# LONG-TERM EFFECTS OF HERBACEOUS SPECIES AND TREES ON RECLAIMED MINE SOIL PROPERTIES[1]

K. McMillen, M. Letalik, E. Carver, A.O. Abaye, C.E. Zipper, A.G.Fannon-Osborne [2]

**Abstract:** The selection of plant species is critical for successful establishment and long-term maintenance of vegetation on reclaimed surface mined soils. Over long terms, the plant species present on reclaimed coal mine sites may also influence surface soil properties and, by extension, related site properties such as surface hydrology. We conducted research to compare effects of 4 herbaceous species on reclaimed mine soil properties over 20 years, and to compare these herbaceous species' effects to those produced by planted trees. The herbaceous experimental treatments were installed in summer 1990 on partially reclaimed mine soils. The experimental design was a complete block, with each plant-species treatments replicated 4 times. Prior to revegetation, a composted mixture of wood chips and biosolids was mixed into the soil to provide initial nutrients. No other fertilizer was applied after the initial fertilization. The plots have been mowed annually to stimulate re-growth. The plant species with greatest persistence and biomass production over two decades are switchgrass, sericea lespedeza, reed canarygrass, tall fescue, and crownvetch. An adjacent area, reclaimed in association with the herbaceous experimental area, was planted with herbaceous species initially and then replanted with trees of various species in the early 1990s. In Summer of 2011, the herbaceous vegetation plots and six locations within the adjacent area planted with trees were sampled and characterized for soil properties.

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[2] K. McMillen, E. Carver, and M. Letalik are undergraduate students, A.O. Abaye is Professor, and C.E. Zipper is Associate Professor, Department of Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg VA 24061. A.G. Fannon-Osborne is Associate Extension Agent, Agriculture and Natural Resources/Mined Land Restoration, Virginia Cooperative Extension, Wise VA.

## Introduction

Coal surface mines reconstruct soil materials as an essential part of the reclamation process. Natural soils are removed and often replaced with rock-derived derived spoils after mining. The spoil materials are revegetated by fertilizing and applying seed with a hydroseeder. When the revegetation strategy involves woody vegetation, trees and shrubs are often hand-planted into the spoil materials.

The nature of soil materials formed from the rock spoils used for surface mine reclamation influence the properties of the reclaimed mine landscape. Surface mine soils vary in their ability to store and supply plants with water and nutrients. Reclaimed soil density influences the ability of restored plant materials to extend roots and, hence, their biological productivity. Surface properties including porosity and water holding capacity influence the ability of mine soils to perform environmental services, such absorbtion and slow release of waters from rainfall.

It is well known that the types of spoil materials used to construct mine soils and the manner in which they are placed in the surface will influence their resulting properties (Daniels and Amos 1985; Roberts et al. 1988; Daniels and Zipper 1997). Much less research has been conducted to investigate how the different plant materials established on mine soils influence those soils' properties as plant growth and hydrologic media. Here, we report on an investigation of soil properties on a mine site with differing types of vegetation that have been established for 21 years.

The objective of this research was to determine the effects of differing types of vegetation on mine soil profile development. Types of vegetation studied include switchgrass, tall fescue, reed canarygrass, sericea lespedeza and hardwood trees.

## Research Methods

In the summer of 1990, an experiment using 16 different plant species and species mixtures was established on partially reclaimed mine soils at Powell River Project Research and Education Center in Wise County, Virginia. The experimental design was a complete block. Each of the 16 treatments were replicated 4 times. Prior to the establishment of these plant species, a coposted 2:1 mixture of wood chips and sewage sludge was mixed into the soil. No other fertilizer was applied after the initial fertilization. The plots are 13 ft by 13 ft, separated by alleys planted with tall fescue. The treatments were initially planted in July 1990, but a second planting was necessary in April 1991 due to poor establishment. The plots have been mowed annually to stimulate re-growth. Among the plant species whose persistence and biomass production were the greatest after 20 years establishment were switchgrass, sericea lespedeza, reed canarygrass, and tall fescue. Hardwood trees were planted on an adjacent mine area that was reclaimed in association with the vegetation plots, using similar materials and techniques and at about the same time. The hardwood trees were planted in the early- to mid-1990s.

In 2011, we assessed the long term effect of switchgrass, tall fescue, reed canarygrass, sericea lespedeza, and hardwood trees on soil development. For each of the four herbaceous species, four of the 13m x 13m experimental plots originally established in 1990 were identified for study and flagged. Six areas within the adjacent area that had been planted with hardwood trees (Tree 1=ash, Tree 2=black walnut, Tree 3=sycamore, Tree 4=northern red oak, Tree

5=autumn olive, Tree 6=black locust) were also identified and flagged. Thus, a total of 22 experimental areas, replicating five vegetation treatments, were studied.

Within each experimental area in (*state month when biomass was collected*) July of 2011, four randomly located 0.25 $m^2$ quadrats were used for sampling of vegetation and plant litter. Within each quadrat, above ground herbaceous vegetation was removed, oven dried at 60 degrees C, and weighed. Also within each quadrat, loose plant litter and organic matter were removed down to mineral soil, oven dried at 60 degrees C, and weighed.

A backhoe was used to excavate a pit within each of the experimental plots. The soil at each soil location was described using procedures and terms that are commonly used on the soil science field. Soil horizons were delineated by the soil scientists using visual observations; and depth extent of each horizon was recorded. Soil materials for each horizon were characterized for texture, Munsell color, structure, and stoniness using standard field methods. Depth of primary plant rooting was also recorded. The term "the primary rooting", as we are using it here, refers to the primary rooting mass that was visible in the soil pit; individual and isolated roots may have occurred below this depth.

Data were analyzed by compositing subsamples collected for each experimental plot to calculated a plot mean. Means for each treatment were calculated from the experimental plot means. Data were analyzed using JMP v. 9.0 software (SAS Institute, Cary NC). Data were analyzed for significant differences among treatments using analysis of variance (ANOVA) and Tukey's HSD procedures. Results are reported at the $\alpha = 0.05$ (or $\alpha = 0.10$?) level of significance.

## Results

### Biomass and Plant Litter

Switchgrass produced more above-ground biomass than any other treatment. The smallest amount of above-ground biomass was present in the tree plots, but the amount did not differ statistically from other species except for switchgrass at $\alpha = 0.05$. No differences among the litter levels produced by the experimental treatments were recorded.

Table 1. Above ground biomass and plant litter (means ± standard error), by experimental treatment.

| Veg Type | Biomass ($g/m^2$) | $\alpha = 0.05$ | $\alpha = 0.10$ | Litter ($g/m^2$) | $\alpha = 0.05$ | $\alpha = 0.10$ |
|---|---|---|---|---|---|---|
| Reed Canary Grass | 525 ± 66 | b | bc | 204 ± 21 | a | a |
| Switchgrass | 1478 ± 223 | a | a | 310 ± 73 | a | a |
| Sericea Lespedeza | 641 ± 116 | b | bc | 222 ± 40 | a | a |
| Tall Fescue | 754 ± 189 | b | b | 243 ± 28 | a | a |
| Trees | 258 ± 28 | b | c | 290 ± 51 | a | a |

Note: Mean values followed by different letters are significantly different from one another at the designated level of statistical significance.

Depths of A horizons recorded did not differ by experimental treatment. Primary rooting depth by sericea lespedeza was significantly less than those recorded for other experimental treatments, but no other significant differences among experimental treatments were noted.

Table 2. Depth of A horizons and primary plant rooting (means ± standard error), by experimental treatment.

| Veg Type | A Horizon Depth (cm) | $\alpha = 0.05$ | $\alpha = 0.10$ | Rooting Depth (cm) | $\alpha = 0.05$ | $\alpha = 0.10$ |
|---|---|---|---|---|---|---|
| Reed Canary Grass | 12.4 ± 1.1 | a | a | 32.4 ± 2.4 | a | a |
| Switchgrass | 14.6 ± 1.2 | a | a | 38.4 ± 2.2 | a | a |
| Sericea Lespedeza | 14.6 ± 0.6 | a | a | 13.3 ± 1.2 | b | b |
| Tall Fescue | 10.8 ± 2.2 | a | a | 33.3 ± 6.1 | a | a |
| Trees | 13.1 ± 1.7 | a | a | 38.5 ± 4.9 | a | a |

Note: Mean values followed by different letters are significantly different from one another at the designated level of statistical significance.

Figure 1. Soil profile under tall fescue.

Figure 2. Soil profile under reed canary grass.

Soil Profiles

Tall Fescue: The tall fescue plots had a typical Entisol horizonation of A,C1, and C2. Soil texture was once again a mix from sandy to clayey. There is very little soil structure of development evident and on average is comprised of 10-40% rock fragments varying in size and type. This is typical of mine soils.

Reed Canary Grass: The Reed canarygrass treatments had typical Entisol horizons; A, AC, C1, C2. While it is a relatively young soil, it has the most development out of all the treatments. This is the only treatment that was noticeably different in horizons from the others due to the deep rooted system. The AC horizon seemed to be noticeably more developed than horizons at the same depth in other profiles and contained the largest amount of rocks. The textures ranged from sandy to clayey, and despite the slight improvement in development these soils are still considered undeveloped Entisols.

Figure 3. Soil profile under sericea lespedeza.

Figure 4. Soil profile under switchgrass.

Sericea Lespedeza: The Sericea lespedeza treatments had a horizonation of either A, C or A, C1, C2. There was hardly any difference between C horizons and very little soil development; typical of an Entisol. The soil textures ranged from sandy in the top horizons to clayey textures increasing with depth. On average there is 30-55% rocks also varying in size and type. Soil development is not evident in this mine soil.

Switchgrass: The switchgrass plots were horizonated as A, C1, and C2; Entisols. They had a mix of loamy to sandy textures. There was very little soil structure or development. The dense switchgrass root mats reached a depth average of 16 inches.

Hardwoods: The mix of hardwoods all had a typical Entisol profile of A, C1, C2. They had shallow, dark A horizons and the C horizons were a mix of all textures. There is very little soil development. Any soil structure seems to be held together by the tree roots.

Figure 5. Soil profile under Tree Number 3, which was a Sycamore.

## Discussion

Switchgrass is well known as a prolific biomass producer, so it is not surprising that the switchgrass plots contained the highest amount of biomass. Prior studies of these herbaceous vegetation experimental area also found that switchgrass was a significant biomass producer (Evanylo et al. 2005). The low levels of herbaceous biomass present in the tree plots are a likely result of shading by the trees; less sunlight was available to the herbaceous vegetation, likely limiting photosynthesis growth by the herbaceous species.

Sericea lespedeza is often prolific on coal surface mines that have been revegetated with herbaceous cover and are not under active management. It is possible that its shallow rooting is a species characteristic that makes it so competitive in this environment, where subsoil materials lack organic matter, often lack soil structure, and often become dense to equipment compaction and gravity-induced physical consolidation. It is possible that the similarity among A-horizon depths of all species, and/or the rooting depths of all species except sericea lespedeza, was a function of the physical treatments applied to the soil materials during reclamation. These materials were heavily compacted by mining equipment prior to biosolids application. Then, the materials were chisel-plowed and disked in.

## Conclusions

Switchgrass produced more above-ground biomass than any other species, and sericea lespedeza had the shallowest rooting depth. Vegetation with more intricate root systems gave rise to increased soil development.

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