Soil Health of Mountaintop Removal Mines in Southern West Virginia

Revised Project Report

By

John Sencindiver, Kyle Stephens, Jeff Skousen, and Alan Sexstone

Division of Plant and Soil Sciences
West Virginia University

January 24, 2001

Abstract

Minesoils are young soils developing in drastically disturbed earth materials. The health and quality of these soils will deviate from native soils. Although minesoil quality in some places may be worse than the native soil quality, research has shown that overburden materials may be manipulated to improve minesoil quality, especially soil physical and chemical properties. However, very little information about microbiological activity in minesoils is available. Therefore, this study was designed to evaluate physical, chemical and microbiological properties of minesoils developing on reclaimed mountaintop removal coal mines in southern West Virginia. Minesoils of different ages and the contiguous native soils were described and sampled on three mines. Routine physical and chemical properties were determined as well as microbial biomass C and N, potentially mineralizable N, and microbial respiration. All minesoils were weakly developed compared to the native soils, but most had a transition horizon (AC) or a weak B horizon (Bw) developing between the A horizon at the surface and the C horizons. The minesoils would be classified as Entisols, while most of the native soils were Inceptisols. Both native and minesoil biomass C and N, potentially mineralizable N, and microbial respiration were generally within ranges of other reported data. In general, there were more similarities between the properties of the oldest minesoils and the native soils than between the younger minesoils and the native soils. There is a trend of C accumulation as the minesoils become older, and it appears that the stable organic pool is increasing with age. This study indicates that the minesoils are approaching stable, developed soils and should become more like the native soils as they continue to develop.

Introduction

Soil quality or health can be broadly defined as the capacity of a living soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health (Doran et al., 1999). Minesoil health is important, not only for initial revegetation, but also for continued long-term productivity and environmental quality. Since minesoils are drastically disturbed soils, their initial properties will be different than the surrounding native soils. However, minesoils are subject to the same soil forming factors and processes that have developed the contiguous native soils. These processes will eventually develop minesoils with properties similar to the native soils. Therefore, studies of minesoil health should include some documentation of minesoil property changes or differences with time. The objective of this study was to document differences in selected minesoil properties, especially those related to microbial activity, on mountaintop removal coal mines of different ages, and to compare the minesoils to the major contiguous native soils.

Methods and Materials

Site Descriptions And Field Sampling

Minesoils and native soils were sampled at the Dal-Tex mine in the Spruce Fork watershed in Logan County, the Hobet-21 mine in the Mud River watershed of Boone County, and the Cannelton mine in the Twentymile Creek watershed in Fayette County. Two different ages of minesoils, with three sampling points each, were selected for sampling at the Hobet-21 (8 and 17 years old) and Cannelton sites (16 and 30 years old). All sampling points at these two mines were 250 m apart, and they were placed 50 m away from the nearest wildlife sampling point. Specific location of each sampling point is presented in Appendix Table 1.

At Hobet-21, the 8-year-old site had slopes ranging from 3 to 5% with a south-southwest aspect. The Hobet-21 17-year-old site had slopes ranging from 3 to 28% with a northwest aspect. Slope inclination at each sampling point is presented in Appendix Table 2. All Hobet-21 sampling points were located at mid slope. At Cannelton, all minesoil sampling points also were located at mid slope and had a south-southwest aspect. Slopes ranged from 5 to 10% on the 16-year-old site, and all slopes were 2% on the 30-year-old site. All minesoils on both of these sites had similar geology and topography, and they had been mined and reclaimed by similar methods.

Three sampling points also were located on the contiguous steeply sloping native soils at both mine sites. These sampling points were located at mid slope and had south-southwest aspects at both sites. Hobet-21 soils had 45 to 72% slopes, and Cannelton soils had 45 to 70% slopes.

Sampling sites at the Dal-Tex mine had been selected for another study (Thomas et al., 2000), but also were used for this study. Four different ages (23, 11, 7, and 2 years old) of minesoils were sampled. Three gently sloping and three steeply sloping sampling points were located on each of the different aged sites. Two steeply sloping native soils were sampled. All minesoil and native soil sampling points had south-southwest aspects. Slope inclination at each sampling point is presented in Appendix Table 2. The distance between sampling points on this mine differed for each age. Each of the sampling points at the 2-year-old site was within a distance of 20 m from the next point. Sampling points on the native soils and on each of the other minesoil ages were more than 20 m apart. The longest distance between points was approximately 100 meters on the 23-year-old site.

Native soils mapped at the three locations are presented below. In general, they are very similar. They are moderately deep and acid with loamy textures.

a. Cannelton – Muskingum; fine-loamy, mixed, active, mesic Typic Dystrochrepts (Gorman and Espy, 1975)

b. Hobet-21 – Berks; loamy-skeletal, mixed, active, mesic Typic Dystrochrepts
Gilpin; fine-loamy, mixed, semiactive, mesic Typic Hapludults (Wolf, 1994)

c. Dal-Tex - Berks; loamy-skeletal, mixed, active, mesic Typic Dystrochrepts
Matewan; loamy-skeletal, mixed, active, mesic Typic Dystrochrepts (Rob Pate, Natural Resources Conservation Service, personal communication)

All native soils at each of the sites were forested. Both minesoil sampling sites at Cannelton were predominantly vegetated with grasses and legumes. The 16-year-old site had scattered black locust (*Robinia pseudoacacia* L.) trees, but the 30-year-old site had more trees of a variety of species including black locust, maples (*Acer* sp.), pines (P*inus* sp.), sweet gum (*Liquidambar styraciflua* L.) and sourwood (*Oxydendrum arboreum* L.). The 8-year-old site at Hobet-21 was covered with grasses and legumes. The major cover on the Hobet-21 17-year-old site was black locust with ground cover of grasses and legumes. At Dal-Tex, the 23-year-old site was predominantly forested with some grasses and legumes on the gently sloping sites. The 7-year-old site had predominantly grasses and legumes with some shrubs. The 11-year-old and the 2- year-old sites were covered with grasses and legumes with scattered trees at the 11-year-old site.

At each sampling point, a soil pit was dug to a depth of 40 cm or more to expose enough of the soil to determine the thickness of the surface mineral horizon and to observe one or more subsurface horizons. The soil was described to the exposed depth, and bulk samples were collected from the surface horizon for laboratory analyses. The average thickness of surface horizons for all soils is presented in Table 1. These samples were collected in early to mid June 2000. All samples were refrigerated at 4^{o} C until they were analyzed. Bulk density of the surface horizon was determined in the field by a frame excavation technique developed by soil scientists at the National Soil Survey Laboratory in Lincoln, NE (Grossman, R.B., unpublished procedure).

Laboratory Analyses

Texture, pH and electrical conductivity were determined by standard methods of the National Soil Survey Laboratory (Soil Survey Staff, 1996). A LECO CNS-2000 analyzer was used to determine total carbon, sulfur, and nitrogen. Microbial biomass C and N were determined by a chloroform-fumigation-extraction procedure (Rice et al., 1996). Twenty grams of sample at field moisture content were used for this extraction procedure. Nitrogen in extracts was determined by a Kjeldahl method, and C was determined by a Tekmar-Dohrman DC-190 automated carbon analyzer. Potentially mineralizable N was determined by an anaerobic incubation procedure (Drinkwater et al., 1996). Microbial respiration was determined by static soil incubation in closed bottles (Zibilske et al., 1994). Triplicate soil samples (25 g field moist) were placed in funnels lined with Whatman #1 filter paper. Soils were then completely saturated with 100 ml of distilled water and allowed to drain for 24 hr to normalize soil moisture. Wetted soil (20 g) was weighed into serum bottles (160 ml) and incubated uncovered in the dark for 24 hr. Each bottle was capped with a butyl rubber stopper, and initial headspace CO_2 levels were established by injecting 1 ml via a syringe into an infrared gas analyzer (IRGA) equipped with a gas recirculation loop. This process was repeated for each bottle at 24, 48, 72, and 96 hr. Microbial respiration rates were determined using linear regression analysis of CO_2 concentrations at each sampling time.

Results and Discussion

The GPS latitude and longitude for each of the minesoil and native soil sampling points are presented in Appendix Table 1. Detailed profile descriptions are presented in Appendix Table 2. All of the minesoils had developed A horizons and most of the profiles had some weak development in the subsoil, so AC or Bw horizons were described. Minesoils at the Dal-Tex 1976-01 and the Hobet-21 1992-01 sites have cambic horizons and would be classified as Inceptisols (Soil Survey Staff, 1998), while all other minesoils are Entisols. All native soils, except Hobet-21 native-01, are classified as Inceptisols. Hobet-21 native 01 has an argillic horizon and is classified as an Ultisol.

In general, A horizons of the strongly sloping minesoils at Dal-Tex were thicker than the A horizons of the gently sloping minesoils (Table 1). Thickness of A horizons directly relates to the depth of incorporation and accumulation of organic matter primarily from root growth, but also from aboveground biomass. Since bulk densities of the gently sloping minesoils were generally greater than the bulk densities of the strongly sloping minesoils (Thomas et al., 2000), roots should have penetrated more deeply on the strongly sloping minesoils developing thicker A horizons. A review of Appendix Table 2 shows that A horizons had more roots than subsurface horizons.

Rock fragment content of minesoil subsoil horizons averaged greater than 35% by volume and was greater than the rock fragment content of A horizons (Appendix Table 2). Therefore, all minesoils were classified as skeletal (Soil Survey Staff, 1998). Some of the native soils had more than 35% and others had less than 35% rock fragments in the subsoil horizons (Appendix Table 2). The average A-horizon rock fragment content for all soils was less than 35% by volume (Table 1, Appendix Table 2).

Minesoil physical and chemical properties are presented in Table 2. Most of the minesoils and native soils had loamy textures, i.e. sandy loam, loam, silt loam, or silty clay loam. Electrical conductivity values were very low for all soils. Minesoil pH ranged from 4.1 on the 23-year-old Dal-Tex site to 7.0 on the 8-year-old Hobet-21 site. Native soil pH values generally ranged from 4.5 to 5.6, but one site at Dal-Tex had a pH of 3.7. Low total S values for all minesoils and native soils in this study were similar to values reported by Smith et al. (1976) for soils and overburdens in nearby Mingo County.

Our minesoil and native soil C and N values are similar to other minesoils with comparable vegetation (Li, 1991; Prince and Raney, 1961; unpublished soil survey data, National Soil Survey Laboratory, Lincoln, NE). However, except for Dal-Tex native-02, the native soil C and N values are on the low end of the range of the other native soils used for comparison. The Dal-Tex native-02 C value of 12.45% is higher than most soils in the region. Total N and C values tended to be lower for minesoils than for native soils on the Dal-Tex site. However, the older minesoils on the Cannelton and Hobet-21 sites, had higher C and N values than the native soils.

Both native soil and minesoil biomass C and N, potentially mineralizable N and microbial respiration (MR) (Table 3) are generally within ranges given for other soils (Myrold, 1987; Insam and Domsch, 1988; Rice et al., 1996). The minesoil biomass C values are generally higher than values reported for soils from long-term cropping experiments, but minesoil biomass N and potentially mineralizable N are similar to values from these experiments (Bonde et al., 1988). The native soils at Dal-Tex and at Cannelton are similar to each other in all three parameters, but the Hobet native soil is lower for all three. The reasons for this difference are not understood at this time since soils and vegetation are similar for the three sites.

Rice et al. (1996) suggest that the ratio of microbial biomass to total soil organic carbon and nitrogen may provide a measure of soil organic matter dynamics and soil quality. These authors quote other studies for agricultural soils (Anderson and Domsch, 1989; Jenkinson, 1988; Sparling, 1992) indicating that microbial biomass C (MBC) normally comprises 1 to 4% of total organic C and microbial biomass N (MBN) comprises 2 to 6% of the total organic N. The biomass C to total C (TC) ratios for all of our minesoils and native soils are within this quoted range (Table 4). The biomass N to total N (TN) ratios of the native soils at Dal-Tex are within this range, but the ratios present in the native soils at the other two mines are generally higher than the reported range. The fact that these soils are forest soils may explain why the MBN:TN range is different than that reported for agricultural soils. Extremely high MBN:TN values for Dal-Tex 7-year-old and 11-year-old sites indicate that these soils have not developed a stable organic matter base.

As the organic carbon pool becomes more stable with time, ratios of MBC:TC, MBN:TN and potentially mineralizable nitrogen (PMN):TC should decrease. This relationship is apparent at the Dal-Tex site. No total N was detectable in the Dal-Tex 2-year-old site, so the ratios could not be calculated. This site is apparently so young that the C and N pools are very unstable. However, the MBN:TN and PMN:TN ratios generally decrease in the following order: 7 years > 11 years > 23 years > native soil. For the MBC:TC ratios, there is a decrease in the following order: 11 years > 7 years = 23 years > native soil. We do not understand at this time why the MBC:TC ratio for the 7-year-old minesoil is not higher than the 11 or 23-year-old minesoil. These same relationships of decreasing ratios with age are not readily apparent at the Cannelton and Hobet-21 sites. The total C values may not be an accurate estimate of organic C in some minesoils because of the presence of coal or high C rock fragments in the samples. Therefore, the N values and ratios are probably more reliable comparisons.

Soil respiration previously has been used to assess decomposition dynamics in West Virginia minesoils (Stroo and Jencks, 1985). Kennedy and Papendick (1995) suggested that a respiratory quotient such as the MR/MBC ratio relates both the size and activity of microbial biomass. A lowering of the ratio indicates a trend to a more stable and mature system (Insam and Domsch, 1988). The respiratory quotient for the Dal-Tex soils decreased in the following order: 7 years > 11 years > 23 years > native soil (Table 4). Again excluding the 2-year-old soil, this trend indicated a maturation of soils at the Dal-Tex site. A decreasing respiratory quotient with site age was not observed at the Cannelton and Hobet sites.

Based upon these data, we conclude that there is a trend toward the accumulation of C as these minesoils age. Also, it appears that the stable organic pool is increasing. The older minesoils, especially the 23-year-old minesoils at Dal-Tex and the 30-year-old minesoils at Cannelton, have properties similar to the native soils. These data and other data (Thomas et al., 2000) indicate that the minesoils sampled in this study are approaching stable, developed soils.

References

Anderson, J.P.E., and K.H. Domsch. 1989. Ratios of microbial biomass carbon to total carbon in arable soils. Soil Biol. Biochem. 21: 471-479.

Bonde, T.A., J. Schnurer, and T. Rosswall. 1988. Microbial biomass as a fraction of potentially mineralizable nitrogen in soils from long-term field experiments. Soil Biol. Biochem. 20:447-452.

Doran, J.W., A.J. Jones, M.A. Arshad, and J.E. Gilley. 1999. Determinants of soil quality and health. Chapter 2. p. 17-36. *In* R. Lal (ed.), Soil Quality and Soil Erosion. CRC Press. Boca Raton, Florida.

Drinkwater, L.E., C.A. Cambardella, J.D. Reeder, and C.W. Rice. 1996. Potentially mineralizable nitrogen as an indicator of biologically active soil nitrogen. Chapter 13, p. 217-229. *In* J.W Doran and A.J. Jones (eds.). Methods for Assessing Soil Quality. SSSA Spec. Publ. No. 49. Soil Science Society of America, Inc. Madison, WI.

Gorman, J.L., and L.E. Espy. 1975. Soil Survey of Fayette and Raleigh Counties, West Virginia. USDA Soil Conservation Service. Washington, DC.

Insam, H. and K.H. Domsch. 1988. Relationship between soil organic carbon and microbial biomass on chronosequences of reclaimed sites. Microbiol. Ecol. 15:177-188.

Jenkinson, D.S. 1988. Determination of microbial biomass carbon and nitrogen in soil. p. 368-386. *In* J.R. Wilson (ed.) Advances in nitrogen cycling in agricultural ecosystems. CAB Int., Wallingford, England.

Kennedy, A.C. and R.I. Papendick. 1995. Microbial characteristics of soil quality. J. Soil and Water Conservation 50:243-248.

Li, R. 1991. Nitrogen cycling in young mine soils in southern Virginia. Ph.D. Dissertation. Virginia Polytechnic Institute and State University. Blacksburg, VA. 150 p.

Myrold, D.D. 1987. Relationship between microbial nitrogen and a nitrogen availability index. Soil Sci. Soc. Am. J. 51:1047-1049.

Prince, A.B. and W.A. Raney (eds.). 1961. Some morphological, physical, and chemical properties of selected Northeastern United States Soils. Northeast Regional Research Publication. Regional Research Project NE-22. Agric. Exper. Station Misc. Publ. 1. University of New Hampshire. Durham, NH.

Rice, C.W., T.B. Moorman, and M.Beare. 1996. Role of microbial biomass carbon and nitrogen in soil quality. Chapter 12, p. 203-215. *In* J.W Doran and A.J. Jones (eds.). Methods for Assessing Soil Quality. SSSA Spec. Publ. No. 49. Soil Science Society of America, Inc. Madison, WI.

Smith, R.M., A.A. Sobek, T. Arkle, Jr., J.C. Sencindiver, and J.R. Freeman. 1976. Extensive overburden potentials for soil and water quality. EPA-600/2-76-184. National Technical Information Service. Springfield, VA.

Soil Survey Staff. 1996. Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42. Version 3.0. USDA Natural Resources Conservation Service. Lincoln, NE.

Soil Survey Staff. 1998. Keys to Soil Taxonomy. Eighth Edition. USDA Natural Resources Conservation Service. U.S. Government Printing Office. Washington, DC.

Sparling, C.P. 1992. Ratio of microbial biomass to soil organic carbon as a sensitive indicator of changes in soil organic matter. Aust. J. Soil Res. 30:195-207.

Stroo and Jencks. 1985. Effect of sewage sludge on microbial activity in an old abandoned minesoil. J. Environ. Qual. 14:301-304.

Thomas, K.A., J.C. Sencindiver, J.G. Skousen, and J.M. Gorman. 2000. Soil development on a mountaintop removal mine in southern West Virginia. p. 546-556. *In* W.L. Daniels and S.G. Richardson (eds.). Proc. Seventeenth Annual Meeting, American Society for Surface Mining and Reclamation. 11-15 June 2000. Tampa, FL. Amer. Soc. Surf. Mining Rec., 3134 Montavesta Rd., Lexington, KY.

Wolf, B.L. 1994. Soil Survey of Boone County, West Virginia. USDA Soil Conservation Service. Washington, DC.

Zibilske, L.M. 1994. Carbon mineralization. Chapter 38. P. 835-863. *In* Methods of Soil Analysis, Part 2. Microbiological and Biochemical Properties. SSSA Book Series No. 5. Soil Science Society of America. Madison, WI.