Powell River Project Annual Report (2010 – 2011)

Restoring Ecological Function to Reforested Mined Lands: Connecting Soils with Forest Productivity and Ecosystem Services

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Project Summary

This project contributes to the legacy of reforestation research at the Powell River Project and provides benefit to the larger Appalachian Coal Region. Dr. Brian Strahm has recently (2009) joined the faculty of the Department of Forest Resources and Environmental Conservation at Virginia Tech following the retirement of Dr. Jim Burger who has led the reforestation research program at the Powell River Project since 1980. Drs. Strahm and Burger have worked very successfully with Dr. Carl Zipper over the last two years to facilitate this transition in order to maintain the strong tradition of reforestation research in reclaimed mined lands centered at the Powell River Project. This level of cooperation is expected to continue into the future as reforestation research moves from an era focused on seedling establishment into one focusing on forest stand development, productivity, and the ability of reforested landscapes to provide valuable ecosystem services, all of which provide benefits to the landowners, mining companies and local communities. Specifically, this project has augmented the core focus of the Forestry Reclamation Approach (FRA) to "fast forward" vegetative succession and return high value hardwoods to the post-mining landscape by providing information to simultaneously "fast-forward" the restoration of the ecological services, function and productivity of the pre-mining forested landscape. Thus, this project utilizes the long-term Controlled Overburden Placement Experiment (COPE) to evaluate the effects of topsoil substitutes and organic amendments on the carbon (C), nitrogen (N), and phosphorus (P) cycles that combine to regulate forest productivity, C sequestration and the buffering of nutrient losses to nearby aquatic ecosystems. Additionally, the project capitalizes on the unique opportunity to work closely with Dr. Lee Daniels to better understand the differences that reclamation through reforestation and herbaceous vegetative cover have on these important biogeochemical cycles. The culmination of this work will help guide reclamation and reforestation efforts on mined lands and directly address the growing social and regulatory pressures facing the coal mining industry regarding the return of ecosystems services and productivity to the post-mining landscape. We have made great strides in this effort to-date and will detail our progress, findings, and plans below.

Scope of Work

Introduction:

During the first few decades following the implementation of the Surface Mining Control and Reclamation Act (SMCRA) of 1977, reforestation efforts in reclaimed mined lands generally resulted in high seedling mortality and low levels of forest productivity. Decades of work centered at the Powell River Project and led by Dr. Jim Burger have identified a five-step process known as the Forestry Reclamation Approach (FRA) to overcome many of the issues preventing successful seedling establishment, and accelerate the return of a forest community that would otherwise take centuries to achieve through natural successional pathways. The FRA has been identified as a desirable method to support forested land uses on reclaimed mined land by the Appalachian Regional Reforestation Initiative (ARRI), the US Office of Surface Mining and many state mining agencies, including the Virginia Department of Mines, Minerals and Energy. Thus, reforestation is an increasingly feasible and appealing option for reclaiming post-mining landscapes throughout the Appalachian region.

The benefits of successful post-mining reforestation include potential financial returns to the landowner in the form of forest products and the provision of valuable ecosystem services [e.g. carbon (C) sequestration, watershed protection] throughout the period of stand development. In fact, the two are so strongly linked that ecosystem services are often provided in direct proportion to forest productivity. Ultimately, however, both of these reforestation benefits are constrained by site quality, and specifically by soil properties and processes.

In the same way the FRA strives to "fast forward" vegetative succession and return high value hardwoods to the post-mining landscape, there is a need to rapidly reestablish the ecosystem services and functions associated with the native pre-mining forested landscape. This is ecologically important in sustaining forests after seedling establishment, but is also critical in addressing the increasing social and regulatory pressures regarding environmental quality following mining operations. Thus, this research project initiates a new line of reforestation research that builds on the concepts and successes of the FRA and represents a critical step toward understanding how the management and manipulation of forest soils can restore ecosystem services, functions and productivity on post-mining reforested landscapes.

The Controlled Overburden Placement Experiment (COPE) at the Powell River Project, co-funded in 1982 by the US Office of Surface Mining and the Powell River Project, is the longest intact and continuously monitored experimental manipulation of topsoil substitutes and organic amendments in the world. Thus, the COPE provides an incredibly unique opportunity to leverage this previous investment and long-term research history to answer fundamental questions regarding reforestation research. Namely, to understand how these different topsoil substitutes [five different mixes of sandstone and siltstone (SS:SiS)] and organic matter amendments (topsoil return, sawdust addition and four incremental loading rates of biosolids) drive forest productivity and provide beneficial ecosystem services under forest cover. All treatments in the COPE are split between herbaceous (dominantly tall fescue) and forest (red oak following pine) vegetation. This provides another advantage by allowing for close collaboration with Dr. Lee Daniels and comparisons with his work on soil weathering that have primarily focused on the herbaceous side of the plots. Such comparisons will provide additional information regarding the differential response of important C and nutrient [nitrogen (N) and phosphorus (P)] cycles, the ultimate drivers of productivity, nutrient retention, and C accumulation/sequestration, to different vegetative reclamation techniques (e.g. reforestation vs. hayland/pasture).

Objectives:

1. Determine the effects of topsoil substitutes and organic amendments on the long-term (~30 year) accumulation of soil nutrient (N and P) and organic C stocks on reforested mined lands.

2. Assess the potential for different topsoil substitutes and organic amendments under forest vegetation to affect the sequestration of C into passive (~1,000 yr residence time) soil pools.

3. Compare the differences in the above measurements across sites with different vegetation histories (e.g. forest vs. herbaceous).

4. Relate observed soil properties to historic observations of forest productivity (e.g. total biomass production).

Methods and Procedures:

We are entering into the second of a two-year study to meet the above objectives. The study focuses on the suite of comparisons available at the COPE across topsoil substitutes, organic amendments, and vegetative histories. The COPE, initiated in 1982, consists of two distinct experimental units. The topsoil substitute portion of the COPE consists of four replications of five overburden mixes. These mixes include pure sandstone (SS), pure siltstone (SiS), and mixes of 2:1 SS:SiS, 1:1 SS:SiS, and 1:2 SS:SiS arranged in a randomized complete block design. The organic amendment portion of the COP experiment was constructed using the 2:1 SS:SiS overburden mix with four replicates each of a control plot (no organic amendment) and additions of native topsoil, sawdust, and four different applications rates of biosolids, arranged in a randomized complete block design. All COPE plots measure 7 x 3.5 m and are split by different vegetative covers (forest vs. herbaceous). Aboveground vegetative responses (biomass and nutrient contents) have been characterized periodically throughout the history of the COPE.

Following Dr. Daniels' recent work on the herbaceous plots, we have sampled from multiple soil pits under historic forest cover in each plot. Present sampling efforts have attempted to account for varied historical methods and allow for the greatest number of comparisons with ancillary studies. To do so, soil was sampled at depths of 0-5 cm, 5-10 cm, and 10-25 cm (Figure 1), and will be analyzed independently and combined mathematically following analysis for comparison with other observations.

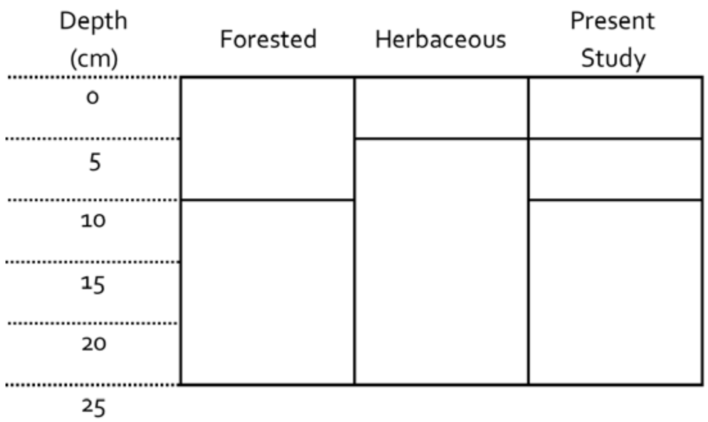

Figure 1. **Correlation of current sampling depths with past sampling depths.**

Two samples were taken at each forested plot. Plots were divided into 30 x 30 cm quadrats. Tree mats were installed around the northern red oaks with dimensions of approximately 60 x 60 cm to suppress vegetative competition immediate to the planted seedlings. Following harvest of the oaks in 2009, it was observed that the mats both preserved the pine litter and excluded the oak litter. For these reasons, quadrats acceptable for sampling will only occur in the corridors. Additionally, only those quadrats completely within the area of influence of the trees will be candidates for sampling. Figure 2 depicts the areas that contain available quadrats, which are signified as black and white numbered plots.

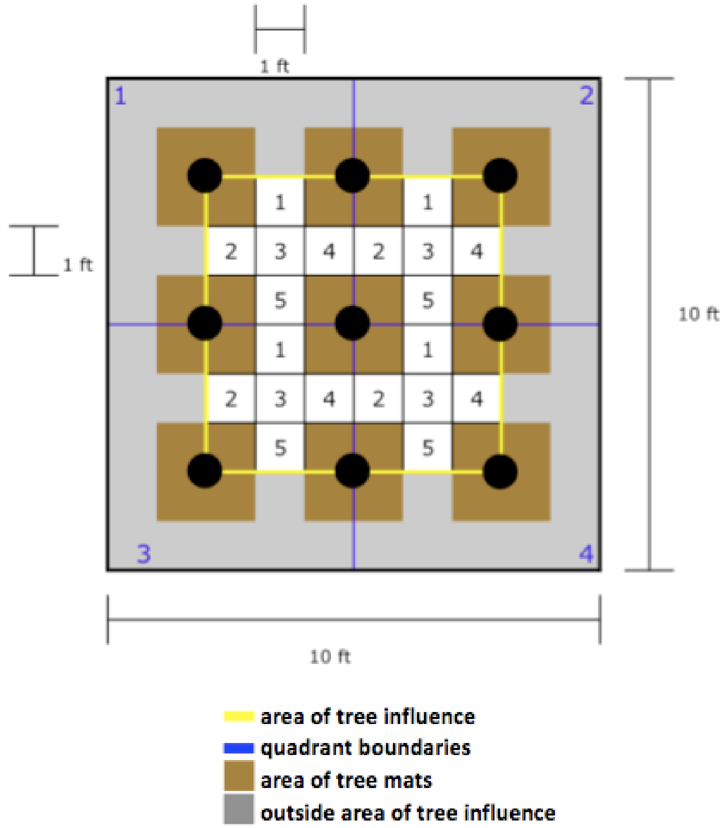

Figure 2. Sample quadrats for random soil sample collection on forested side of COPE plots.

Random number generation was used to select sampling sites. Each plot was divided into four quadrants. Two quadrants were randomly selected. From those two quadrants, one quadrat was selected. This method was utilized to maximize spatial variability of samples. Further exclusion criteria were required to avoid areas that did not yield representative samples. These criteria included, but were not limited to, if the quadrat contained a pine stump, had a large cobble-sized or greater stone on the surface, was visibly disturbed (e.g. used for past sampling), or was adjacent to another quadrat chosen for sampling. Any stones or roots that were too large to take in the sample or could not be extricated were measured for volume and the volume recorded.

Results:

We found that the total carbon and total nitrogen concentrations (%) under forest vegetation were both significantly different ($p<0.05$) between rock mixes at depths of 5 to 10 cm and 10 to 25 cm; however, there were no significant differences from 0 to 5 cm. Significant differences ($p<0.05$) of organic carbon concentrations in rock mixes under forest vegetation were only found in the 5 to 10 cm depth. The concentrations showed a general increasing trend along the gradient of pure SS to pure SiS at depths of 5 to 10 cm and 10 to 25 cm (Figure 3). No significant differences ($p<0.05$) were found for total carbon, organic carbon, or total nitrogen contents (Mg ha^{-1}) between rock mixes at any depth (Figure 3).

The organic carbon contents were significantly different ($p<0.05$) between forested and herbaceous plots for all rock mixes from 0 to 25 cm. Furthermore, the herbaceous plots had significantly higher organic carbon contents than the forested plots for all rock mixes (Figure 4). Total nitrogen contents were significantly higher ($p<0.05$) in the herbaceous plots compared to the forested plots from 0 to 25 cm for the pure SS and 2:1 SS to SiS rock mixes. Again, the herbaceous plots had significantly higher ($p<0.05$) total nitrogen contents than the forested plots for all rock mixes (Figure 5).

To date, the total carbon, total nitrogen and organic carbon of the topsoil substitute, organic amendment and unmined samples have been determined. Additionally, all samples have been analyzed for pH, macro- and micronutrients, base saturation and soluble salts. Subsequent laboratory analyses include available phosphorus extraction and particle size distribution.

Further examination of the data includes relation of the forested rock mix chemical and physical properties to those of the unmined soils. The forested chemical and soil properties will also be correlated to past above-ground forest biomass measurements and charted over the history of the COPE.

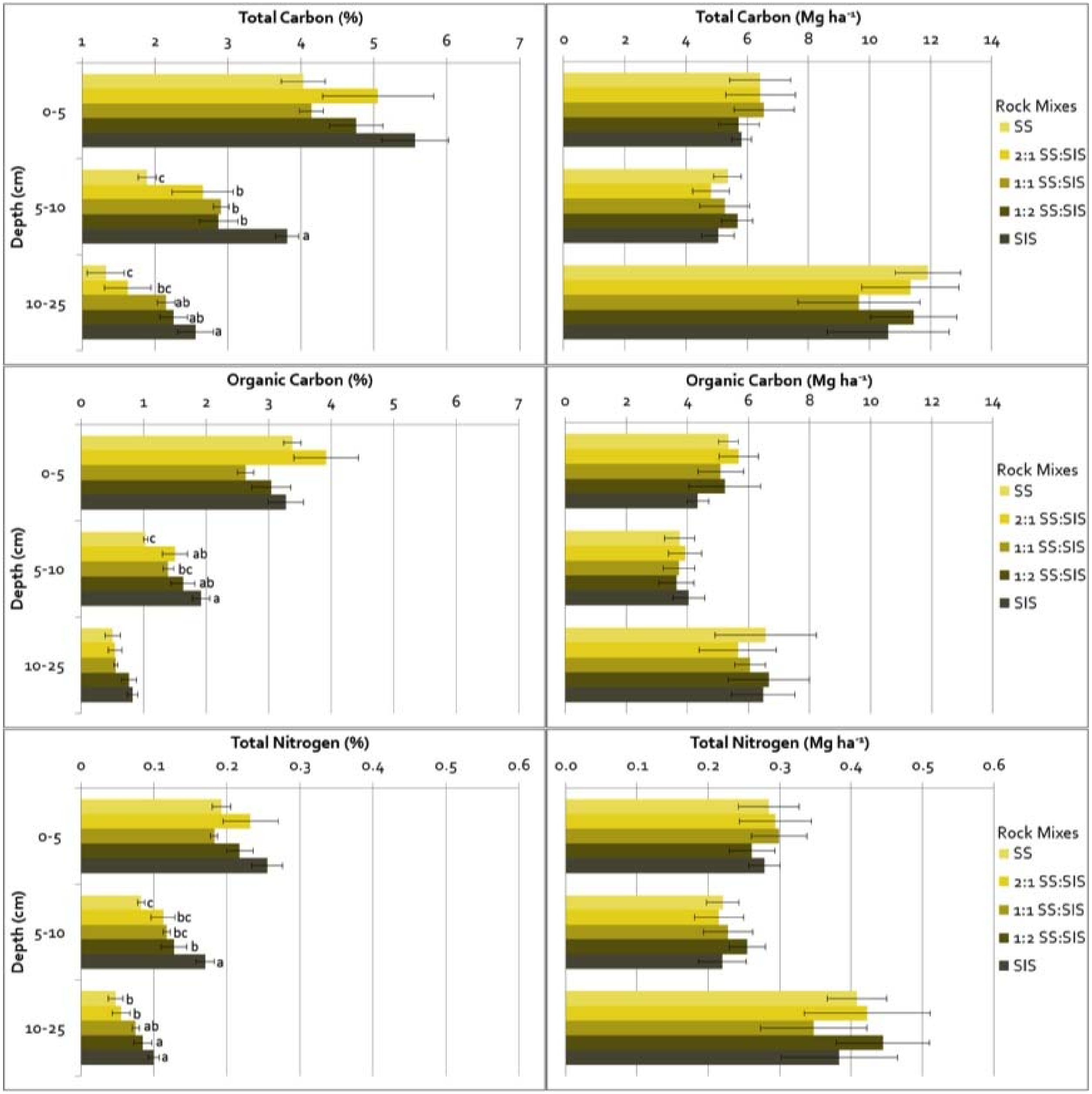

Figure 3. Percent (left) and content (Mg ha^{-1}) (right) of total carbon (TC), organic carbon (OC) and total nitrogen (TN) under forest vegetation at depths of 0-5 cm, 5-10 cm and 10-25 cm for rock mix treatments. Post-hoc letters indicate significantly different (α=0.05) TC, OC or TN of a treatment within each depth group.

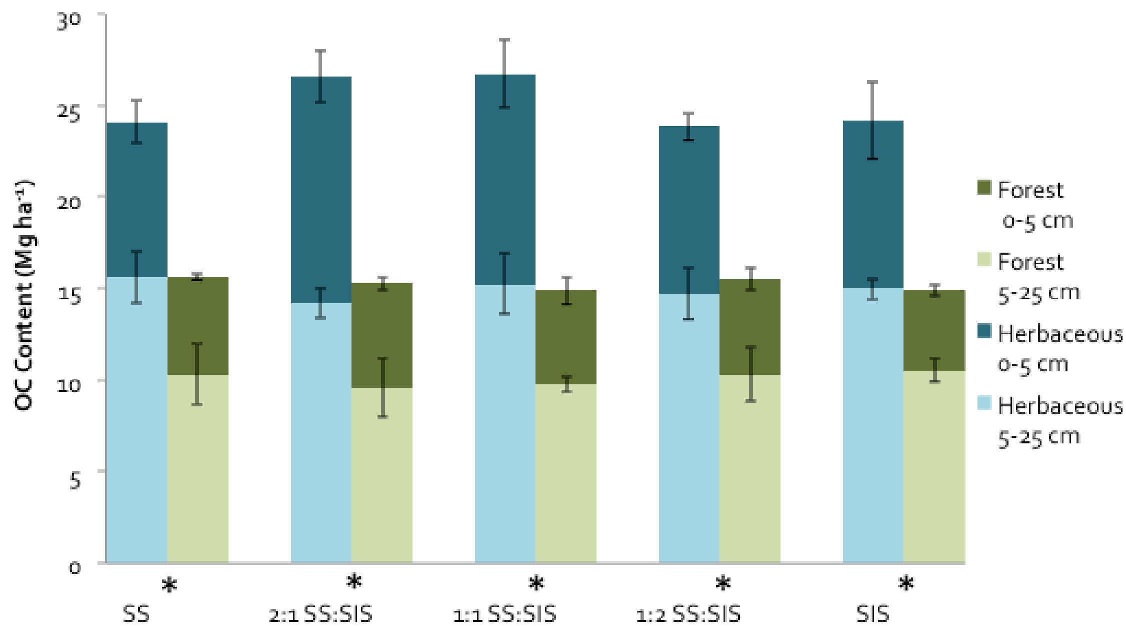

Figure 4. Comparison of OC contents (Mg ha^{-1}) under herbaceous and forest cover types across Rock Mix gradient for 0-5 and 5-25 cm depths. Standard error bars for 0-5 and 5-25 cm depths; asterisks denote significant difference between OC in forest and herbaceous plots for 0-25 cm.

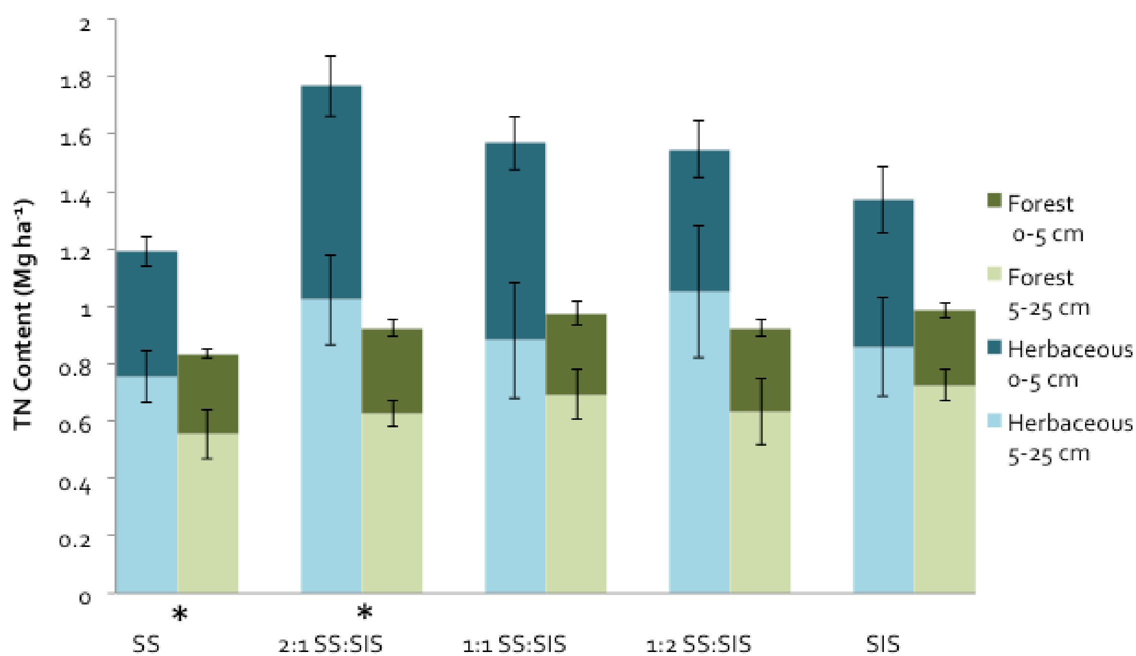

Figure 5. Comparison of TN contents (Mg ha^{-1}) under herbaceous and forest cover types across Rock Mix gradient for 0-5 and 5-25 cm depths. Standard error bars for 0-5 and 5-25 cm depths; asterisks denote significant difference between OC in forest and herbaceous plots for 0-25 cm.

Deliverables:

To date, this work has been presented at three conferences, one of which was an invited talk at an international conference. The references for the presentations are given below:

Craig, N.G., B.D. Strahm, J.A. Burger, W.L. Nash, W.L. Daniels. Long-term Soil Carbon Accumulation in Reclaimed Mine Soils as Affected by Overburden Rock Type and Vegetation Prescriptions. 8th North American Forest Ecology Workshop. Roanoke, VA. June 19-23, 2011.

Craig, N.G., B.D. Strahm, J.A. Burger, W.L. Nash, W.L. Daniels. Soil carbon and nitrogen comparisons in reconstructed mine soils under contrasting vegetation in southestern Virginia. 28th Annual Meeting of the American Society of Mining and Reclamation. Bismarck, ND. June 12-16, 2011.

Strahm, B.D., J.A. Burger, W.L. Daniels. Total Aboveground Biomass of Northern Red Oak in Response to Different Topsoil Substitutes. 2010 Joint Mining Reclamation Conference of the American Society of Mining and Reclamation and the Appalachian Regional Reforestation Iniative, Pittsburgh, PA. June 5-10, 2010.

For her presentation at the 28th annual ASMR meeting, Ms. Craig received the award of "Best Poster." This adds to her other distinction as best poster presentation at the Virginia Tech Department of Forest Resources and Environmental Conservation Graduate Student Symposium in 2011.

We are currently in the process of preparing three peer reviewed manuscripts detailing the results from this work. At the end of the project we will also author a Virginia Cooperative Extension bulletin to aid in the transfer of this information to land owners, land managers, and reclamation specialists. Additionally, we will present the next iteration of our results at the Soil Science Society of America International Annual Meeting in San Antonio, TX in October of 2011.