appalachian hardwoods (Table 1). Plot locations were randomized within each block. The experiment was begun with site preparation and planting in March of 2004. This paper is an analysis of measurements taken in October of 2007 following the fourth growing season. Greater detail on the establishment of the experiment and first-year survival and growth results can be found in Casselman et al. (2006) and Casselman (2005).

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[1] Paper was presented at the 2008 National Meeting of the American Society of Mining and Reclamation, Richmond VA, June 14-19, 2008. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

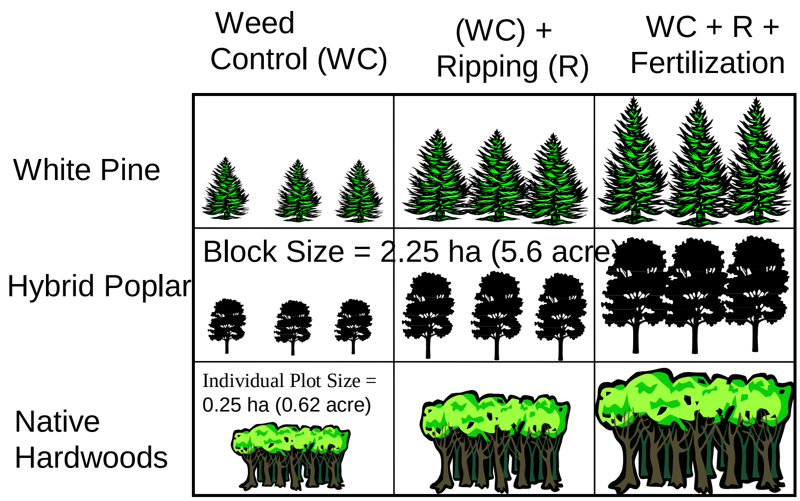

Figure 1. Hypothetical 3x3 layout of a single block of treatments. This series of plots was replicated 3 times in each of 3 states (VA, WV, and OH).

Table 1. Species combinations selected for mixed Appalachian hardwoods treatment in three states.

Species	Ohio	West Virginia	Virginia
	---------------	%	---------------
Bitternut hickory (*Carya cordiformis*)	9.6	0.0	10.9
Black oak (*Quercus velutina*)	9.6	0.0	0.0
Chestnut oak (*Quercus prinus*)	19.2	0.0	0.0
Flowering dogwood (*Cornus florida*)	7.7	7.8	7.8
Northern red oak (*Quercus rubra*)	9.6	15.3	10.9
Red maple (*Acer rubrum*)	0.0	15.3	0.0
Redbud (*Cercis canadensis*)	7.7	7.8	7.8
Scarlet oak (*Quercus coccinea*)	9.6	0.0	0.0
Sugar maple (*Acer saccharum*)	9.6	15.3	10.9
Tulip poplar (*Liriodendron tulipifera)*	9.6	15.3	10.9
Washington hawthorn (*Cretaegus phaenopyrum*)	7.7	7.8	7.8
White ash (*Fraxinus americana*)	0.0	15.3	10.9
White oak (*Quercus alba*)	0.0	0.0	21.9

Site Description

The Ohio (OH) sites were located at 38.75°N; 82.63°W in Lawrence County, the West Virginia (WV) sites at 38.13°N; 80.65°W in Nicholas County, and the Virginia (VA) sites at 37.05°N; 82.70°W in Wise County. These sites had been previously mined for coal before being reclaimed to grass. Grasses and legumes formed a dense vegetative cover at the time of tree establishment. Siltstone dominated the mine spoils on the sites in Ohio, shale dominated the

West Virginia sites, and sandstone dominated the Virginia sites; together these rock types are representative of the range of overburdens removed and then returned as spoils and soil substitutes on mined areas that are reclaimed in the Appalachian region (Casselman et al. 2006).

There were other notable differences in reclamation techniques, vegetation and soil properties among the three sites. The Ohio siltstone minesoils had topsoil returned to cap the study areas to a depth of 5 to 51 cm. This was the sites' pre-mining topsoil that had been stored for post-mining replacement. The topsoil was more acidic, had lower electrical conductivity, and had lower bulk density than the underlying mine spoils. Having been reclaimed approximately 10 years previously, the Ohio sites were well vegetated with tall fescue (*Festuca arundinacea*) and sericea lepedeza (*Lespedeza cuneata*). Topsoil "capping," as occurred on the experimental sites, is a common reclamation practice in Ohio. The West Virginia shale mine soils had no topsoil cap and, upon reclamation approximately 10 years previously, had been revegetated with tall fescue that had been actively used for grazing. The mine soil had a high coarse fragment content and a high bulk density. The Virginia sandstone mine soils were capped with a soil substitute of crushed sandstone (Daniels and Amos 1984) to a depth of 0 to 47 cm across the study area. Two Virginia study blocks had been reclaimed less than five years previously and vegetated with tall fescue and sweet clover (*Melilotus alba*), while the third had been reclaimed the previous year and revegetated with annuals. The Virginia soils had a high bulk density and high proportion of coarse fragments (Casselman et al. 2006).

Species Description

Eastern white pine has been commonly planted as a crop tree on southern Appalachian reclaimed surface mine lands (Torbert and Burger 2000). Hybrid poplar was also planted as an experimental treatment (*Populus trichocarpa* L. (Torr. and Gray ex Hook.) x *Populus deltoids* (Bartr. Ex Marsh.) hybrid 52-225). The third species group included a mix of native Appalachian hardwoods meant to simulate the forest composition that existed before mining (Table 1).

Trees were planted in these proportions on their respective sites in March of 2004. Eastern white pine was planted as 2-0 bare root seedlings, hardwoods were planted as 1-0 bare root seedlings and the planted hybrid poplars were approximately 20 cm-long stem cuttings. Species groups were planted in uniform plots and not intermixed with each other, though plots containing different species were adjacent to each other on the ground as a part of the three replication blocks in each state.. Planting density for all species and treatments was 2.4m x 3.0m or 1,345 trees per hectare (Casselman et al., 2006).

Silvicultural Treatments

Weed Control

All of the study areas received 9.35 liters per hectare of glyphosate broadcast across the study areas in August of 2003. In addition, 4.92 liters per hectare of a pre-emergent herbicide with pendimethalin for grass control was broadcast across the study areas in April of 2004 after tree planting. Glyphosate was then used in spot applications immediately around each tree seedling in July of 2004, with the exception of one study block in Virginia where no competing vegetation was present. During the application process, seedlings were shielded from drifting herbicide. Weed control treatment was constant across all study plots and was therefore a control variable rather than an experimental variable (Casselman et al. 2006).

Subsoil Ripping

Two-thirds of the study areas were ripped in the spring of 2004 prior to tree planting. Differing local availability caused a variety of equipment to be used, including multiple shanks, single shank with bed-creating coulters, and single shank only. Ripping depths were set at 61 to 91 cm (Casselman et al. 2006).

Fertilization

One-third of the study areas, which had also been ripped, were fertilized beginning in May of 2004 after seedling planting. Diammonium phosphate was applied in a banded pattern at a rate of 272 kg per hectare, adding 49.0 kg per hectare N and 55.1 kg per hectare P. Around the base of each seedling, 91 kg per hectare of muriate of potash and 20 kg per hectare of a micronutrient mix was applied, adding 46.8 kg per hectare K, 1.8 kg per hectare S, 0.2 kg per hectare B, 0.2 kg per hectare Cu, 0.8 kg per hectare Mn, and 4.0 kg per hectare Zn (Casselman et al. 2006).

Tree Measurement and Data Analysis

Each treatment plot was 0.25 ha with a 0.04-ha 50-tree measurement plot nested inside. Survival was determined by dividing the number of surviving trees by the number of trees originally planted in each plot. This analysis looked at cumulative survival since the beginning of the experiment and not survival since the previous year.

Ground line diameter, diameter at breast height, and tree height were measured. Biomass index was calculated by: BI (cm^3) = D^2 (cm^2) x Ht (cm) using groundline diameter for D. The biomass indices of individual trees were summed to determine a plot biomass which was then divided by the number of surviving trees to determine an average biomass per tree. Therefore, the primary data analysis looked at the average biomass per surviving tree and is independent of survival rates.

Data were analyzed using JMP 7.0 (SAS Institute Inc., Cary NC). Differences in survival and growth among treatments within states were determined using a randomized block ANOVA. Tukey-Kramer HSD was used for mean separations ($P < 0.10$). Multi-factor analysis was also performed to analyze species by treatment interaction and state effects. Multi-factor analysis involved comparing each possible silvicultural treatment-species combination, each silvicultural treatment-state combination, each species-state combination, and each silvicultural treatment-species-state combination with all of the other combinations in each category to determine any significant interaction effects among the experimental variables. Multi-factor analysis was performed using the fit model feature in JMP 7.0 with Tukey-Kramer HSD for mean separation.

Results

Tree Response to Treatments

Tree survival and growth means by silvicultural treatment across all states and species varied, but there were interaction effects (Table 2) among experimental variables that made statistical analysis of these overall means invalid. However, there were significant effects of silvicultural treatments on individual species groups as responses by species groups to the same silvicultural treatments differed (Table 3). Survival and growth of trees in Ohio, and growth of trees in Virginia, were affected by species selection. Survival and growth of trees in West Virginia were affected by silvicultural treatment and species selection and an interaction of species and treatment. Survival and growth were affected by species selection, state location and silvicultural treatment (Table 2). Survival and growth on all sites together were also affected by interactions of species with state and of state with treatment but only growth was affected by an interaction of species with silvicultural treatment (Table 2).

Table 2. Analysis of variance for survival and growth of trees planted on reclaimed mine sites.

Site and Source	Degrees of Freedom	Variable (Pr > F)	
		Survival	Biomass Index
All Sites			
Species	2	0.0007	<.0001
State	2	<.0001	0.0017
Treatment	2	0.0016	0.0012
Species x State	4	0.0551	0.0002
Species x Treatment	4	0.3236	<.0001
State x Treatment	4	0.0560	0.0643
Species x State x Treatment	8	0.6478	0.0409
Model	26		
Error	54		
Total	80	<.0001	<.0001
Virginia			
Species	2	0.1180	<.0001
Treatment	2	0.1665	0.2302
Species x Treatment	4	0.6276	0.2204
Model	8		
Error	18		
Total	26	0.2508	<.0001
West Virginia			
Species	2	0.0075	<.0001
Treatment	2	0.0001	0.0169
Species x Treatment	4	0.2348	0.0075
Model	8		
Error	18		
Total	26	0.0007	<.0001
Ohio			
Species	2	0.0131	0.0030
Treatment	2	0.2701	0.2470
Species x Treatment	4	0.5020	0.2209
Model	8		
Error	18		
Total	26	0.0812	0.0189

Table 3. Mean survival and biomass index by treatment across all states and species. WC = weed control only; WC+R = weed control plus subsoil ripping; WC+R+F = weed control plus subsoil ripping and fertilization.

Treatment	Survival (%)	Biomass Index (cm^3)
WC	44	981
WC+R	64	4956
WC+R+F	52	4482

Survival

Survival was significantly affected by a variety of factors (Table 4). Hybrid poplars survived better than white pines in Virginia. Mixed hardwoods survived better than hybrid poplar in West Virginia. Mixed hardwoods and hybrid poplars survived better than white pines in Ohio. Across all states and treatments, mixed hardwoods survived better than white pines. Subsoil ripping improved survival of white pines and of all species groups aggregated together in Virginia. Subsoil ripping also improved survival of mixed hardwoods and hybrid poplars and of all species groups aggregated together in West Virginia, but the addition of fertilization with ripping to hybrid poplars reduced survival to the level of weed control alone. Subsoil ripping improved the survival of only hybrid poplars in Ohio, and only relative to the most intensive cultural treatment (weed control plus ripping and fertilization); this effect was not evident for an aggregate of all species groups.

Table 4. Mean percent survival of all replications by species, state, and treatment after four years.

	Tree Species							
Site and Treatment	**WP**		**MH**		**HP**		**Treatment Mean**	
Virginia								
WC	49.7	b	52.3	a	78.7	a	**60.2**	**b**
WC+R	77.0	a	82.3	a	82.0	a	**80.4**	**a**
WC+R+F	51.3	ab	79.0	a	84.3	a	**71.5**	**ab**
Species Mean	**59.3**	**Y**	**71.2**	**YZ**	**81.7**	**Z**	**70.7**	**A**
West Virginia								
WC	31.3	a	36.0	b	22.0	b	**29.8**	**b**
WC+R	60.7	a	73.7	a	62.3	a	**65.6**	**a**
WC+R+F	42.7	a	79.3	a	38.0	b	**53.3**	**a**
Species Mean	**44.9**	**YZ**	**63.0**	**Z**	**40.8**	**Y**	**49.6**	**B**
Ohio								
WC	33.3	a	48.7	a	48.0	a	**43.3**	**a**
WC+R	16.7	a	69.3	a	55.0	a	**47.0**	**a**
WC+R+F	18.3	a	48.3	a	25.7	b	**30.8**	**a**
Species Mean	**22.8**	**Y**	**55.4**	**Z**	**42.9**	**Z**	**40.4**	**B**
All Sites Species Mean	**42.3**	**Y**	**63.2**	**Z**	**55.1**	**YZ**	**53.6**	

*The same letter connecting treatment response data for each species means no significant difference at p = .10. Lowercase a's and b's: statistically same treatment means within state vertically. Uppercase A's and B's: statistically same state means across all treatments and species vertically. Uppercase Z's and Y's: statistically same species means across all treatments horizontally.

Growth

Growth was also significantly affected by multiple factors (Table 5). Eastern white pine, mixed hardwoods and hybrid poplar grew equally well within their species groups under all silvicultural treatments in both Virginia and Ohio, as did Eastern white pine and mixed hardwoods in West Virginia. Hybrid poplar in West Virginia grew faster with the addition of subsoil ripping, both with and without fertilization, though the addition of fertilization to ripping did not significantly alter growth. Across all species, silvicultural treatment had no effect on growth in Virginia, West Virginia or Ohio. Across all states and silvicultural treatments, hybrid poplar grew faster than both Eastern white pine and mixed hardwoods.

Table 5. Mean biomass index [(groundline diameter)^2 x height] in cm^3 of all replications by species, state and treatment after four years.

	Tree Species							
Site and Treatment	**WP**		**MH**		**HP**		**Treatment Mean**	
Virginia								
WC	261.5	a	333.9	a	5163.9	a	**1919.8**	**a**
WC+R	411.8	a	184.5	a	11806.9	a	**4134.4**	**a**
WC+R+F	304.5	a	321.6	a	10914.2	a	**3846.8**	**a**
Species Mean	**325.9**	**Y**	**280.0**	**Y**	**9295.0**	**Z**	**3300.3**	**A**
West Virginia								
WC	233.1	a	31.4	a	1577.8	b	**614.1**	**a**
WC+R	604.5	a	150.4	a	27159.6	a	**9304.8**	**a**
WC+R+F	358.4	a	101.5	a	20837.7	a	**7099.2**	**a**
Species Mean	**398.7**	**Y**	**94.4**	**Y**	**16525.0**	**Z**	**5672.7**	**A**
Ohio								
WC	101.5	a	33.9	a	1090.0	a	**408.5**	**a**
WC+R	29.5	a	58.7	a	4201.3	a	**1429.8**	**a**
WC+R+F	14.0	a	21.6	a	7466.8	a	**2500.8**	**a**
Species Mean	**48.3**	**Y**	**38.1**	**Y**	**4252.7**	**Z**	**1446.4**	**A**
All Sites Species Means	**257.6**	**Y**	**137.5**	**Y**	**10024.2**	**Z**	**3473.1**	

*The same letter connecting treatment response data for each species means no significant difference at p = .10. Lowercase a's and b's: statistically same treatment means within state vertically. Uppercase A's and B's: statistically same state means across all treatments and species vertically. Uppercase Z's and Y's: statistically same species means across all treatments horizontally.

Interaction Effects

Table 2 indicated the existence of significant effects on survival and growth by interactions among various experimental factors. These interactions are graphically illustrated in Figures 2-6. Non-parallel lines indicate potentially significant interactions among factors beyond those normally expected from the effects of individual factors. Ripping, both with and without fertilization, increased West Virginia trees' survival (Fig. 2). Hybrid poplars were sensitive to fertilization in West Virginia (Fig. 3), as exhibited by decreased survival relative to ripping alone. Growth was most improved by ripping in West Virginia, where both of the ripping treatments had a significant influence on growth relative to weed control alone (Fig. 4). Hybrid poplar growth was greater in West Virginia than in Virginia, but none of the other species groups exhibited state-by-state growth differences (Fig. 5). Similarly, hybrid poplar growth across all states was positively influenced by both ripping treatments, relative to weed control alone (Fig. 6).

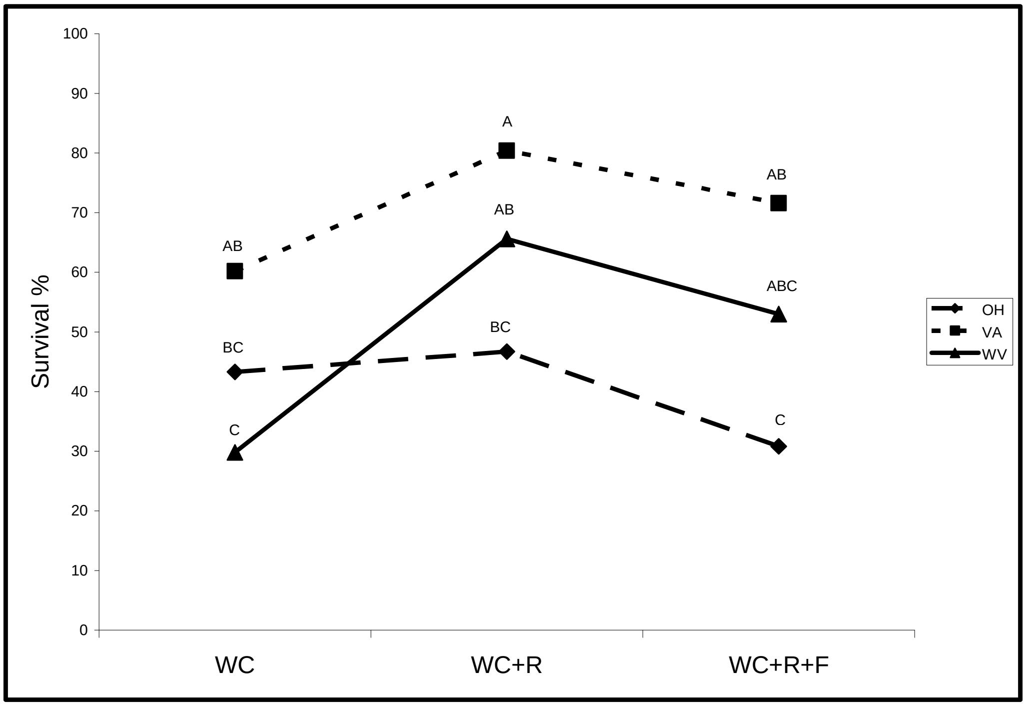

Figure 2. Interaction between silvicultural treatment and state location on percent survival after fourth year of growth. Data points with the same letter are not significantly different.

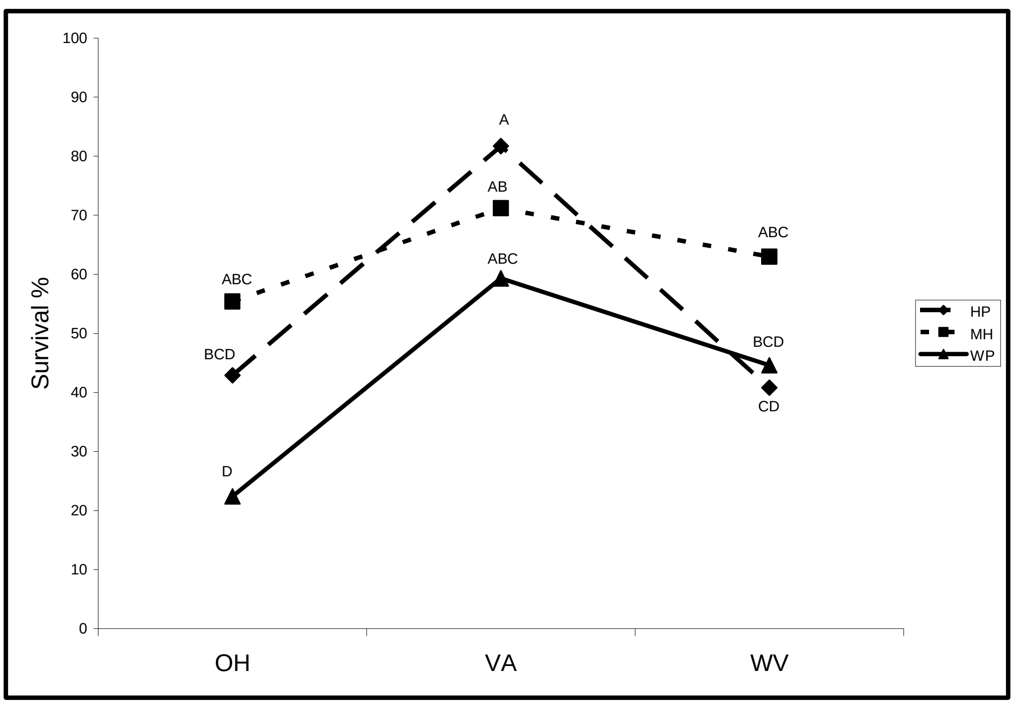

Figure 3. Interaction between state location and species group on percent survival after fourth year of growth. Data points with the same letter are not significantly different.

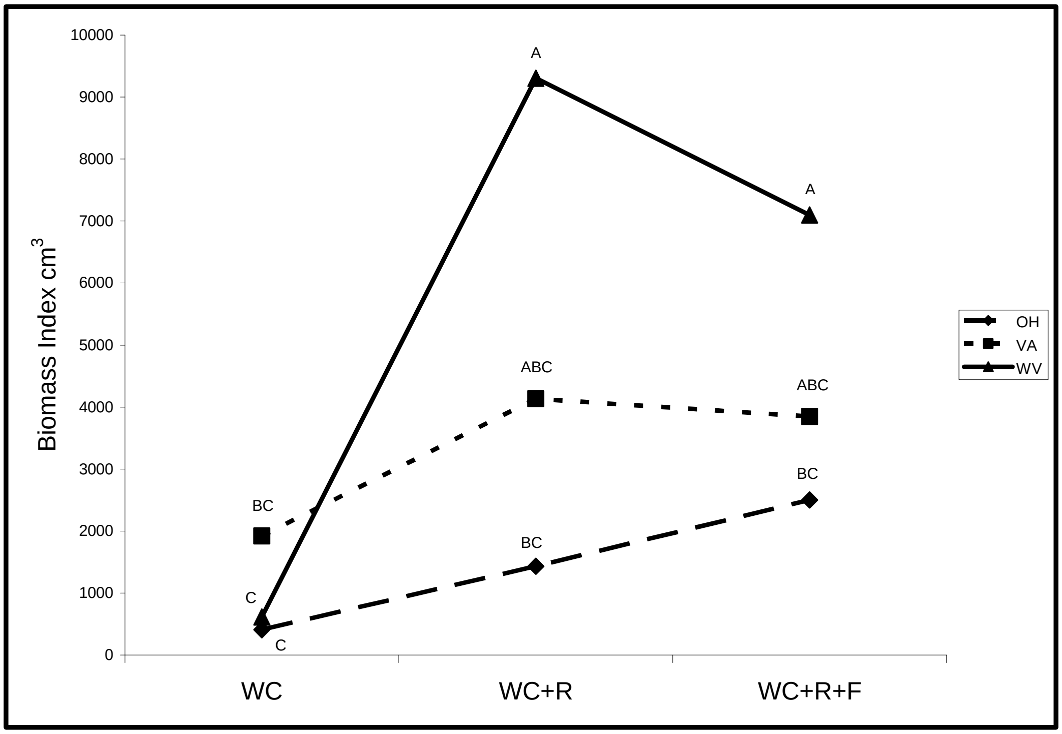

Figure 4. Interaction between silvicultural treatment and state location on biomass index after fourth year of growth. Data points with the same letter are not significantly different.

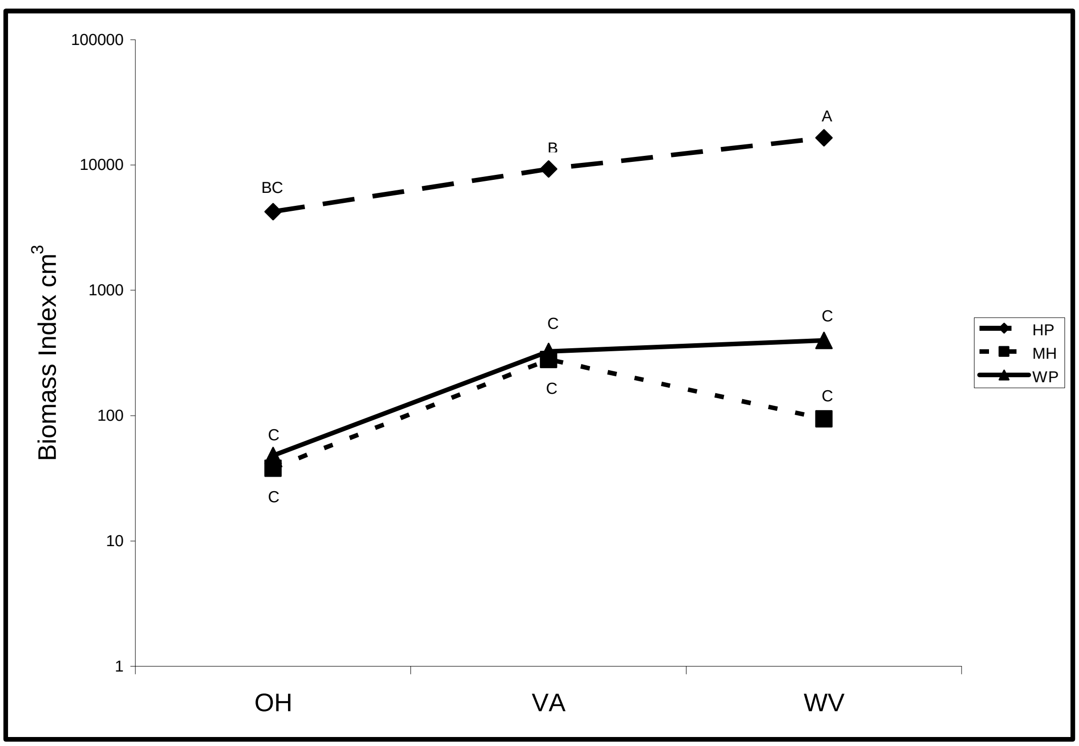

Figure 5. Interaction between state location and species group on biomass index after fourth year of growth. Data points with the same letter are not significantly different.

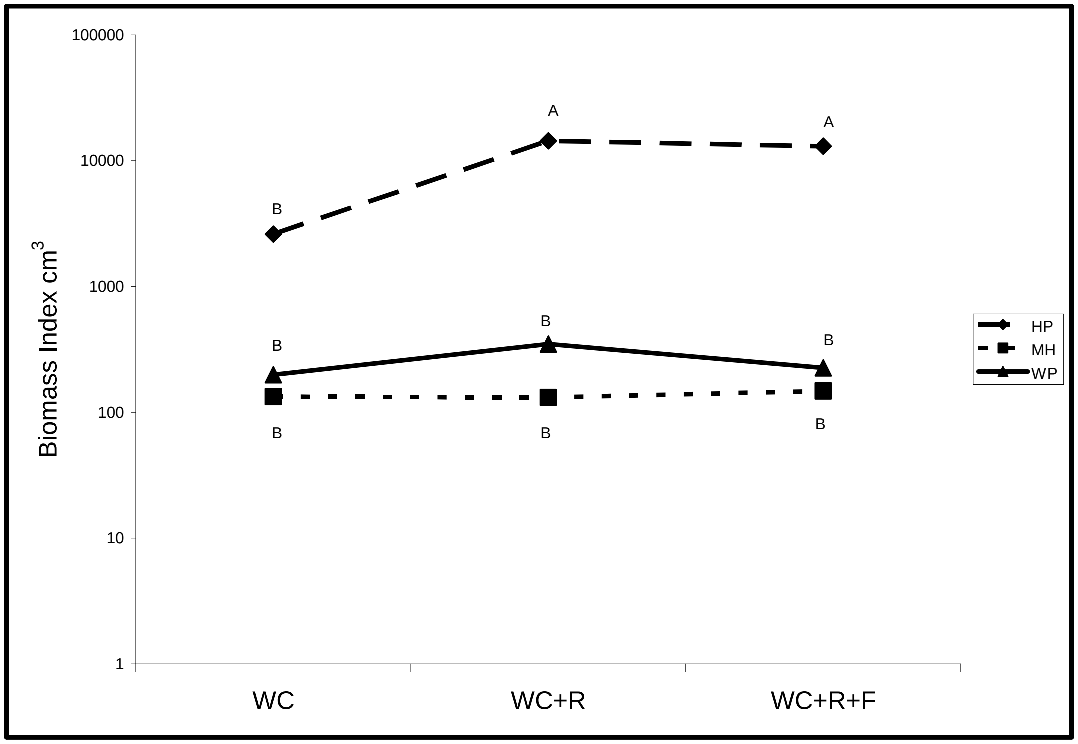

Figure 6. Interaction between silvicultural treatment and species group on biomass index after fourth year of growth. Data points with the same letter are not significantly different.

Discussion

Hybrid poplar had superior volume growth in all three states during the four-year period. Hybrid poplar had 72 times more biomass than the mixed Appalachian hardwoods and 39 times more than eastern white pine across all sites. Hybrid poplar is in a class by itself in terms of early growth potential; these responses are similar to those reported for both mine soils (McGill et al. 2004) and natural soils (Van den Driessche 1999). This hybrid is especially useful for sequestering carbon or producing woody biomass at least for short-term planning horizons (Scott and Kuhn 2000).

West Virginia, with its shale-based, uncapped minesoils, produced nearly four times the growth of Ohio, with its siltstone minesoils capped with topsoil. The Virginia sandstones, capped with crushed sandstone soil substitute, had an intermediate value not significantly different from the other sites. One problem with comparing the three sites was the presence of confounding variables that affected the three sites differently, such as deer browse activity and the possibility that the previously grazed site in West Virginia had been fertilized while being actively grazed prior to tree establishment. Virginia had significantly greater survival rates across all treatments and species than West Virginia and Ohio. This suggests that the site factors that affect survival may differ from those that affect growth (Torbert et al. 1990).

The addition of ripping to herbaceous weed control as a silvicultural treatment produced consistently beneficial results. Ripping increased survival significantly in West Virginia for both mixed hardwoods and hybrid poplar. It also increased growth of hybrid poplar in West Virginia. Better survival and growth is a relatively common response when compacted mine soils are ripped (Philo et al. 1982). For our overall study across all sites and species, ripping significantly improved both survival and growth.

Adding fertilizer along with weed control and ripping failed to produce any additional improvement in survival or growth in any aspect of this experiment. In fact, it produced results that were statistically similar to the weed control treatment for hybrid poplar survival and growth in West Virginia and for overall survival rates across the entire experiment. Applying powdered fertilizer to the base of young seedlings can cause severe damage and even mortality. The fertilizer treatment was applied in this way by parties who were not aware of this problem during the experiment's establishment. Other studies have found fertilization to cause significant improvements in survival or growth if applied appropriately (Ramsey et al. 2001), but that result cannot be inferred from this particular experiment.

Hybrid poplar and mixed hardwoods had significantly greater survival rates than eastern white pine across all states and treatments. This suggests that parties seeking to achieve high stocking rates when reforesting older mine sites might utilize hybrid poplar if biomass production is desired or native mixes of Appalachian hardwoods if native forest restoration is desired.

Another observation was that the variation between blocks that were designed as replications was often as great, or greater than, the variation between the species x state x treatment combinations that were being compared. This could be due to micro-site factors related to the specific origin and geologic makeup of mine spoils deposited with each spoil load which may have differed from one block to the next, to differences in browse activity amongst the blocks, or to any number of other variables that might not have been adequately controlled such as topography and microclimate. Following up on these results, it would be useful to conduct additional experiments targeting key factors that this study suggests would most improve tree survival and growth on reclaimed mine sites.

Conclusions

Forest productivity of post-SMCRA grasslands can be restored using traditional silvicultural practices. In this study, we investigated the relative effectiveness of weed control only, weed control plus deep tillage, and weed control plus tillage and fertilization for restoring forest vegetation and productivity on previously-reclaimed mine sites in Ohio, Virginia, and West Virginia. Experimental plots were planted with eastern white pine, hybrid poplar, and mixed Appalachian hardwoods. After four years, deep tillage and weed control, when applied together, increased both survival and growth compared to the effect of weed control alone. The addition of fertilization did not increase survival or growth relative to the other treatments, but this may have occurred due to improper fertilizer placement. Silvicultural treatment effects exhibited high variability between locations and species, indicating that planted seedlings' survival and growth response to silvicultural treatments will, in many cases, be site-specific.

Acknowledgments

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Nesting Results and Initial Habitat Assessment of the Nesting Box Trail for *Sialia sialis* (Eastern Bluebird) In the Powell River Project Education Center Year 2: Expansion

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Abstract

The nesting box trail for the Eastern Blue Bird was expanded to a second field that is part of the Powell River Education Center. The new sites consist of paired boxes with the same design as the boxes used the first year of the study; each pair consisted of one box with a solid roof and one with a screen roof. During the 2008 nesting season (March to July), nesting activity was again limited to the closed top boxes. Bluebirds produced nests in both fields, but only nests in the original field were successful in fledging young. At the end of the season, a total of eight (8) bluebird chicks were fledged. Student volunteers and an administrator from the Mountain Empire Community College assisted in mounting the new boxes, monitoring activity and collecting insect samples.

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Introduction

During the second year of the project, the bluebird trail established at the Powell River Education Center was expanded to a second field just north of the original trail located adjacent to the Powell River Education Center. The addition of five sets of boxes brought the total to thirteen nesting sites. Student volunteers mounted the new nesting boxes, participated in monitoring nesting activity and collected insect samples. It was expected that with the increase in the number of nesting sites, that there would be an increase in nesting activity to test nesting box design preference, however nesting activity was light.

Methods

Nesting box preference- The objective of this study was to test whether bluebirds have a preference for the open or closed boxes. Each nesting box site consisted of two boxes, one traditional box with the closed top (Figure 1a) and a second box with an screen top that allows the elements in but keeps predators out (Figure 1b). The nests were monitored using the protocols of the Virginia Bluebird Society (Virginia Bluebird Trail Monitoring Information, 2006) and the North American Blue Bird Society (Fact Sheet: Monitoring Bluebird Nest Boxes, 2002).

a.

b.

Figure 1. (a) Closed and (b) open topped nesting boxes.

For the second year of the study, we expanded the study area by adding five boxes of each design along the fence that surrounds the field located just north of the original study site (figure 2). Boxes were mounted on fence posts that supported the electrical fence surrounding the pasture. Because tree swallows (*Tachycineta bicolor*) are common cavity nesters around the project, boxes were paired within an area to reduce interspecies competition for nesting space (Wildlife: Eastern Bluebird, 2006).

Figure 2: Location of field 1 adjacent to the barn (B) and field 2. (Image from Microsoft Virtual Earth.)

Boxes were monitored for activity on a weekly basis between April 10 and July 18, 2008 following the protocols established by the North American Bluebird Society (Fact Sheet: Monitoring Bluebird Nest Boxes, 2002) and the Virginia Bluebird Society (Virginia Bluebird Trail Monitoring Information, 2006). Data was recorded on forms provided on the Virginia Bluebird Society website.

Survey of insect and invertebrate populations. Insects and other invertebrates were sampled using passive pan traps, substrate sampling (surface and soil), and insect nets along 30 m transects. Sample sites are indicated in figures 3 and 4. Pan traps were placed outside the fences to prevent injury to cattle, while substrate sampling and transect sampling took place inside the fence lines. Pan traps consisted of 13 in x 9 in metal cake pans sprayed yellow to attract a large variety of insects (figure 5a; Terrestrial Arthropod Densities, 1994), and placed flush with the substrate. The pans were filled with a soap and salt solution, which acted as a trap and as a temporary preservative. The traps remained in place for seven days after which specimens were collected by pouring the contents of the pan though a strainer. The specimens were rinsed with water and placed in 80% ethanol. Soil removed during placement of the pan traps was placed in plastic bags to determine composition of soil fauna. Unlike the previous year, soil samples were moist so samples were transferred to funnels constructed from water bottles and placed in sample jars containing the soap/salt solution. Samples sat for a week to allow them to dry; as the soil dried the specimens moved down into the jars. The soil samples were sifted to collect insects any specimens that remained in the samples. Surface samples (on soil surface and on plants) were collected within a 1 m quadrat (figure 5b) and placed in sample jars containing 80% ethanol. Animals were also collected along 30 m transects by sweeping vegetation with an insect net (figure 5c; Perry et al, 2001), and transferred to a jar containing 80% ethanol. Specimens were identified and grouped into groups using the National Audubon Society Field Guides to North American Insects and Butterflies.

Figure 3. Field 1: Nesting box sites indicated by numbers. Soil, pan and surface sample locations indicated by □'s. Transect locations indicated by dashed lines (----). (Image from Microsoft Virtual Earth.)

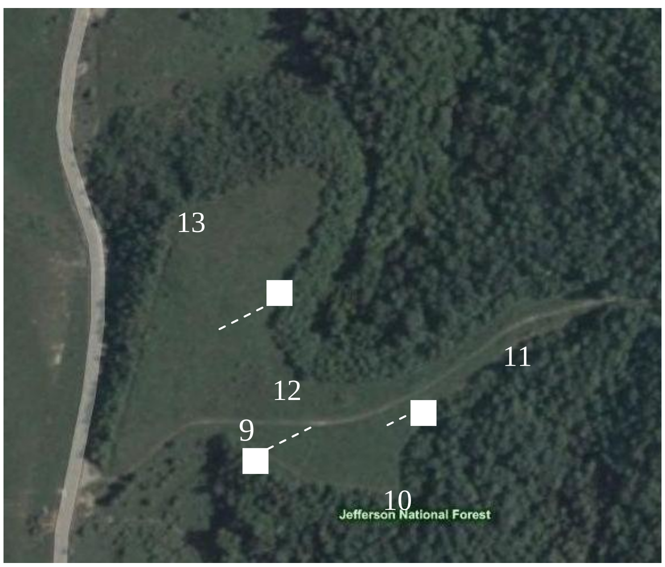

Figure 4. Field 2: Nesting box sites indicated by numbers. Soil, pan and surface sample locations indicated by □'s. Transect locations indicated by dashed lines (----). (Image from Microsoft Virtual Earth.)

Figure 5. (a) L. Clayton placing a pan trap; (b) L. Clayton, J. Genco and C. Burkart collecting specimens from a $1m^2$ quadrat; and (c) J. Genco collecting specimens along a 30 m transect line.

Results

Nesting activity: Just as in the previous year, bluebirds built nests only in the closed top boxes (Table 1). Bluebird nesting activity (complete nest with two eggs) was first observed on April 17 in box 7A. A total of five eggs was observed and hatched, but on May 15 the chicks were found dead. The loss may have been weather related; weather data collected at NOAA weather station KLNP located at the airport at Wise VA indicated that a cold front passes through the area earlier in the week (May 10-12) (Weather Underground, 2008). Over this period, barometric pressure dropped from a high of 29.93 in. on May 10 to a low of 29.41 in. on May 11 (the lowest of the month). Humidity during this period reached 100% suggesting precipitation. Average daily temperatures dropped 10^{o} F from May 11 to May 12. Early morning lows dropped from 51^{o} F on May 11 to 39^{o} F on May 13. Wind gusts recorded during this time reached 48 mph and 37 mph for May 11 and 12, respectively.

Eggs were also laid in box 13 A in field 2 during early May (May 5-9), but on May 15, the box was open and the eggs were gone. In addition to the missing eggs from box 13 A, the top was pulled off box 9 A. It is possible that the damage was a result of vandalism, but it is more likely that it was a black bear; a bear does live in the area and has been known to come into the Powell River Education Center (J. Rockett, per. comm.). There was no further nesting activity recorded in this box.

Bluebird nesting activity started again in June, but only in boxes 4 A and 5 A. On June 16, a female bluebird was observed incubating eggs in box 4 A, but the number of eggs was not determined because she did not leave the nest. On July 11, four chicks were found in the box, and by July 18 they had all fledged. On June 2, five eggs were observed in box 5 A, but were gone on June 9. On June 16, a new clutch of five eggs was found in the box. By July 11, four of the five eggs had hatch and by July 18, the chicks had fledged.

Box	Species	# of Eggs	# of Hatchlings	# Fledged
1 A	--	0	0	0
1 B	--	0	0	0
2 A	--	0	0	0
2 B	--	0	0	0
3 A	--	0	0	0
3 B	--	0	0	0
4 A	BB	?	4	4
4 B	--	0	0	0
5 A	BB	10	4	4
5 B	--	0	0	0
6 A	--	0	0	0
6 B	--	0	0	0
7 A	BB	5	0	0
7 B	--	0	0	0
8 A	--	0	0	0
9 A	--	0	0	0
9 B	--	0	0	0
10 A	--	0	0	0
10 B	--	0	0	0
11 A	--	0	0	0
11 B	--	0	0	0
12 A	--	0	0	0
12 B	--	0	0	0
13 A	BB	5	0	0
13 B	--	0	0	0

Table 1. Nesting results for the 2008 nesting season. (A: closed top box; B: open top box; BB: bluebirds).

Unlike the previous year, tree sparrows did not nest in any of the boxes. In April, dead tree swallows had been found in box 5 A (one each on April 17 and 25), and in box 8 A (April 10). Because box 5 A had been a favored nesting site the previous year, the box was replaced in case of disease or contamination. Tree swallows were not observed in the boxes for the remainder of the season.

Flora: Grasses are the most common plants found in both fields, however, grass height varied between the two fields. Large sections of field 1 (between boxes 1, 2, 5 and 8) had relatively short grass (mowed to approximately 40 cm), while the grass in the remainder of field 1 and in all of field 2 was as tall as 120 cm.

Insect and invertebrate survey: Insects and other invertebrates were sampled by four methods [insect net, pan trap, soil sample and quadrat (Tables 2-5)]. A total of 9480 specimens were identified. The largest numbers of specimens were collected by the pan traps and by transect sampling. Specimens were identified and placed into one of twenty-five invertebrate groups using Milne et al. (2005). In addition to the invertebrates, salamanders were collected in pan traps 1, 2, 4 and 6.

Group	**30 m Transects**						
	Field 1			**Field 2**			
	1	**2**	**3**	**4**	**5**	**6**	**7**
Ants	0	0	1	0	0	1	0
Aphids	0	0	10	0	0	0	0
Bees	5	11	24	60	219	783	179
Beetles	2	32	17	28	9	9	3
Butterflies	0	1	0	0	1	0	0
Caterpillars	0	1	1	1	0	0	0
Centipedes	0	0	0	0	0	0	0
Crickets	4	6	2	1	0	0	0
Dragonflies	0	0	0	0	0	1	1
Earwigs	0	0	0	0	0	0	0
Flies	23	40	24	29	19	33	17
Grasshoppers	4	102	2	44	17	37	12
Lacewing	0	0	0	0	0	2	1
Leafhoppers	77	99	45	47	20	81	18
Long-legged seed bug	0	0	0	0	0	0	0
Millipedes	0	0	0	0	0	0	0
Mosquitoes	0	1	5	1	0	2	0
Moths	0	3	0	3	0	0	0
Mill bugs	0	0	0	0	0	0	0
Slugs	0	0	0	0	0	0	0
Snails	0	0	0	0	0	0	0
Spiders	2	3	9	18	6	9	2
Ticks	0	0	0	0	0	0	0
Wasps	0	1	4	0	0	25	7
Weevils	0	4	2	0	0	3	1

Table 2. Results of insect and invertebrate transect surveys conducted July 11 (field 1) and July 18 (field 2), 2008.

	Pan Traps						
	Field 1				Field 2		
Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Ants	48	81	14	13	32	33	18
Aphids	0	0	0	0	0	0	2
Bees	33	31	34	47	56	56	28
Beetles	61	69	78	148	28	39	23
Butterflies	3	0	0	1	2	0	0
Caterpillars	0	0	2	0	0	0	1
Centipedes	2	1	0	0	3	1	0
Crickets	7	26	29	15	17	13	6
Dragonflies	0	0	0	0	0	0	0
Earwigs	0	0	1	0	0	0	0
Flies	58	110	83	151	73	71	115
Grasshoppers	16	14	21	16	29	28	5
Lacewing	1	0	0	0	2	0	2
Leafhoppers	120	765	213	139	295	506	90
Long-legged seed bugs	0	0	12	0	0	0	0
Millipedes	0	0	1	0	1	2	0
Mosquitoes	1	3	16	2	1	2	8
Moths	0	2	2	0	0	3	4
Mill bugs	0	0	1	1	4	0	0
Slugs	0	1	0	0	0	0	0
Snails	0	12	1	1	0	0	0
Spiders	17	61	7	6	5	13	1
Ticks	0	0	2	0	1	0	0
Wasps	4	11	31	18	24	18	34
Weevils	2	1	1	4	7	9	0

Table 3. Results of insect and invertebrate pan surveys conducted between July 11 and 18 (field 1) and July 18 and 25 (field 2), 2008.

Group	Soil Samples						
	Field 1				Field 2		
	1	2	3	4	5	6	7
Ants	0	0	0	0	0	0	0
Aphids	0	0	0	0	0	0	0
Bees	0	0	0	0	0	0	0
Beetles	0	1	0	0	0	2	1
Butterflies	0	0	0	0	0	0	0
Caterpillars	0	0	0	0	0	0	0
Centipedes	0	0	0	0	0	0	0
Crickets	0	0	0	0	0	0	0
Dragonflies	0	0	0	0	0	0	0
Earwigs	0	0	0	0	0	0	0
Flies	0	0	0	0	0	0	0
Grasshoppers	0	0	0	0	0	0	0
Lacewing	0	0	0	0	0	0	0
Leafhoppers	0	0	0	0	0	0	0
Long-legged seed bug	0	0	0	0	0	0	0
Millipedes	0	0	0	0	0	0	0
Mosquitoes	0	0	0	0	0	0	0
Moths	0	0	0	0	0	0	0
Mill bugs	0	0	0	0	0	0	0
Slugs	0	0	0	0	0	0	0
Snails	0	0	0	0	0	1	0
Spiders	0	0	0	0	0	0	0
Ticks	0	0	0	0	0	0	0
Wasps	0	0	0	0	0	0	0
Weevils	0	0	0	0	0	0	0

Table 4. Results of insect and invertebrate soil surveys conducted July 11 (field 1) and July 18 (field 2), 2008.

Group	Surface Samples						
	Field 1				Field 2		
	1	2	3	4	5	6	7
Ants	0	0	0	0	1	1	1
Aphids	0	0	0	0	0	0	0
Bees	0	0	0	0	1	1	0
Beetles	3	0	3	0	4	0	0
Butterflies	0	0	0	0	0	0	0
Caterpillars	0	0	0	0	1	0	0
Centipedes	0	0	0	1	0	0	0
Crickets	0	0	0	1	0	0	0
Dragonflies	0	0	0	0	0	0	0
Earwigs	0	0	0	0	0	0	0
Flies	2	0	1	0	0	0	0
Grasshoppers	0	0	0	0	3	1	0
Lacewing	0	0	0	0	0	0	0
Leafhoppers	2	1	0	3	1	1	3
Long-legged seed bugs	0	0	0	0	0	0	0
Millipedes	0	0	0	1	1	0	0
Mosquitoes	0	0	0	2	0	0	0
Moths	0	0	0	0	0	0	0
Mill bugs	1	0	0	0	0	0	0
Slugs	0	0	0	0	0	0	0
Snails	0	1	0	0	0	1	1
Spiders	2	0	0	1	0	1	0
Ticks	0	0	0	2	0	0	0
Wasps	0	0	0	0	0	0	0
Weevils	0	0	0	0	0	0	0

Table 5. Results of insect and invertebrate surface surveys conducted July 11 (field 1) and July 18 (field 2), 2008. Samples were collected from 1 m^2 quadrats.

Discussion: From the results of the 2007 and the 2008 nesting season, it can be concluded that bluebirds prefer closed topped nesting boxes over the present open design. For the 2009 season, open boxes will be modified with an awning to provide shade, without compromising the open design. The pattern of nesting box site use is more difficult to determine, however it may have less to do with the distribution of insects and invertebrates (figure 6) and more with the characteristics of the grasses around the boxes. Arthropods that often make up the largest proportions of the bluebird diet include: grasshoppers, crickets, butterflies, moths, spiders, beetles and leafhoppers (Sullivan, 1995). These arthropods were found in abundance at most of the sample sites (sums for these groups at each site: site 1 = 312, site 2 = 1184, site 3 = 428, site 4 = 470, site 5 = 434, site 6 = 742, site 7 = 168). Bluebirds hunt insects by perching on a branch or wire in areas with sparse or mowed grass; when an insect is located the bird will dive onto ground to catch the prey item (Sullivan, 1995). The boxes that have had the most nesting activity during both seasons (i.e.: 3 A during the 2007 season, 4 A and 5 A during the 2007 and 2008 seasons), are the boxes closest to the areas where grass is shortest due to frequent mowing (boxes

4 A and 5 A) or the grass at maturity is relatively short (40 cm by box 3A) in comparison to grass found in other locations (120 cm in field 2).

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lands in southwestern Virginia

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Introduction

Environmental and land use studies are frequently conducted on reclaimed coal mines, but limited work has been done to determine the response of wildlife populations to these reclamation efforts. Land use typically changes following the mining process, and post-mining habitat and land-use may be strikingly different from their former composition. Changes in vegetative cover, vegetation type and composition, soil properties, and topography can provide different resources for wildlife than those previously available. There are opportunities to "improve" habitat, or at least provide substrates or topography that may be lacking in adjacent areas, if planned properly ahead of time (Scott and Zimmerman 1984).

Wildlife are often displaced from their native environments after mining, and may not return without the appropriate conditions necessary for their survival. Disturbances to wildlife during a mining operation include more than just excavation at the actual mine pit. Impacts can be widespread and affect areas adjacent to and removed from the mine site. Other disturbances affecting wildlife and their habitat include the construction and use of temporary road systems and heavy machinery, noise, erosion, changes in topography and landforms, loss of native vegetation and cover, and sometimes environmental health concerns. Habitat complexity is often reduced following mining or other disturbances, causing a shift in the composition of wildlife communities such as birds (Wray et al. 1982). For example, a mature forest will support different species and abundances of birds than an open shrubland or managed pasture.

This project focuses on studying avian and amphibian communities on reclaimed mine sites. Wildlife such as birds often act as initiators of succession on barren sites that lack initial seed banks. These early initiators often contribute greatly to the revegetation process by transferring seeds to the area through droppings or food transfer (Walker and del Moral 2003). Amphibians, on the other hand, are a sensitive group and play an essential role in the cycling of nutrients into the food chain. Amphibians often represent the largest component of biomass in Eastern forests, making them an important component of the ecosystem. In recent years, there have been ample data to suggest that substantial amphibian declines have occurred throughout their range due to habitat disturbance and other anthropogenic influences. Because of strong site fidelity and limited dispersal capacity, even small disturbances that result in habitat fragmentation could isolate amphibians from important breeding or foraging habitat necessary for survival (Krishnamurthy 2003). Even though amphibian species that inhabit the coal-producing regions of North America have not shown signs of imminent danger, by understanding the habitat designs that impact these species, we can apply these findings to species in other geographic locations (Lacki et al. 1992).

This purpose of this study is to monitor wildlife use on mined sites of varying ages (since mining) and post-mining cover types at two locations in southwestern Virginia. Bird, salamander, and frog communities are being sampled to gain an understanding of site use and species composition. This information will be compared with wildlife communities on nearby reference forests to better understand the impacts of mining and reclamation.

Objectives
Our research is intended to contribute to our understanding of wildlife use of reclaimed mine lands. The specific objectives are:

1. Determine avian and amphibian community composition in different age classes of reclaimed mined lands that have been restored to wildlife habitat and forest post-mining land uses.
2. Compare avian and amphibian communities of reclaimed wildlife habitat and forest communities to: (1) reference forests that have not been recently disturbed by mining and (2) forests that are regenerating after harvesting.
3. Compare the structure and composition of reference forests to that of forests established on reclaimed sites, and compare the response of selected wildlife species to habitat patterns on reference and reclaimed sites.
4. Develop guidelines that can be used to suggest means to reclaim sites with forests that will meet wildlife objectives.

Overview of Methods
Field work was conducted at the Powell River Project site in Wise County, Virginia, and also on the Public Access Lands for Sportsmen (PALS) property owned and managed by The Forestland Group, LLC in Dickenson County. Data collection is nearly completed for this two year study.

We used a random-stratified sampling design to sample from 6 dominant age classes and cover types: pre-SMCRA, early successional, mid-successional, managed pastureland, reference, and recently harvested reference (Table 1, Figure 1). Pre-SMCRA sites are those that were mined prior to the institution of the Surface Mining Control and Reclamation Act of 1977 (SMCRA). We also established study sites on areas that have been mined and reclaimed since the establishment of SMCRA, which are further divided into early successional (approximately 5-12 years since mining), mid-successional or "teenage" stands (approximately 12-20 years since mining), and those that are actively managed for livestock grazing purposes. Reference forests in close proximity to mining sites were also sampled to gain understanding of the composition of and wildlife associated with the forest prior to mining. In addition to reference forests that were not recently disturbed, forests that have been disturbed by traditional forestry practices such as clearcutting were also sampled.

Table 1. Sampling point distribution across study areas (Powell River Project [PRP] and Public Access Lands for Sportsmen [PALS]) and vegetation cover type categories.

	Number of sampling points		
Cover Type	**PALS**	**PRP**	**TOTAL**
Early successional *(~5-12 years)*	9	10	19
Mid successional *(~13-20 years)*	4	7	11
Harvested *(within the last 15 years)*	5	2	7
Managed pastureland	13	3	16
Pre-SMCRA (prior to 1977)	27	6	33
Reference/ mature	8	8	16
TOTAL	**66**	**36**	**102**

Figure 1. Representative photos of general cover type categories used to distribute sampling points. Photos were all taken at sites on the PALS site.

A. Early successional

B. Mid-successional

C. Harvested

D. Managed pastureland

E. Pre-SMCRA

F. Reference/mature

Bird sampling

We used point counts with a 50 m radius to sample the bird community at the same points surveyed in 2007. This consisted of tallying all bird species and counting individuals during a 5 minute survey period. After arriving at the point, observers delayed the survey for 1 minute to allow for a settling period. During the 2008 field season, each point was visited 5 times between May 13 and July 9. All surveys were conducted between 6 and 9 am on clear mornings with minimal winds. Distance from the observer to the bird and any behavior or habitat use was also noted during surveys. This will allow for estimates of relative abundance and density of bird species during data analysis. We also noted whether the bird recorded was using the cover patch being sampled, or was in an adjacent habitat patch. A summary of the 71 bird species observed in 2008 is provided in the Appendix.

Salamander sampling

Two methods were used to sample salamander populations. In May 2007, a series of coverboards were placed in habitat types of interest to act as artificial cover structures that provide habitat for salamanders. These boards are approximately 20 x 10 x 5 cm in size and were placed in arrays of 6 boards at each sampled location. They were checked no more than once a week for salamanders. Data recorded includes the species, weight, and length (snout-vent length and tail length) for each salamander captured. Coverboards were checked from June through August 2007, and will be surveyed May through September this year.

In addition to coverboard surveys, constrained time searches were also done on appropriately rainy, humid evenings in the summer months when salamanders would be actively foraging and generally visible on the surface. This procedure consists of the observers actively searching for a constrained amount of time at each cover type of interest. Two observers and a 20 minute time limit were used for 2008 surveys. We also recorded salamander encounters, or incidental observations of species while conducting other work on the sites. Natural cover objects, such as logs and rocks, were sampled opportunistically for salamanders when available. Tables 2 and 3 present a summary of data collected on salamanders during the 2008 field season.

Table 2. Salamander species detected during May- July 2008 at PRP. As of July 31, two night searches were conducted for salamanders during appropriate weather conditions.

Species	Night searches	Coverboard surveys	Encounter	Cover type where observed
Longtail salamander	X		X	Pre-SMCRA, Reference
Red-spotted newt (Red eft)	X	X	X	Pre-SMCRA, Reference
Slimy salamander	X	X	X	Pre, SMCRA, Reference

Table 3. Salamanders detected during May-July 2008 at PALS. As of July 31, no night searches were conducted for salamanders.

Species	Night searches	Coverboard surveys	Encounter	Cover type where observed
Red-spotted newt (Red eft)			X	Reference
Slimy salamander		X		Pre-SMCRA

Frog sampling

Frogs were sampled on wet evenings using frog call survey methods. Water bodies were visited following a rain event or on wet, humid evenings and frog calls were identified by species and ranked in intensity (one individual to a full chorus). We also recorded frog encounters, or incidental observations of species while conducting other work on the sites (Tables 4 & 5).

Table 4. Frog species detected during May-July 2008 at PRP. As of July 31, four call surveys were conducted for frogs.

Species	Call surveys	Encounter
Spring peeper	X	X
Bullfrog	X	
Green frog	X	
Pickeral frog	X	
American toad	X	

Table 5. Frog species detected during May-July 2008 at PALS. Call surveys were not conducted at PALS because of accessibility and lack of permanent water bodies on-site.

Species	Call surveys	Encounter
Spring peeper		X
Green frog		X
Gray treefrog		X

Habitat sampling

In 2007, habitat data were collected at each point surveyed for birds and salamanders. In 2008, we used identical habitat data collection methods to re-evaluate early successional and other sites determined to be dynamic in nature (e.g. clearcuts). The procedures were adapted from Noon (1981), and consisted of 4 sub-plots to measure components of interest at each wildlife sampling point. Habitat characteristics of interest included species and diameter at breast height (DBH) of trees, shrub density, canopy and ground cover, slope, canopy height, and tree and log dispersion. We will analyze the abundance and distribution of birds and salamanders in relation to these habitat features in the future.

Expected Outcomes

Ultimately, we will obtain a better understanding of which species use reclaimed mine sites, and which practices used during the reclamation process are most attractive to wildlife. Because of the sensitivity of many wildlife species, especially amphibians, to disturbance, we hope to use our results as an indication of the potential of mined sites to support wildlife and suggest reclamation efforts that could be used to attract wildlife. With this knowledge, we will be able to recommend reclamation practices that provide adequate habitat for wildlife and support wildlife habitat as a viable land use under current SMCRA requirements.

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Appendix. Bird species encountered at survey points in 6 cover types sampled on the Powell River Project (PRP) and the Public Access Lands for Sportsmen (PALS) sites in Wise and Dickinson County, VA, 2008. Cover types sampled were early successional (5-12 years) reclaimed sites, older (12-20 years) reclaimed sites (Mid Successional), forest harvested with traditional forest management methods (Harvested), sites managed for grazing (Pasture), pre-SMCRA reclaimed sites (Pre-SMCRA), and unharvested reference forest (Reference). The value given represents the number of birds observed per survey point per visit (or observations per unit effort). Bird observations were made during 5 early morning surveys on each of 102 sampling points distributed across the sites during May, June, and July, 2008.

	Cover type and Study Area											
	Early successional		**Mid-successional**		**Harvested**		**Pasture**		**pre-SMCRA**		**Reference**	
	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS
Species	*n=10*	*n=9*	*n=7*	*n=4*	*n=2*	*n=5*	*n=3*	*n=13*	*n=6*	*n=27*	*n=8*	*n=8*
American crow	0.36	0.27	0.29	0.30	0.40	0.28	0.13	0.23	0.33	0.18	0.28	0.10
American goldfinch	0.38	0.40	0.06	0.70		0.44	0.13	0.66	0.07	0.19	0.03	0.08
Barn swallow							0.27	0.02				
Black-and-white warbler	0.04	0.11	0.11	0.10	0.40	0.20		0.11	0.37	0.61	0.20	0.30
Black-billed cuckoo	0.08				0.10					0.01		
Blackburnian warbler												0.03
Black-capped chickadee								0.06	0.07	0.05		0.05
Black-throated blue warbler			0.03							0.01	0.08	0.08
Black-throated green warbler			0.06		0.20				0.47	0.07	0.30	0.05
Blue jay	0.02	0.02	0.06					0.03	0.13	0.10		0.03
Blue-gray gnatcatcher										0.05		
Blue-headed vireo									0.07	0.01	0.18	0.08
Blue-winged warbler	0.12	0.27	0.03	0.65		0.16		0.14		0.18	0.03	0.08
Brown thrasher	0.06		0.06	0.10								
Brown-headed cowbird	0.02	0.07				0.20		0.15				0.03
Carolina chickadee	0.04	0.09	0.09	0.05		0.12		0.05	0.17	0.19	0.08	0.15
Carolina wren	0.16	0.27	0.31	0.25		0.32	0.13	0.09	0.30	0.34	0.03	0.18
Cedar waxwing	0.16					0.08		0.06		0.04		0.15
Chestnut-sided warbler	0.02		0.03			0.08					0.08	
Chimney swift								0.05				
Chipping sparrow		0.02					0.07	0.08		0.13	0.03	0.03
Common raven			0.03									
Common yellowthroat	0.12	0.18	0.17				0.13	0.03	0.23	0.07	0.03	

Appendix, Continued.

	Cover type and Study Area											
	Early successional		**Mid-successional**		**Harvested**		**Pasture**		**pre-SMCRA**		**Reference**	
	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS
Species	*n=10*	*n=9*	*n=7*	*n=4*	*n=2*	*n=5*	*n=3*	*n=13*	*n=6*	*n=27*	*n=8*	*n=8*
Dark-eyed junco									0.10	0.04		
Downy woodpecker	0.02							0.02	0.13	0.01	0.05	
Eastern bluebird	0.04		0.03				0.13					
Eastern meadowlark	0.04						0.47	0.05	0.03			
Eastern phoebe	0.02	0.11				0.08			0.10	0.09		
Eastern towhee	0.36	0.62	0.43	0.55		1.00	0.20	0.65	0.13	0.28	0.08	0.48
Eastern wood-pewee						0.08				0.01		
European starling							2.53	0.11				
Field sparrow	0.56	1.29	0.31	0.80			0.93	1.02	0.07	0.04	0.20	0.08
Golden-winged warbler	0.16	0.07						0.02	0.03			
Grasshopper sparrow	0.14			0.10			1.33	0.23				
Gray catbird						0.04				0.01		
Hairy woodpecker		0.02							0.03	0.01		0.05
Hooded warbler	0.12	0.22	0.37	0.10	0.30	0.32	0.07	0.09	0.47	0.25	0.75	0.68
Indigo bunting	1.48	1.11	1.14	1.60		1.00	0.73	1.54	0.67	1.18	0.55	0.48
Kentucky warbler												0.03
Mallard	0.06											
Mourning dove	0.04	0.07	0.06	0.05		0.32	0.13	0.03	0.03	0.07		0.03
Northern bobwhite	0.16	0.02	0.11				0.20		0.10	0.01	0.05	
Northern cardinal	0.14	0.29	0.11	0.20		0.04		0.22	0.17	0.27	0.03	0.15
Northern parula												0.03
Ovenbird	0.02		0.09		1.10	0.04		0.11	0.33	0.04	0.63	0.18
Pileated woodpecker		0.02	0.03	0.10	0.10			0.09	0.13	0.16		0.10
Pine warbler				0.05								
Prairie warbler	0.74	0.76	0.14	0.20			0.20	0.15		0.01	0.05	
Red winged blackbird										0.01		
Red-bellied woodpecker		0.02						0.02	0.03	0.01		
Red-eyed vireo	0.18	0.13	0.66	0.20	1.10	0.24	0.13	0.23	0.87	0.68	0.75	0.65
Red-headed woodpecker										0.01		
Red-tailed hawk	0.02											
Rough-winged swallow		0.04										
Ruby-throated hummingbird		0.02				0.08		0.05		0.01		

Appendix, Continued.

	Cover type and Study Area											
	Early successional		**Mid-successional**		**Harvested**		**Pasture**		**pre-SMCRA**		**Reference**	
	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS	PRP	PALS
Species	*n=10*	*n=9*	*n=7*	*n=4*	*n=2*	*n=5*	*n=3*	*n=13*	*n=6*	*n=27*	*n=8*	*n=8*
Scarlet tanager	0.02					0.28			0.03	0.08	0.05	0.18
Song sparrow			0.03				0.13	0.05				
Swainson's warbler			0.03							0.01	0.08	0.03
Tree swallow	0.02							0.02				
Tufted titmouse	0.06	0.18	0.09	0.10	0.20	0.04	0.07	0.09	0.37	0.36	0.05	0.23
Veery											0.03	
White-breasted nuthatch										0.01		0.03
White-eyed vireo	0.10	0.13	0.06	0.10		0.32		0.03		0.04	0.05	0.03
Wild turkey			0.06	0.05			0.07			0.04		0.03
Wood thrush			0.11		0.30	0.12		0.09	0.07	0.12	0.13	0.18
Woodpecker spp.	0.02	0.11	0.03		0.10			0.05	0.03	0.08	0.03	0.10
Worm-eating warbler										0.01		
Yellow-billed cuckoo		0.07	0.03		0.10	0.04		0.02	0.03	0.04		0.08
Yellow-breasted chat	0.60	0.87	0.23	0.55		1.04	0.67	0.15	0.07	0.14	0.18	0.35
Yellow-throated vireo										0.01		

Long-Term Mine Soil Weathering and Treatment Effects: Do Topsoil Substitutes Really Mimic Natural Soils?

2007/2008 Powell River Project Annual Progress Report

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Introduction and Background

The Surface Mine Control and Reclamation Act (SMCRA) of 1977 contained a number of contentious provisions including return to original contour (AOC), long-term liability bonding periods, and return to "equal or better" post-mining land use conditions. However, one of the more stealthy provisions was SMCRA's allowance for use of pre-selected overburden materials as topsoil substitutes when (A) the native A+E horizon materials are less than 6 inches thick, and (B) the physical and chemical properties of the proposed substitute spoil materials are deemed suitable for such use. Since native topsoil layers throughout the Appalachian coalfields are usually less than six inches thick, and removing them from steep slopes is difficult and expensive, the vast majority of coal mined lands in the region have employed topsoil substitutes.

In 1982, the USDI Office of Surface Mining and the Powell River Project co-funded the installation of the Controlled Overburden Placement (COP) experiment to objectively assess the viability of the topsoil substitute concept and to determine whether or not organic amendments would be beneficial. In one component of the COP experiment we are directly comparing five mixes of sandstone:siltstone (SS:SiS) overburden while in a separate experiment we are following the effects of topsoil return, sawdust addition and four incremental loading rates of biosolids. All treatments are replicated four times and the plots are split between herbaceous (dominantly tall fescue) and forest (red oak following pine) vegetation. We intensively monitored those two side-by-side experiments through the late 1980's, and our results can be reviewed at the PRP web site and at http://www.cses.vt.edu/revegetation/minereclam.html. In summary, we found that (A) properly selected and placed spoil materials provided an outstanding soil medium for tall fescue production and allowed vigorous invasion of native herbaceous species; (B) higher pH spoils such as the siltstone strata employed were deleterious to pine tree growth; and (C) higher rates of biosolids amendments drove high fescue production while suppressing the pines. The COP experiment remains the longest intact and continuously monitored study of mine soil genesis in the World. Follow-up studies by our group at other sites in the 1990's and early 2000's also characterized the wider effects of biosolids applications and the nature of inherent variability in mine soil properties in the Research & Education Center. However, very little detailed soil analyses have ever been performed on the native pre-mining soils in the Research & Education Center area for direct comparison.

Over the past decade, the concept of topsoil substitution has been directly and indirectly criticized from a number of perspectives. First of all, advocates of the return of Appalachian mined lands to native forest covers have pointed to the lack of topsoil salvage and the inclusion of higher pH unweathered spoils as directly inhibiting effective reforestation. These objections have been raised by citizens and certain well-trained scientists alike. Secondly, the fact that relatively unweathered spoils (such as those employed in the COP study) release significant total dissolved solids (TDS) loads to drainage waters over time has been implicated as a component of mining related surface water degradation under both low and moderate pH conditions. Finally, the ability of these mine soils to accumulate organic matter, maintain a stable and viable microbial biomass and available nutrient pools, and overall productivity potentials beyond the requisite five-year performance liability period is also questioned by many citizens' groups.

In 2007, we proposed to directly address a number of these challenges by initiating a new program of mine soil sampling and analysis utilizing our established baseline experiments at the Research and Education Center, and at other locations where long-term baseline data sets are available, that will allow us to study changes in mine soil properties and productivity relationships over prolonged periods of time. Furthermore, we will directly compare mine soil properties for a range of important parameters (e.g. pH, organic matter content, P-forms, microbial biomass) with a suite of unmined native soils forming out of the same rocks. Thus, by a combination of direct and differential analysis, we propose to meet the following objectives:

Research Objectives

1. To determine the long-term (20+ years) effects of overburden rock type and surface treatments on important mine soil morphological, physical, chemical and microbiological properties.

2. To directly compare the properties of weathering mine soils of varying age with unmined native soils formed from the same strata.

3. To measure the net TDS elution potential of a range of fresh, partially weathered and well-weathered topsoil substitute materials.

4. To predict the ability of selected overburden materials to weather and transform into mine soils suitable for the support of native hardwoods and hayland/pasture vegetation, and to estimate the rate of transformation.

Methods and Procedures

Overall Approach

We are fortunate to have an array of well-characterized, documented and "preserved" research sites throughout the Powell River Project Research & Education Center area and the surrounding region. These include the COP experiment, areas to the north of Powell River that have been minimally disturbed since 1990, and certain limited locations south of Powell River that have not been re-mined since 1990. While much of the 1990 aged mine soil surface received a uniform treatment of biosolids+compost, there are significant areas of that surface that did not. By differentially sampling across these contrasting treatment areas, we will be able to directly determine the net effect of organic matter additions on long term soil development process and important mine soil productivity parameters.

Furthermore, the recent re-mining activity to the south of Powell River will allow us to sample and “pair up” mine soil pedons that are very young (1 to 10 years) with much older mine soils (25+ years) to the north that formed out of identical parent materials. Finally, we also have access to a range of relatively intact native forest soils in the overall Powell River area that occur between mining disturbances.

We are now completing the first year (of three) of this study. In year one, we focused field work on a wide range of unweathered and weathered spoil types in the region and on sampling pedons within the immediate vicinity of the Research & Education Center as described above. In year two, we will work with Jim Burger, and other collaborators to locate pedons south of Powell River and across the region where we can be assured of good “control” of spoil age and type and treatments, and where we have access to archived original spoil samples (where possible) or original data sets to determine rates of change of various mine soil properties. In the final year, we will complete all laboratory work, sample or re-sample additional pedons to fill out the data set, and construct a qualitative model of how basic mine soil morphological, chemical, physical and microbiological properties respond to (A) initial spoil type and (B) initial surface treatments over extended periods of time.

As discussed below, we are sampling a range of mine soil and natural soil pedons in the area of the Research & Education Center and beyond. Each morphological horizon sample and selected depth increment samples will be analyzed for the following parameters:

pH and total titratable acidity
Saturated paste electrical conductance and solid salts species (cations + anions)
Total organic carbon and Walkley-Black organic matter
Organic matter fractions
Microbial biomass
Bulk microbial activity (incubation/CO_2 evolution)
Total-P and fractions (e.g. OM-P, Ca-P, Fe-P)
Total-N
Exchangeable cations
Dilute acid extractable nutrients and metals
Extractable Fe and Mn oxides
Total-S and S-forms if S $\geq$ 0.2%
Calcium carbonate equivalence
% Rock fragments
Particle size analysis
Aggregate stability
Moisture desorption/water holding capacity on < 2mm fractions

In addition, the incremental depth samples will all be subjected to the soluble salt and dilute acid extractable nutrients+metals analyses described above. This suite of extracts will also be run on the 1982 and 1990 archived samples for each matching pedon. This will allow us to determine both the mass leaching that has occurred over time within pedons and the net amount lost over 15 to 25 years.

Progress to Date (August 2008)

Our efforts over the first year of this study have focused on 1) collecting and characterizing spoil samples representing a variety of geologic materials and weathering extent, and 2) describing, sampling, and characterizing soil profiles developed in both undisturbed materials and in various spoil types.

Spoil Characterization and Leaching/Weathering Trials

Fifteen samples representing fresh, partially weathered and well-weathered topsoil substitute materials were collected from PRP and other mines in southwest Virginia and east Kentucky. These samples represent a variety of spoil types including sandstone, siltstone and shale in different proportions and at various degrees of weathering. The pH of these spoil samples ranges from 6.2 – 8.2, and all have low peroxide potential acidity (PPA) values (< 4 tons $CaCO_3$/1000 tons material) and low total S (< 0.25 %). A summary of some physical and chemical properties of these materials is presented in Table 1.

A leaching column study was established in July 2008 to characterize element release from a subset of the spoil materials. The leaching columns were built from PVC pipe with a diameter of 7.6 cm and a length of 40 cm (volume = 1200 cm^3). Three spoil samples (OSM 2, OSM 3, and OSM 11) were selected to be run in triplicate under saturated and unsaturated conditions (18 columns total). The columns will be leached and sampled twice a week for at least 6 months (until the leachate stabilizes) using a simulated rainfall solution (pH 4.8). To date, 4 leaching cycles have been completed. Leachate solution samples are analyzed for several constituents including total dissolved solids (TDS), total organic carbon (TOC), cations, metals, Cl and SO_4.

Intensive Sampling of COP Experiment

In 2008 we also initiated full plot-by-plot sampling of the Controlled Overburden Placement Experiment. Each plot (48 total in two experiments) is being volumetrically sampled from two random locations each under the herbaceous side and the forested side. The standing biomass and any litter layers are removed first from above each sampling quadrat (30 cm x 30 cm). Next, the mine soil is volumetrically excavated from 0-5 cm and 5 to 25 cm depths. Thus, we are sampling four total locations per plot with two bulk samples per location. These samples will be analyzed for a similar suite of parameters to the mine soil pedons as described above. This sampling is the first time since 1985 that these plots have been subjected to detailed volumetric sampling. The advantages of this intensive sampling protocol include that (A) we will be able to statistically determine the long term (25+ years) effects of rock type and surface treatments on mine soil properties and (B) plant growth response. By sampling both sides of each plot, we will (C) also be able to determine the differential effects of herbaceous vs. pine/hardwood vegetation and litter layers on surface soil properties after this extended period of time. Finally, (D) the volumetric sampling protocol employed will also allow us to readily calculate important changes in net C-sequestration and nutrient accumulation over this period of time.

Table 1. Some chemical and physical characteristics of topsoil substitute materials.

Lab-ID	Geologic Description	Coal Seam[1]	<1 cm	>1 cm	pH	EC	PPA[2]	S	C
			%	%		dS/m		%	%
OSM[3] 1	unweathered sandstone	to be determined	23	77	6.9	1.27	0.00	0.06	0.89
OSM 2	dark gray carbonaceous shale	Hazard #7, Hazard #8	60	40	7.0	3.48	0.00	0.23	4.73
OSM 3	highly weathered ss; unweathered gray siltstone	to be determined	87	13	6.9	0.94	3.58	0.07	3.25
OSM 4	weathered, reddish-brown shale	Clintwood/ Blair	85	15	6.5	0.29	0.22	0.03	1.48
OSM 5	weathered and unweathered sandstone	Clintwood/ Blair	79	21	6.2	0.90	0.15	0.04	1.48
OSM 6	minimally weathered gray siltstone	Clintwood/ Blair	79	21	7.3	1.40	0.00	0.14	1.89
OSM 7	weathered brown-gray siltstone	to be determined	62	38	7.7	0.20	0.12	0.03	0.28
OSM 8	unweathered gray siltstone	to be determined	69	31	7.6	0.47	0.24	0.19	4.28
OSM 9	weathered and unweathered sandstone; weathered and unweathered gray siltstone	to be determined	49	51	7.7	0.40	0.00	0.08	2.15
OSM 10	unweathered gray shale	Philips	72	28	7.8	0.66	0.00	0.10	2.92
OSM 11	weathered sandstone	Taggart	68	32	6.3	0.56	0.28	0.02	0.78
OSM 12	unweathered sandstone	Taggart	45	55	7.8	0.40	0.00	0.14	2.39
OSM 13	weathered and unweathered sandstone	Bolling (Imboden)	64	36	7.6	0.28	0.00	0.04	1.88
OSM 14	weathered sandstone	Clintwood/ Blair	65	35	7.5	0.36	0.12	0.02	0.85
OSM 15	unweathered siltstone	Clintwood/ Blair	47	53	8.2	0.67	0.00	0.09	1.78

[1] Coal seam information provided by mine representatives.
[2] PPA = Peroxide Potential Acidity: results expressed in tons of $CaCO_3$ lime demand per 1000 tons material.
[3] These samples are also being utilized in a parallel study funded by OSM to estimate long term weathering and element release rates.

Soil Profiles

Eight soil profiles, including 3 unmined native soils and 5 mine soils, were described in the field and sampled. All soil profile samples are undergoing full characterization (as described above) in the laboratory. Table 2 provides a summary of the types of soil profiles described and sampled to date. Three soil profile descriptions based on currently available information, and photos, are provided in Figures 1-3. These descriptions include a native profile developed over the Taggart sandstone and two different aged mine soils developed from Taggart spoil.

Table 2. Soil profiles described and sampled at Powell River Project (Nov 2007 to Jul 2008).

profile ID	parent material	age (yrs)	relevant site information
PRP 1 (native)	Philips shale		
PRP 2 (native)	Taggart sandstone		
PRP 3 (native)	Taggart sandstone		
PRPS 1 (mine soil)	Taggart sandstone (on Philips bench)	6	
PRPS 2 (mine soil)	Taggart sandstone (on Philips bench)	2	
PRPS 3 (mine soil)	Taggart sandstone (with Standiford shale)	18	no biosolids
PRPS 4 (mine soil)	Taggart sandstone (with Standiford shale)	18	"mine mix" biosolids applied to surface
PRPS 5 (mine soil)	Taggart sandstone	40	

A – 0 – 8 cm; dark brown (10YR 3/3) gravelly sandy loam; weak fine granular structure; very friable; common to many fine medium and coarse roots; 20% coarse fragments; extremely acid; clear smooth boundary

Bw – 8 – 38 cm; yellowish brown (10YR 5/6) sandy loam; weak fine and medium subangular blocky structure; very friable; common to many fine medium and coarse roots; 12% coarse fragments; extremely acid; clear smooth boundary.

CB – 38 – 51 cm; light yellowish brown (10YR 6/4) sandy loam; weak fine and medium granular and medium subangular blocky structure; friable; common fine and medium roots; 10% coarse fragments; extremely acid.

C – 51 – 69 cm; brownish yellow (10YR 6/6) sandy loam; massive; friable; few coarse roots; 14% coarse fragments; very strongly acid

Cr – 69+ cm.

Figure 1. PRP 2 – Unmined native soil over Taggart sandstone

^A – 0 – 10 cm; brown (10YR 4/3) loam; weak to moderate fine granular and subangular blocky structure; very friable; many fine and common medium roots; clear smooth boundary.

^AC – 10 – 29 cm; 50% dark yellowish brown (10YR 4/4), 30% gray (5YR 5/1), and 20% yellowish brown (10YR 5/8) gravelly loam; massive to weak moderate subangular blocky structure; friable; common fine and medium roots; clear wavy boundary.

^C1 – 29 – 62 cm; dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/8) very gravelly loam; massive; friable to firm; few fine roots; gradual wavy boundary.

^C2 – 62 – 95+ cm; very dark grayish brown (10YR 3/2) very gravelly loam; massive; friable.

Figure 2. PRPS 3 – Mine soil (18 years old) over Taggart sandstone.

^A1 – 0 – 10 cm; very dark grayish brown (10YR 3/2) and brown (10YR 4/3) loam; moderate fine and medium granular structure; very friable; many fine and medium roots; clear smooth boundary.

^Bw – 10 – 24 cm; brown (10YR 4/3) very channery loam; moderate medium subangular blocky structure; friable; common fine and medium roots; 40% siltstone channers; abrupt smooth boundary.

^2C – 24 – 60 cm; black (5Y 2.5/1), gray (2.5Y 5/1), and brown (10YR 5/3); massive (80%) and fine subangular blocky (20%) structure; few fine roots; 40% rock fragments; common coal; abrupt wavy boundary.

^3C – 60 – 148 cm; brownish yellow (10YR 6/8), light yellowish brown (2.5Y 6/4), black (5Y 2.5/1); massive; friable; 20% saprolitic sandstone boulders; common iron depletions and concentrations; abrupt smooth boundary.

^4Cr – 148 – 170+ cm; bluish gray (10B 5/1) siltstone; massive; very firm.

Figure 3. PRPS 5 – Mine soil (40 years old) over Taggart sandstone.

Summary Work Planned for Years 2 and 3

In year 2, we will expand sampling to areas near the Research & Education center that lie to the south of Powell River and to other more distant locations where we can develop adequate data base control on original spoil conditions, site/weathering age, and treatments applied. For example, we still have existing pine stands and small islands of undisturbed 1970's era mined lands in isolated pockets long the Taggart bench and certain higher levels. At several of these locations, our program described and sampled soil pits in 1980, and Dr. Burger's program has continuously monitored pine stand plantings. Directly adjacent to almost all these locations we can sample relatively young mine soils and/or raw spoils. In Year 3, we will complete any additional sampling needed to round out the data set across different spoil types.

Data Analysis, Synthesis and Expected Results

At the end of year two, we will be able to directly determine and report the relative effect of rock type and surface treatments in the COP experiment on 25 years of mixed herbaceous vegetation and tree growth. We will also be able to contrast the differential effects of the two different vegetative cover conditions on surface soil properties. Similarly, by comparing the properties of the biosolids treated/untreated 15 year-old Taggart mine soils, we will be able to confirm overall rates of important mine soil transformation such as pH reduction and organic matter accumulation in an initially high pH sandstone system. By the comparing the bulk salt and acid extractable nutrient+metal data for each pedon with depth, we will be able to calculate the mass "TDS leaching potential" of each mine spoil material and assess how much of the TDS load appears to have leached over 15 and 25 year time spans and from what depth. These data and findings will be reinforced by our spoil leaching column trials which were established in 2008 and will continue for at least six months. Finally, we will directly compare and contrast all mine soil pedons with nearby natural soils over the same strata.

At the completion of the study, we will integrate all data sets from all components of the study to specifically address and meet our first three objectives. The latter part of the final project year will be focused upon constructing a qualitative (but well quantified!) model of how SW Virginia mine soil properties change with time, and the relative effects of original spoil type and surface treatments on those processes.

Effects of Total Dissolved Solids in Streams of Southwestern Virginia

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Background and Approach

Total dissolved solids (TDS) are the inorganic salts, organic matter, and other dissolved materials in water. Elevated TDS can be toxic to freshwater animals by causing osmotic stress and affecting the osmoregulatory capability of the organism (McCulloch *et al.* 1993). Several prior studies have concluded that the toxicity of TDS is a function of the solution's ionic composition as well as the TDS concentration (Goetsch and Palmer 1997, Mount *et al.* 1997; Clements 2002; Goodfellow 2000; SETAC 2004; Kennedy *et al.* 2005) and organism sensitivity.

Under the Clean Water Act, water quality criteria are components of water quality standards. As defined by the Code of Federal Regulations, criteria are "… elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use" [40 CFR 131.3(b)]. All Virginia waters are required to support a designated use defined by Virginia Department of Environmental Quality (DEQ) as "the propagation and growth of a balanced, indigenous population of aquatic life" (Virginia DEQ, 2007).

In 2006, Virginia DEQ initiated an evaluation of the potential to establish water quality standards for TDS as a response to total maximum daily load (TMDL) studies of streams draining watersheds affected by mining in southwestern Virginia (Maptech Inc 2004, 2005a, 2005b). Based on this evaluation, DEQ decided to proceed with an evaluation of the potential to establish a TDS water quality criterion.

A review of scientific literature and an analysis of Virginia DEQ water monitoring data concluded that neither of these two information sources provides an adequate basis for establishing water quality standards for TDS in Virginia (Zipper and Berenzweig 2007). The report recommended that, should Virginia DEQ choose to proceed with development of TDS criteria despite the lack of an adequate scientific knowledge base, such development should be based on studies of aquatic communities in natural streams of varying TDS levels where non-TDS stressors have minimal influence. The report suggested that component-ion effects should be considered in the development of such criteria.

Furthermore, Zipper and Berenzweig (2007) recommended that the benthic macroinvertebrate community should be considered as the target community in TDS criteria development, given that Virginia DEQ currently uses the benthic macroinvertebrate community as a bioindicator for Clean Water Act enforcement, and considering the wording of Virginia water-quality standards, which protect "the propagation and growth of a *balanced, indigenous population* of aquatic life" [italicized emphasis added], and the trophic role of benthic macroinvertebrates in aquatic systems. Such an approach is consistent with discussion regarding potential TDS criteria among US Environmental Protection Agency, Maptech, Virginia DEQ, Virginia Department of Mines, Minerals and Energy, and Virginia Tech personnel in late 2006.

Virginia DEQ currently uses a multimetric benthic macroinvertebrate community index, the Stream Condition Index (SCI), as its basis for water-quality assessment of benthic macroinvertebrate data (Burton and Gerritsen 2003; Virginia DEQ 2006). The approach proposed here will utilize the Virginia SCI (VSCI) to evaluate TDS and/or component ion effects on benthic macroinvertebrate communities. Research goals will be (1) to develop a database comprised of TDS-SCI relationships, and associated attributes such as habitat metrics, for freshwater streams that can support a recommended TDS criterion; and (2) to define a TDS and/or component ion concentration level that may be considered by DEQ for designation as a water quality criterion.

Research Methods

1. Identify freshwater stream research sites that have elevated (i.e., above reference or background) TDS concentrations but appear to be otherwise relatively unaffected by non-TDS stressor effects.

Research sites will be identified in consultation with VDMME, Virginia DEQ, and other cooperators. Virginia DMME databases will be accessed to identify active mining sites and completed mining sites, and streams draining those sites where TDS concentrations are elevated relative to background. GIS analyses, aerial photography and/or satellite imagery, and DEQ/DMME point-source discharge databases will be used in an effort to identify those high-TDS sites where non-TDS stressors do not appear to be present. We will attempt to locate 40 to 50 non-reference (elevated TDS) research sites, in total.

2. Identify 10 to 20 freshwater stream research sites that can serve as unstressed reference locations.

These research sites will be used as reference sites for comparison with TDS-affected sites. Reference streams will be selected based on similar geology and topography to the applicable non-reference streams in an effort to isolate TDS and the benthic population as the variables.

3. At each research site, sample benthic macroinvertebrates.

Sampling should be carried out during the spring and fall benthic macroinvertebrate sampling seasons under baseflow conditions (verified by DEQ/DMME flow data if available), avoiding time periods immediately following potentially scouring stormflow events, using a qualitative protocol similar to that described in Barbour et al (1999). Benthic macroinvertebrate samples will be identified to the genus level with the exception of midges, which will be identified to the tribe level

4. Characterize non-TDS stressor and other benthic macroinvertebrate community influences at all research sites by sampling habitat elements and water quality.

A complete physical habitat assessment will be conducted at each sampling site according to protocols described in Barbour et al. (1999). Parameters characteristic of low-gradient streams like channel sinuosity, pool variability, and pool substrate characterization will be excluded.

Water quality at each site will be characterized at the time of spring and fall benthic macroinvertebrate sampling for field parameters (pH, conductivity, temperature, dissolved oxygen) using a portable multi-probe sampler, major ions (Ca, Mg, K, Na, Cl, Sulfate), total dissolved solids, and metals (to include Cu, Zn, Mn, Se, Al, Fe). Samples that will be used in metals analyses will be field filtered. Inductively coupled plasma emission spectrometry (ICP) will be used to measure dissolved Ca, Mg, K, Cu, Zn, Mn, Se, Al, Fe (APHA 1998). Ion chromatography (IC) will be used to measure CO_3^{2-}/HCO_3^{-}, Cl and sulfate; TDS will be measured via filtration followed by drying at 180°C; and total alkalinity will be measured via titration with standard acid.

5. Analyze data to determine a potential TDS criterion.

The VSCI will be the biotic indicator used to define an impairment threshold for use in data analysis. The impairment threshold used by Virginia DEQ (VSCI = 60) will be used in this study.

The influences of TDS and component ions on the biotic indicator metric scores will be determined through a multiple regression approach. Component ion concentrations will be expressed on relative scales by summing all major cations (K^+, Ca^{++}, Mg^{++}, Na^+) and anions (CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-) separately and expressing each component-ion concentration both as a percentage of the cation/anion concentration total and as a concentration. In this multiple regression procedure, the VSCI will be the dependent variable and (relative-) concentrations of component ions will be the independent variables. In this procedure, potential multicollinearity effects of component ion concentrations and TDS will be controlled. Discriminant analysis will be employed to determine whether or not any of the measured habitat elements or other site characteristics is exerting an influence on SCI scores; if so, these will also be included as independent variables in the multiple regression procedure. A stepwise variable selection procedure will be employed to identify those variables exerting influence on the SCI scores at the research sites, and an SCI-prediction equation will be developed. Potential criteria will be defined using the SCI prediction equation to define TDS and/or component ion concentrations (or concentration relationships) that are adequate to maintain SCI scores at non-impaired levels. In addition, data will be analyzed to define a TDS/component ion levels that assure presence of all major functional groups and families that are normally present as significant community components in reference streams. Potential TDS criteria will be defined at levels where the data indicate adequacy to support "a balanced, indigenous population of aquatic life."

Progress to Date

The study is being conducted with financial support that combines resources from Virginia DEQ, Virginia DMME, and Powell River Project (PRP).

Full-time activities were initiated in late July, 2008, with plans to conclude activities in December 2010. Activities to date include meeting with Virginia DEQ and Virginia DMME personnel to assure coordination, initiation of efforts to locate suitable sampling sites, and initiation of field sampling trials for the purpose of refining and standardizing sampling procedures. We intend to initiate sampling in the fall of 2008; and to continue sampling site location efforts through the winter of 2008-09 so as to have the full suite of field sampling sites identified by spring of 2009.

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A WORKING LABORATORY AT THE POWELL RIVER PROJECT TO RESEARCH AND PROMOTE SUSTAINABLE FOREST MANAGEMENT

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Introduction

Virginia Cooperative Extension and Virginia Tech's Department of Forestry are working to take the next step in coalfield reclamation by researching and demonstrating sustainable forest management in natural and planted forests at the Powell River Project. The purpose is to establish research and education programs related to the management of forested ecosystems on Appalachian mining lands. Initial objectives include rehabilitating degraded natural forests and demonstrating outcomes to landowners, practitioners, and youth via Extension programs. Other aims are to research effective thinning and regeneration treatments in highly variable reclamation stands and develop a systematic approach for collectively managing rehabilitated natural and planted stands. During the summer of 2008, a field technician established a permanent inventory system consisting of comprehensive timber, tree regeneration, downed woody debris, and herbaceous measurements on about 200 acres of natural forests at the Powell River Project.

Background

Coal mining is a tradition in the mountains of deep Southwestern Virginia. Yet forestry and natural resources management are also a critical part of the region's character and economy. Over the past 25 years, scientists have been working with the mining community to develop effective methods for re-establishing forests on formerly mined lands. The Powell River Project has played a key role in hosting research to support this effort. Now, partners are working to take the next step in forest management on coalfields by researching and demonstrating sustainable forest management in the Powell River Project's natural and planted forests.

An outdoor sustainable forest management classroom at the Powell River Project Research and Education Center will offer research and education programs related to managing forested ecosystems on mining lands. Initial objectives include rehabilitating degraded natural forests and demonstrating the benefits to landowners, practitioners, and youth. Other aims are to explore the opportunities for managing forests planted after mining operations, develop a systematic approach for managing both natural and planted forests, and track changes using periodic field inventory.

Methods

Four compartments (A, B, C, and D) were defined based on geography and topography; each compartment spans a ridge line, drain-way to drain-way (Figure 1). Grid systems housing 1/10th

acre permanent over-story plots, mil-acre regeneration plots, and woody debris transects were established in each compartment. Stems one inch in diameter at breast height (dbh) and greater were inventoried. Dbh, basal area, live crown ratio and crown positions (suppressed, co dominant and dominant) were recorded. Merchantability was determined for each tree and a grade of acceptable or unacceptable growing stock was given based on species, bole shape, crown position and tree damage. Number of bolts (8 ft long) or logs (16 ft long) contained in each acceptable stem were recorded. Four regeneration plots were randomly established on the outer boundary of each over-story plot and used to measure understory seedling, herbaceous plants, and depth of litter layer. Lastly, downed woody debris were measured using random transects.

The entire inventory system was mapped using a Global Positioning System and entered into a Geographic Information System. Data collected at each plot will be used to identify management prescriptions and inform research design.

A 12-acre prescribed burn occurred in compartment A in April 2008. Prescribed burning targeted invasive species and sought to enhance desirable regeneration with the ultimate goal of preparing for restorative harvesting at a later point in time. Research plots were established in the burned comparment (compartment A) to assess impacts on invasive vigor and compare herbaceous cover and tree regeneration with like data from an unburned control compartment (compartment B).

Progress

During the summer of 2008, more than 60 permanent plots were established to collect baseline data on about 200 acres. Data will be analyzed in the fall of 2008 and used to guide future management prescriptions and Extension programming. It will also allow educators and researchers to assess progress in terms of the biological, economic, and social benefits of sustainable forest management. More specifically, data collected from compartment A (burned compartment) and B (control compartment) will be analyzed as part of an undergraduate research project in the Department of Forestry at Virginia Tech. Follow-on work will consist of inventory in additional acreage, periodic re-inventory of established plots, photographic documentation, controlled burning in adjacent compartments (C and D), restorative timber harvesting where warranted, annual educational conferences, and the establishment of additional partnerships to support additional research and demonstration.

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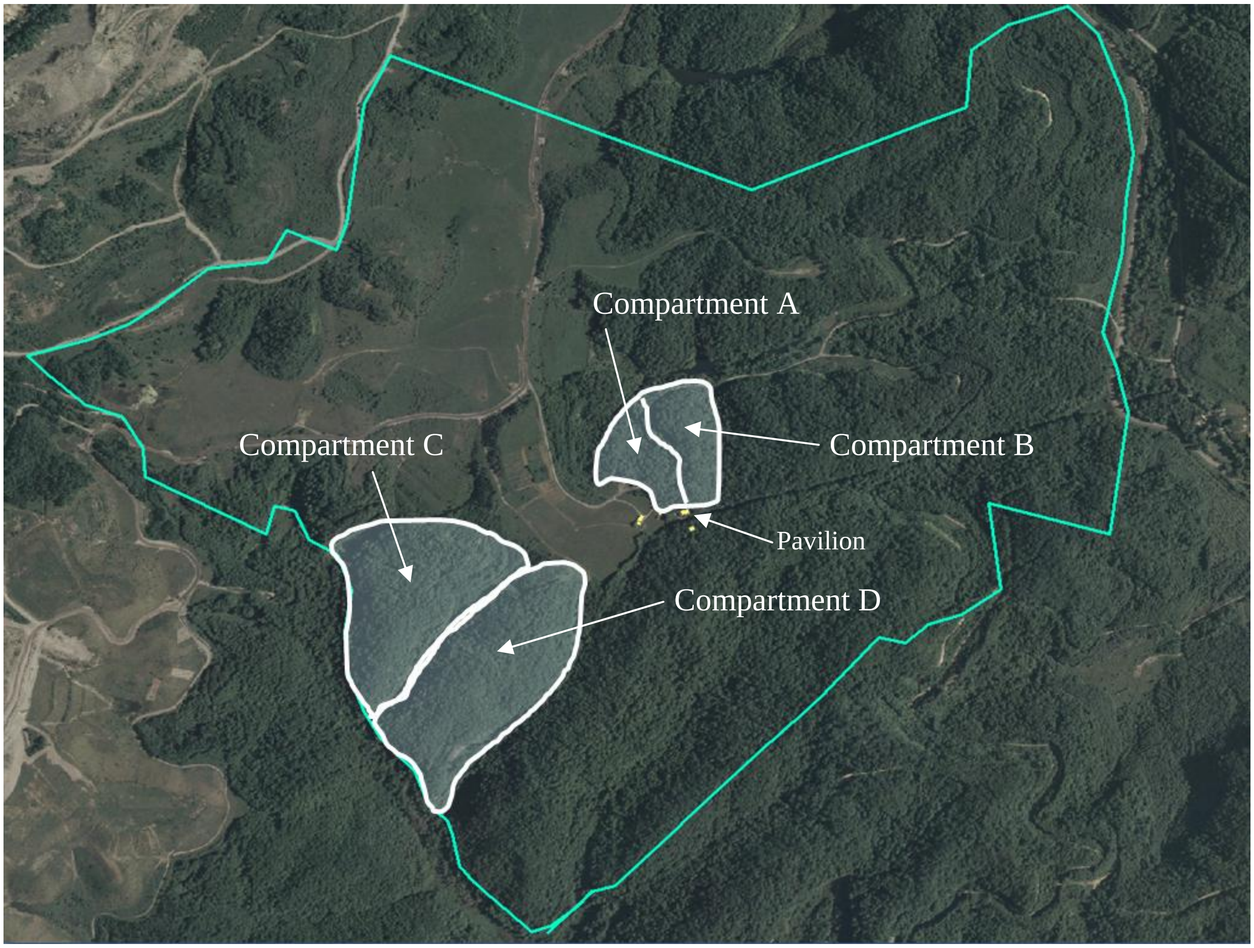

Figure 1. Four compartments at the Powell River Project inventoried during the summer of 2008.

POWELL RIVER PROJECT

Project Update

Herbaceous Crops for a Biofuels/Bioproducts Industry on Reclaimed Mine Lands

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Summary

In 2007, we began a project to investigate yield capacity of several feedstock species with potential suitability for revegetating mined land. Seeded species included panicgrass, switchgrass, a 1:1 seed mix of panic- and switchgrasses, and two species established from vegetative propagules: hardy sugarcane and miscanthus. Plants were established at the Powell River Project Research and Education Center on 30 May 2007 and stand survival and plant measures were taken 4 October 2007. A single biomass harvest was taken 11 January 2008, and estimates of frost heaving were made at that time as well. Of the plant species tested, hardy sugarcane had the greatest stand success (97% survival) and sugarcane plants were the most robust as measured by plant size. Biomass yields of the larger, vegetatively propagated species (miscanthus and sugarcane) were limited by the number of plants established within a plot (100). Although panicgrass and switchgrass were smaller in size, establishment by seed conveyed a yield advantage because plants were well-distributed across the plots. Drought conditions limited growth of all plants (based on crop performance at other research sites) and may have contributed to susceptibility to frost heaving for smaller plants (panic- and switchgrasses) on wet, poorly drained sites. Although sugarcane appeared the best plant for establishment under the difficult conditions of 2007, preliminary observations in March 2008 suggest it may not have survived the winter.

I. Introduction:

Interest in renewable, bio-based energy sources is driving current research on plant resources for bioenergy cropping systems. Species that can be productive on sites with limited production capacity are of particular interest, because such land use could bring reclaimed mine lands back into production and will not contribute to competition between food and fuel production. Such systems may also bolster rural economies, given that few other new agricultural enterprises have the potential for such broad-scale impact as biorenewables industries.

Yield per land area will be an important determinant for economic viability of a biomass-to-biorenewables industry. Because raw biomass will be a low-value commodity (in dollars per ton), yields must be sufficient to warrant producer adoption and market entry. Given the extensive nature of sometimes difficult terrain, these sites will also need to be productive with minimal inputs.

II. Objectives:

1. Evaluate and compare stand establishment of potential biofuel/bioproduct crops (switchgrass, coastal panicgrass, and a mix of these two native grasses, along with two non-natives, miscanthus, and hardy sugarcane) on reclaimed mine lands in Southwest Virginia.

2. Evaluate these crops for growth traits such as plant height, crown width, tiller number, lodging, and leaf:stem ratio that relate to yield and feedstock quality.

3. Quantify yields in the establishment year and succeeding years.

4. Examine feedstock quality (cellulose, hemicellulose, lignin, nitrogen, and ash) of these potential biomass crops.

5. Determine the carbon sequestration potential of these biomass crops.

III. Methods and Procedures:

Plant species:
Switchgrass, coastal panicgrass, and a 1:1 mixture of these species were seeded into plots with a plot seeder on 30 May 2007. At the same time, 100 plants/plot were established for both miscanthus and hardy sugarcane. Subsequent research determined that the miscanthus species planted in 2007 was not the species intended, and these plots were killed out and replanted in summer of 2008.

Measurements:
Stand counts and plant growth measurements such as plant height, crown width, and tiller number were in October 2007. Biomass samples were collected in January 2008, and plots also were evaluated for frost heaving. In March 2008, plots were evaluated for winter kill.

Plant measures and biomass harvests will again be conducted in Fall 2008 and Winter 2009.

IV. Brief progress report:

Hardy sugarcane plants (Table 1) were the largest, and most vigorous of the biomass plantings, being about 30% taller than miscanthus plants. Stems size and tiller numbers were also much greater than for any other planting. Despite persistent drought, stand percent was greatest among all crops as of October 2007. However, winter kill – which was quite variable by replicate – will be a substantial obstacle to utilization of hardy sugarcane. In March 2008, sugarcane survival (estimated as plants with live green tissue) ranged from 18 to 54%. Limited amount of material for replanting – coupled with the large death losses – is leading us to abandon this species for use in mineland energy cropping.

About 70% survival during the establishment phase was noted for miscanthus, and the plant did not winter kill. Establishment success rates were greater than at other sites where weed pressure was greater. Observation suggests miscanthus is quite drought tolerant once established, but it is sensitive to drought during the establishment phase.

Despite these potentially promising results, these observations were not taken on *M.* × *Giganteus*, but likely rather on a large form of *M. sinensis*. *M. sinensis* can produce viable seed and has displayed invasive potential in other ecosystems. Thus all *M. sinensis* plants established in 2007 were killed in 2008 and plants were replaced with *M.* × *Giganteus*.

Table 1. Plant growth measures, establishment, frost heaving, and yield values for energy crops established at Powell River Project.

Species	**Height (m)**	**Stem diameter (mm)**	**Tiller no.**	**Stand (%)***	**Frost heaved (%)**	**Yield (kg/ha)**
Panicgrass	0.44	1.85	3.2	70	38.2	129
Switchgrass	0.50	1.90	3.0	81	11.5	139
Mix**	0.38	1.52	2.5	76	30.9	83
H. sugarcane	0.66	4.27	10.8	97	0	66
Miscanthus	0.51	2.71	3.0	81	0	15

*Reflects cover in seeded plots or percent survival of 100 vegetatively established plants
**Mix = Panic + Switchgrass (1:1 seeding)

Despite smaller plant sizes and moderate establishment success, panic and switchgrasses produced greater amounts of biomass on a land area basis due to their distribution across the plot. Mortality rates were high due to frost heaving, however, and these plots were overseeded with un-stratified seed in March 2008. It appears that portions of the soil in this replicate are limiting, as overseeding has failed to produce a good stand this spring and summer.

The variability of stand establishment (see Fig. 1) and production results highlights the inconsistent nature of mine land soils and the challenge of producing a dependable crop in these sites.

Figure 1. Stand success is variable. Hardy sugar cane (far left) appears productive on some sites but much was subject to winter kill (inset). Panic- and switchgrasses (right) also have displayed sensitivity to site of establishment.