PLANT COMMUNITY CHARACTERISTICS AS AN INDICATOR OF MINESOIL CONDITIONS ON AML SITES IN WEST VIRGINIA[1]

By Curt D. Johnson[2] and Jeff G. Skousen[3]

Abstract. A study was conducted to determine plant community characteristics that could be used to predict minesoil conditions on 15 AML sites mined for Pittsburgh, Freeport, and Kittanning coal in northern West Virginia. On each site, three 1-m deep pits were dug and minesoil samples were extracted from the top horizons. The following characteristics were determined: particle size distribution; bulk density; porosity; water retention difference; Ph; exchangeable bases; S fractionation; electrical conductivity; effective CEC; and base saturation. The plant community was analyzed at each site in three 10 m x 10 m plots for tree canopy cover and importance values, and in four 1 m x 1 m plots for herbaceous cover in each of the 10 m x 10 m plots.

A principal component analysis (PCA) was utilized to synthesize the minesoil data of five Kittanning sites to detect relationships among plant species and edaphic variables. The PCA established a graph of minesoil gradients which were related to vegetation by plotting the canopy cover of red maple (*Acer rubrum* L.), black birch (*Betula lenta* L.), and total canopy on the ordinations. Canopy cover of red maple, black birch, and total cover increased with increasing acidity. In general, revegetation of acidic AML sites could be facilitated by enhancing germination of red maple and black birch seeds since these two species were predominant and seemed to grow best on acidic Kittanning minesoils.

A cluster analysis was performed on soil variables and on vegetation variables (importance values) to detect complex patterns of similarity between all 15 sites based on minesoil and vegetation conditions. Three minesoil types ("A", "B", and "C") were determined in the soil cluster analysis. Three vegetation communities ("X", "Y", and "Z") were determined in the vegetation cluster analysis. The "X" plant communities occurred 85% of the time on minesoil type "A"; "Y" plant communities occurred 65% of the time on minesoil type "B"; and "Z" plant communities occurred 46% of the time on minesoil type "C". In this study, three components of a plant community (herbaceous, red maple, and black birch) were necessary to predict probable minesoil conditions. These indicator communities could be used by mining operators and reclamation planners to help screen sites for remining and/or reclamation, and to select soil analyses which may help ascertain specific mining and reclamation techniques that should be used on the site.

ADDITIONAL KEY WORDS: minesoil gradients, geobotany, remining, reclamation, natural reclamation.

[1]Paper presented at the 1992 National Meeting of the American Society of Surface Mining and Reclamation, Duluth, Minnesota, June 14-18, 1992. This research has been supported by the Bureau of Mines, U.S. Department of Interior, under the National Mine Land Reclamation Center. Publication in this proceedings does not preclude authors from publishing their manuscripts, whole or in part, in other publication outlets.

[2]Reclamation Scientist, Florida Institute of Phosphate Research (FIPR), Bartow, FL 33830-4338.

[3]Assistant Professor, Division of Plant and Soil Sciences, West Virginia University, Morgantown, WV 26506-6108.

Proceedings America Society of Mining and Reclamation, 1992 pp 289-303
DOI: 10.21000/JASMR92010289

https://doi.org/10.21000/JASMR92010289

Introduction

Approximately 34,000 ha of mined land in West Virginia have been designated as Abandoned Mine Land (AML) (Soil Conservation Service, 1979). AMLs are past mining disturbances which were left in an inadequate reclamation status before the passage of the Surface Mining Control and Reclamation Act (SMCRA) on August 3, 1977; and where no company, individual, or agency has any reclamation responsibility under state or federal laws. Title IV in SMCRA created the Abandoned Mine Land Reclamation Fund (AMLRF) to restore AMLs and to improve their water quality. The fund is generated by taxing each ton of coal mined and is projected to generate $3 billion during its 15-year tenure. The U.S. Congress (1977) realized that this fund would be inadequate to reclaim all AMLs and consequently established the following priority system for ranking AML sites for AML reclamation:

1. Protection of public health and property from extremely dangerous AMLs;
2. Protection of public health from adverse AMLs;
3. Restoration of the environment on AMLs;

In 1990, Congress reauthorized the coal production tax to generate AML funds from 1992 to 1996.

In West Virginia, the focus of AML reclamation has been directed toward priorities 1 and 2. This emphasis is unlikely to change, for the reclamation cost of identified priority 1 and 2 sites has been estimated to be $2.3 billion requiring an estimated 100 years of work (West Virginia Mining and Reclamation Association, 1989). Consequently, the Office of Surface Mining (OSM) foresees that only about 10% of the nation's AML problems will be corrected within the tenure of the original program. Since 1979, the AML program in West Virginia has reclaimed approximately 4% of the total AML area (Neil Robinson, West Virginia Division of Energy, personal communication).

Since such a small percentage of AMLs will be reclaimed with AML money, alternative solutions must be found to help reclaim remaining AML sites. One possible solution is remining. Most coal states have some degree of industry-based remining reclamation where coal companies reclaimed on-site or adjacent AML problems while mining with current permits (Blauch, 1986). OSM and other state reclamation agencies would like to promote remining and reclamation of AMLs to maximize environmental improvement and resource recovery. However, remining and reclamation of AML has been difficult to encourage and administer in areas where operators may become responsible for existing acid mine drainage and acid-producing refuse piles. Another solution is natural reclamation and no redisturbance. Many AML sites with few edaphic factors that limit plant invasion and growth will gradually reclaim. Those sites with severe edaphic factors that restrict plant establishment or growth may take long time periods before natural processes make the site habitable for desired organisms.

Properties of rock and soil materials on AMLs should be considered when assessing a site's potential for acid mine drainage, acid soils, or ability to reclaim naturally. During remining or AML reclamation preparation and planning, operators and regulators could benefit from knowing if a site presents a large financial liability because earth moving may expose acid-producing materials. This study measured several vegetation and soil characteristics on fifteen AML sites to evaluate vegetation characteristics that could be used to predict minesoil conditions and to find tree species adapted to AML acid minesoils that could be used to inexpensively reclaim AML sites.

Materials and Methods

Fifteen AML sites in northern West Virginia were sampled. The AML inventory list of the West Virginia Division of Energy was used as the pool of available sites for selection. This pool was then reduced to sites with south- to west-facing highwall aspects to control micro-climatic variation. After determining the coal seam mined on each site, five sites from the Pittsburgh (PEP, LP, HU, FR, PEC), five sites from the Freeport (VP, BR, JP, JS, LG), and five sites from the Kittanning (SH, CAR, CO, RB, BAK) coal seams were randomly selected to reduce the variation among parent materials of all AML sites. Time since abandonment was not purposely selected; however, through random sampling the selected sites were of different ages.

Vegetation was sampled at each AML site in four randomly located 10 x 10 m plots. The stem diameter of trees was measured to obtain the basal area of each species. The canopy cover was estimated by the line-intercept method in %, such that a value of 0 % indicated no canopy, 100 % indicated a complete canopy, and >100 % indicated an overlapping canopy. The largest trees were cored to determine a minimum estimate of the time since the site had been disturbed.

An Importance Value (IV) for each tree species on each site was calculated by the method of Curtis and McIntosh (1951), which accounted for relative density, relative dominance, and relative frequency of each species on each site.

Herbaceous cover was determined in four randomly located 1 x 1 m plots within each 10 x 10 m plot. Herbaceous cover was estimated using a modified Daubenmire cover class technique (Skousen et al., 1989).

Three soil pits were dug to a depth of 1 m next to the first three 10 x 10 m plots. Soil samples were collected from the top horizons. The following characteristics were determined: particle size distribution; bulk density of fine earth; porosity; water retention difference (WRD); Ph; exchangeable bases (Ca, Mg, Na, K, and Total); S fractionation of total S into pyritic S, sulfate S, and organic S; electrical conductivity; and exchangeable acidity. Effective CEC and base saturation (BS) were calculated. The sulfur forms were relativized by dividing each form by total S on a per pit per horizon basis. Analytical methods may be found in Johnson (1992).

Statistics

A principal component analysis (PCA) was utilized to synthesize the minesoil data on five Kittanning sites to detect relationships among plant species and edaphic variables (Russel and La Roi. 1985). The PCA established a graph of minesoil gradients which were related to vegetation by plotting the canopy cover of red maple (*Acer rubrum* L.), black birch (*Betula lenta* L.), and total canopy on the ordinations.

A cluster analysis using Ward's minimum variance method (Ward, 1963) was performed on soil variables and on vegetation variables to detect complex patterns of similarity between all 15 sites based on vegetation and soils.

Detailed descriptions of both the PCA and clustering methods can be found in Johnson (1992), which also further examined minesoil development and plant succession on AMLs.

Results and Discussion

Principal Component Analysis

The Kittanning PCA plot (Figure 1a) revealed a minesoil gradient of increasing acidity and a gradient of increasing <2 mm. In addition there were two "<2 mm" gradient systems operating. The larger system occurred on highly acidic sites having a gradient of increasing <2 mm along with WRD and pyritic S. The smaller system occurred on less acidic sites having only a gradient of increasing <2 mm.

The "increasing <2 mm and pyritic S" gradient on highly acidic Kittanning sites suggests that pyrite oxidation was more rapid in rocky minesoils than <2 mm dominated minesoils due to rapid water infiltration and high oxidizing environment of rocky soils. Consequently, <2 mm dominated minesoils may have a greater probability of having high amounts of pyritic S remaining than more rockier minesoils.

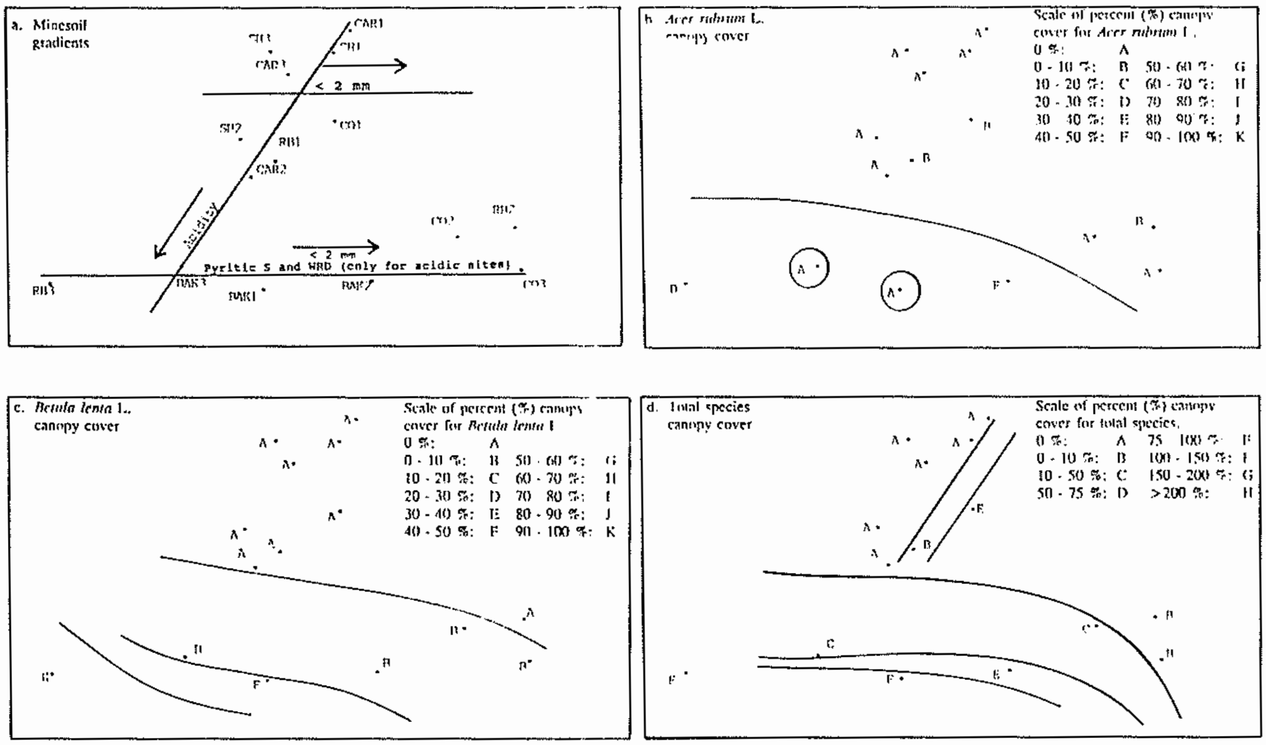

Figure 1. Principal component analysis (PC1 vs PC2) of Kittanning tree canopy cover with superimposed minesoil gradients (a), *Acer rubrum* L. canopy cover (b), *Betula lenta* L. canopy cover (c), and total canopy cover (d). The edaphic variables plotted in Figure 1a are one point for each pit including exchangeable acidity (acidity), percent pyritic S (pyritic S), water retention difference (WRD), and percent soil (< 2 mm).

Table 1. Correlation matrix of soil variables and canopy cover of red maple and black birch on Kittanning sites.

Variables	Red maple	Black birch
Greater than 3/4 inch	-	.50
1/4-3/4 inch	-	-
2mm-1/4 inch	-	-.70@
Greater than 2 mm	-	-
Less than 2 mm	-	-
Sand	-	.83**
Silt	-	-.85**
Clay	-	-.52#
Density of fine earth	-	-
Water retention difference	-	-
Porosity	-	-
Ph	-	-.61#
Acidity	-	.63#
Ca	-	-.66@
Mg	-	-.75@
Na	-	-
K	-	-
Total exchangeable bases	-	-.70@
CEC	-.61#	-
Base saturation	-	-.65#
Electrical conductivity	-	-
Total S	-	-
Pyritic S	-	-
Sulfate S	-	-
Organic S	-	.50
Relative Pyritic S	-	-
Relative Sulfate S	-	-
Relative Organic S	-	-
Neutralization potential	-	-.52#
Age	.54	.63#

Spearman's Rank Order probability symbols: no symbol p<=0.1; # p<=0.05; @ p<=.01; * p<=.001; and ** p<=.0001. A lone dash "-" indicates a correlation <.50.

Red maple canopy cover (Figure 1b) increased with increasing acidity. These sites generally had high acidity, low Ph, and low CEC.

Black birch canopy cover followed a minesoil gradient of increasing acidity and decreasing <2 mm, WRD, and pyritic S (Figure 4c). These sites had similar levels of acidity, Ph, and CEC in minesoils as those sites in red maple. This distribution was very well supported by correlations (Table 1) between cover and silt (r=-0.85) implying decreasing <2 mm, base saturation (r=-0.65), acidity (r=0.63), and Ph (r=-0.61).

Total canopy cover (Figure 1d) increased with increasing acidity. On highly acidic sites (>8 +cmol/kg), total canopy cover increased with decreasing <2 mm, pyritic S, and WRD. Yet, on low acidic sites (<5 +cmol/kg), total canopy cover increased with increasing <2 mm. This latter opposing trend was due to two of the sites having no canopy that probably were limed and seeded with aggressive herbaceous species like *Lespedeza* sp., which may not have allowed tree seedlings. Two other sites, on the other hand, were not limed or seeded, and had a forest type community.

<u>PCA Implications.</u> Throughout the Kittanning sites, red maple and black birch increased with increasing acidity. Interestingly on Indiana and Illinois minesoils (Ashby et al., 1988), red maple had no relationship with acidity, but only with Ph. These authors found that red maple growth decreased as Ph increased above 4.5 with a regression of -0.50 between diameter at breast height (dbh) and Ph. However, black birch had a weaker regression with dbh and Ph (r^2=-0.17). Davidson (1977 and 1979) found that black birch had its best growth and survival on minesoils between Ph 3.3 and 4.

This information can be used by reclamation/mining operators to help reclaim high acid and low CEC AML sites. Since red maple and black birch seeds are wind dispersed onto AML sites, can germinate in favorable microsites, and their optimum growth is on very acid and low CEC minesoils; one could facilitate reclamation with red maple and black by providing additional favorable microsites for seed catchment and germination. These microsites were termed "treetop ecocenters" by Keeney (1980) and were essentially brush piles.

Keeney (1980) hypothesized that the brush provided moderate shade, reduced wind velocity, and trapped snow, leaves, and seed. Furthermore, water potential measurements indicated improved soil moisture conditions which enhanced seedling survival. In addition, light intensity was reduced by 90% under the brush compared to no shade.

On high acid and low CEC sites, an individual could easily establish brush piles and let the wind disperse seeds onto the site or broadcast red maple and black birch seeds to further facilitate the reclamation process.

<u>Clustering</u>

<u>Soil Cluster.</u> The cluster dendrogram of the soil data on all 15 sites (Figure 2) produced three clusters which were named minesoil types "A", "B", and "C". Minesoil type "A" was the least harsh minesoil type with low levels of acidity, high BS, strongly acid to neutral, high levels of CEC and total S (Table 2). Minesoil type "B" was the most variable and harshest minesoil type with high levels of acidity, very low to moderate levels of BS, extremely acid to strongly acid, moderate CEC and total S, and low levels of relative pyrite. Minesoil type "C" was moderate in harshness with low to mod levels of acidity, low BS, extremely acid to strongly acid, low levels of CEC, low fine earth, clay, and total S.

Interestingly, Tyner and Smith (1945) also grouped minesoils in West Virginia into three classes (Types A-C). Their type A minesoil was extremely acid to very strongly acid (Ph 3.5 to 5). This minesoil type developed from shale and sandstone with pyritic roof coals of

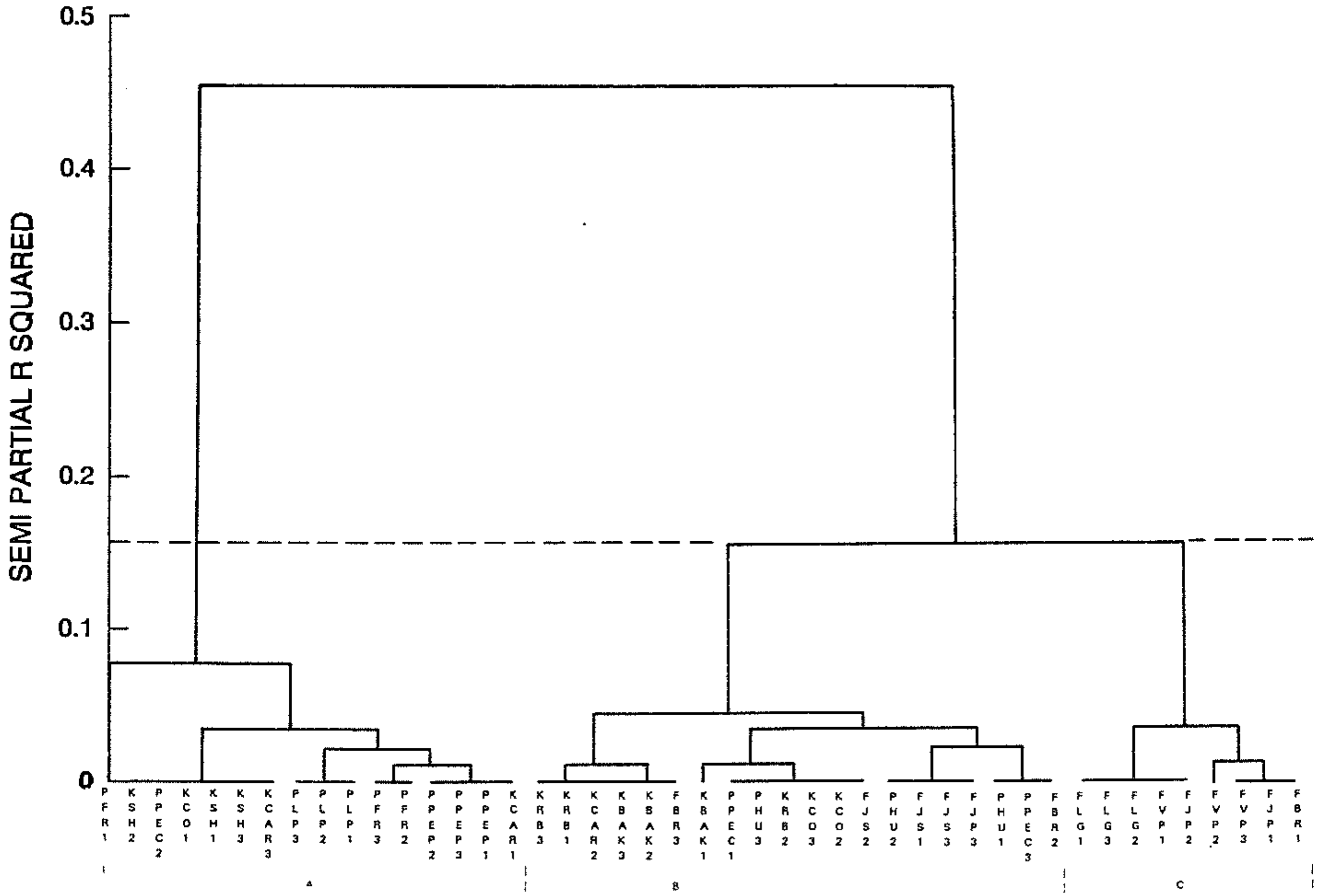

Figure 2. Cluster dendrogram derived from Ward's (1963) method of cluster analysis applied to the first three principal components of the soil physical and chemical variables from all AML pit sites. The pit sites were identified by the first letter indicating minesoil seam (i.e. P for Pittsburgh), the next two or three letters indicating site name (i.e. FR), and the number indicating pit number (i.e. 1). Three main minesoil types (A, B, and C) were recognized (at level of dashed line).

Table 2. Cluster summary of soil variables.

Cluster	Pits per Seam	Sites/Age	Soil Variables [1]Acid	BS	Ph	CEC	<2	Sand	Silt	Clay	TotS	RPyr	RSulf
A	P-10	FR/30, PEC/33, LP/27, PEP/26	0-2	70-100	5-7.4	10-30	25-55	10-25	40-65	10-40	0.10-0.60	0-30	0-45
	K-6	SH/13, CO/25, CAR/13,											
B	K-9	RB/27, CAR/13, BAK/35, CO/25	5-17	0-60	3-5	6-17	20-60	15-50	30-55	15-30	0.10-0.25	0-15	0-50
	F-6	BR/24, JS/32, JP/28											
	P-5	PEC/33, HU/27,											
C	F-9	LG/33, VP/20, JP/28, BR/24	1-10	6-30	4-4.6	5-10	13-40	45-70	20-30	10-20	0.02-0.10	0-30	0-45

[1]Units of soil variables:

Acidity:	+cmol/kg
Base saturation:	%
Ph:	unitless
CEC:	+cmol/kg
<2 mm:	%
Sand:	%
Silt:	%
Clay:	%
Total S:	%
Relative pyritic S:	%
Relative sulfate S:	%

Pittsburgh and Redstone seams. Their type B minesoil was the most variable being very strongly acid to alkaline (Ph 5 to >7.4). This minesoil type developed from calcareous shale and limestone strata with black pyritic shales and pyritic roof coals of the Pittsburgh and Redstone seams. Their type C minesoil was very strongly acid to slightly acid (Ph 5 to 6.5) and developed from shales and sandstones over Bakerstown and Freeport seams. Thus, only two of their minesoil types had similar Ph ranges and developed from the same overburdens as the minesoil types of this study. Their type A minesoil resembled minesoil Type "B" of this study. Their type B minesoil resembled minesoil Type "A" of this study. Their type C minesoil was more alkaline than Type "C" of this study, but both types developed on Freeport overburden.

The minesoil types in this study were not separated and classed according to specific coal seams (except for Type "C") indicating variation in mining techniques within a coal seam, and also variation in the chemical/physical nature of the overburden. Nor were the minesoil types separated into age groupings indicating that other factors besides time influenced soil development. For example, minesoil Types "B" and "C" may have developed along different patterns due to differences in soil properties. Minesoil type "B" had less sand, more silt and clay, and a higher percent total S than minesoil Type "C". Consequently, Type "B"'s high percent clay provided a high CEC (buffering capacity) which could retain acidic cations generated from pyrite oxidation. Minesoil Type "A" had the highest percent total S, but had low acidity due to higher NP levels than the other minesoil types.

Vegetation Cluster. The cluster dendrogram of tree species and total herbaceous importance values on all 15 sites (Figure 3) produced three clusters, which were named plant community types "X", "Y", and "Z". Plant community type "X" (Table 3) always had an herbaceous plant component, and either sycamore, black cherry, elm, or no trees. Plant community type "Y" had a variable herbaceous component, and always red maple with various other tree species (except black birch unless aspen was also present). Plant community type "Z" had no to low herbaceous plants, and always black birch with various tree species (low to moderately low red maple IV and no aspen). These three plant community types ("X", "Y", and "Z") were then subdivided into more discrete plant community types, which are summarized in Table 3.

The three main plant communities did not cluster into a temporal sequence as occurred with Wisconsin minesite plant communities (Kimmerer, 1984). This lack of a temporal sequence dismissed the anticipated overall successional gradient. However, "X" plant communities developed 85% of the time on minesoil type "A". The "Y" plant communities developed 65% of the time on the minesoil type "B". Lastly, the "Z" plant communities developed 46% of the time on minesoil type "C". Thus, each plant community type tended to develop on a distinct minesoil type. Consequently, succession should be analyzed within each main plant community, for each minesoil type was influencing succession differently.

In examining the ages of sites in each plant community type, there was not a temporal sequence or a definite successional sequence of early invading tree species giving way to later successional tree species. Instead the subplant communities (i.e. Y1, Y2, Y3, Y4, Y5) were largely differentiated by early invading species. Although the X3, Y5 & Y6, and Z4 plant communities always had a small component of later successional tree species, these species were also sporadically present in the other plant communities.

Clustering Implications. The implications of the plant and minesoil cluster analyses relate to the field of ecophysiology where certain plants have adaptations or mechanisms which allow them to grow more effectively in specific locations compared to other species. These analyses also relate to the

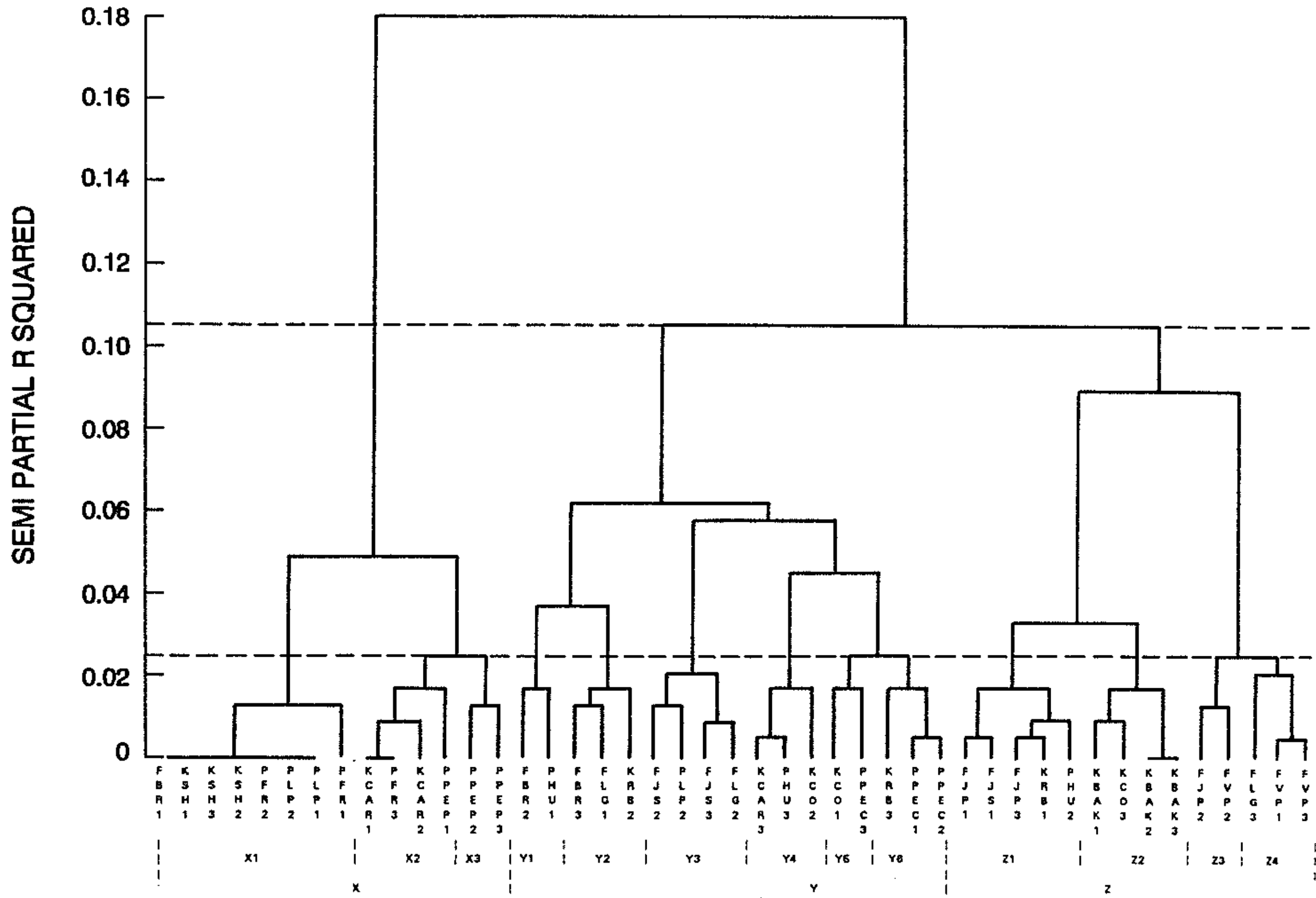

Figure 3. Cluster dendrogram derived from Ward's (1963) method of cluster analysis applied to tree species and total herbaceous importance values from all AML pit sites. The pit sites were identified by the first letter indicating minesoil seam (i.e. F for Freeport), next two or three letters indicating site name (i.e. BR), and the number indicating pit number (i.e. 1). Three main plant community types (X, Y, Z) were recognized (at level of upper dashed line). Thirteen subplant communities (i.e. X1, X2, X3) were recognized (at level of lower dashed line).

Table 3. Cluster summary of tree species and total herbaceous importance values (IV).

Cluster	Pit(Seam)	Sites/Age	Total Herbaceous IV	Tree species IV
X1	P-4 K-3 F-1	FR/30, LP/27 SH/13 BR/24	High (240-290)	None
X2	P-2 K-2	PEP/26, FR/30 CAR/13	Mod low (80-120) to High (250)	Mod to high (120-300) Sycamore
X3	P-2	PEP/26	Low (60-70)	Low (40-120) Black cherry and Elm
Y1	P-1 F-1	HU/27 BR/24	Barren (10) to high (290)	Low to mod low (90-150) Aspen, low (30-40) Birch, low (20-40) Red maple, low (20) Red oak
Y2	F-2 K-1	BR/24, LG/33 RB/27	Barren (0-10) to high (290)	Low to mod (70-150) Aspen and low to mod low (50-140) Red maple
Y3	F-3 P-1	LG/33, JS/32 LP/27	Barren (6-20) to high (260)	Low (30-80) Red maple and low to high (60-300) Black locust
Y4	K-2 P-1	CAR/13, CO/25 HU/27	Barren to high (3-280)	Mod high (150-220) Red maple low to mod low (80-120) Sourwood
Y5	P-1 K-1	PEC/33 CO/25	Low (30-90)	Mod low (100) Red maple, low (30) Black cherry, low to mod low (30-90) Tulip
Y6	P-2 K-1	PEC/33 RB/27	Barren to low (0-90)	Mod low (80-100) Red maple, low (30-80) Black cherry & Black locust, low (30-50) Tulip

Table 3. Cluster summary of tree species and total herbaceous importance values (IV).

Cluster	Pit(Seam)	Sites/Age	Total Herbaceous IV	Tree species IV
Z1	F-3 P-1 K-1	JP/28, JS/32 HU/27 RB/27	Barren to low (0-60)	Low to mod high (30-200) Birch and Red Maple, Low to mod low (30-110) Sourwood
Z2	K-4	BAK/35, CO/25	Barren (0-30)	Mod to high (140-300) Birch
Z3	F-2	JP/28, VP/20,	Barren (10-20)	Mod low (90-140) Birch, Low (30-40) Black locust, Low to mod low (20-80) Red maple Low (20) Red oak and Cherry
Z4	F-3	VP/20, LG/33	Barren (5-15)	Low to mod low (50-110) Birch, low (20-70) Red maple, low (10-40) Cherry, low (10-20) Aspen, Black locust, Red oak, Tulip, and White oak

field of geobotany in which the presence of certain plant species can indicate mineral deposits. A geobotany example in Australia (Cole, 1991) involved yellowjack (*Eucalyptus peltata*) and bloodwood (*E.* affin. *polycarpa*) replacing other *Eucalyptus* species on sites over a zinc-lead-copper ore deposit. In this study the presence and dominance of three components (total herbaceous, red maple, and black birch) in a minesite plant community indicated the minesoil type.

A plant community with an herbaceous component and either sycamore, black cherry, elm, or no trees indicated (85%) a minesoil with low levels of acidity, high BS, strongly acid to neutral, and high levels of CEC and total S. A plant community having a variable (no or high) herbaceous component and red maple with various other tree species (black birch was present only with aspen) indicated (65%) a harsh and variable minesoil with high levels of acidity, very low to moderate levels of BS, extremely acid to strongly acid, moderate CEC and total S, and low levels of relative pyritic S. Lastly, a plant community having a low herbaceous component and black birch with various tree species (low to moderately red maple IV and no aspen) indicated (46%) a moderately harsh minesoil with low to moderate levels of acidity, low BS, extremely acid to strongly acid, low levels of CEC, low fine earth, clay, and total S.

This information can be used by mining operators and reclamation planners to help screen sites for remining and/or reclamation, and to select soil analyses which may help ascertain specific mining and reclamation techniques that should be used on the site. For example, an understanding of minesoil properties before remining or redisturbance may provide clues as to the present minesoil suitability for replacement on the surface. This knowledge could greatly influence the expense of reclamation because "topsoil" may not have to be "borrowed" from another site and imported. During overburden coring to determine the depth and quality of material to be moved or exposed, acid-base accounts may be used, as they were in this study, to estimate future weathering and acid or base potentials. Lastly, plant species most likely to grow on acidic Kittanning sites have been identified, and the plants can be matched to small variations in minesoil properties on these sites.

Many of the AML sites we studied may not require total reclamation by SMCRA standards. SMCRA requires identification and selective placement of toxic materials, grading to approximate original contour (AOC), topsoiling, and the addition of amendments (lime, fertilizer and mulch) to prepare the site for seeding. Revegetation often involves seeding grasses and legumes to produce a vigorous herbaceous plant cover to control erosion. Trees may be planted but they often have difficulty surviving in the competitive herbaceous community.

On the sites we studied, none were completely barren. Some had large areas of barren areas but they were broken apart by vegetation islands. Several sites had areas of complete tree canopy cover, complete herbaceous cover, or a combination of trees and herbaceous cover. With this type of plant community development, it seems careless to disturb the site again to simply reclaim it. Augmenting the already established plant community and using the minesoils already in place seems a prudent way of using AML funds. A simple application of lime (10 to 20 Mg/ha) may reduce the acidity of the minesoil, raise the exchangeable cations, and elevate Ph to release the barren minesoils from toxicity problems. The establishment of brush piles in barren areas may initiate the return of plant species to these areas. Hedin and Hedin (1990) described a "bottleneck", defined as the most limiting factor to plant colonization of acid AML sites in Pennsylvania. Seedlings of certain species may not survive due to one limiting factor while mature plants of the same species do rather well on the same sites. They explained that small amounts of amendments (they used mulch, lime, and phosphorous) removed the "bottleneck" effect which promoted the survival of seedlings on these harsh acid sites. Such a practice would greatly benefit the development of plants on some of the sites we studied and, in reality, cost little in terms of reclaiming a site when compared to complete SMCRA-required regrading and reclamation costs.

LITERATURE CITED

Ashby, W.C., W.H. Davidson, and W.G. Vogel. 1988. Soil Ph guidelines for reclamation tree plantings. *In* Proc. Society of American Foresters, Rochester, NY. 16-19 Oct. 1988.

Blauch, B. 1986. Encouraging AML reclamation via remining. LandMARC 9 (4): 6-8, 10-12, 24, 30.

Cole, M.M. 1991. Remote sensing, geobotany and biogeochemistry in detection of Thalanga zinc-lead-copper deposit near Charters Towers, Queensland, Australia. Trans. Instn Min. Metall. (Sect. B: Appl. earth sci.) 100:B1-B8.

Curtis, J.T., and R.P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 32:476-498.
http://dx.doi.org/10.2307/1931725

Davidson, W.H. 1977. Birch species survive well on problem coal mine spoils. *In* Proc. 24th Northeastern Forest Tree Improvement Conference. Univ. Md., College Park, MD. p. 95-101.

Davidson, W.H. 1979. Results of tree and shrub plantings on low Ph strip-mine banks. USDA Forest Service Res. Paper NE-285.

Hedin, R.S. and E.R. Hedin. 1990. Stimulation of aspen establishment on unreclaimed mine spoils. *In* J. Skousen, J. Sencindiver, and D. Samuel (ed.s), Proc. Mining and Reclamation Conference and Exhibition. West Virginia University, Morgantown, WV. p. 589-594.
https://doi.org/10.21000/JASMR90010589

Johnson, C.D. 1992. Natural reclamation of abandoned mine land. Masters Thesis. West Virginia University, Morgantown, WV.

Keeney, T.A. 1980. Abandoned mine lands: pedologic and geologic evidences toward their diagnosis and treatment. Masters Thesis, West Virginia University, Morgantown, WV.

Kimmerer, R.W. 1984. Vegetation development on a dated series of abandoned lead and zinc mines in southwestern Wisconsin. Am. Midland Naturalist 111:332-341.
http://dx.doi.org/10.2307/2425328

Russel, W.B., and G.H. La Roi. 1985. Natural vegetation and ecology of abandoned coal-mined land, Rocky Mountain foothills, Alberta, Canada. Canadian Journal of Botany 64:1286-1298.
http://dx.doi.org/10.1139/b86-177

Skousen, J.G., J.N. Davis, and J.D. Brotherson. 1989. Pinyon-juniper chaining and seeding for big game in central Utah. J. Range Manag. 42:98-104.
http://dx.doi.org/10.2307/3899303

Soil Conservation Service. 1979. The status of land disturbed by surface mining in the United States. SCS-TP-158. USDA, Soil Conservation Service, Washington, DC. 124 p.

Tyner, E.H. and R.M. Smith. 1945. The reclamation of the strip-mined coal lands of West Virginia with forage species. Soil Science Society of America Proc. 10:429-436.
http://dx.doi.org/10.2136/sssaj1946.036159950010000C00075x

U.S. Congress. 1977. Surface Mining Control and Reclamation Act of 1977. 30 USC 1201. U.S. Gov. Print. Office, Washington, DC.

Ward, J.H. 1963. Hierarchical grouping to optimize an objective function. Journal of the American Statistical Association 58:236-244.
http://dx.doi.org/10.1080/01621459.1963.10500845

West Virginia Mining and Reclamation Association. 1989. AML keeps turning the dollars. Green Lands 19:6-11.