Land Reclamation

Natural Revegetation of 15 Abandoned Mine Land Sites in West Virginia

J. G. Skousen, * C. D. Johnson, and K. Garbutt

ABSTRACT

Fifteen AML sites ranging in age from 13 to 35 yr in Northern West Virginia were selected from three surface-mined coal beds (Pittsburgh, Freeport, and Kittanning) to evaluate plant invasion and establishment on disturbed sites. Three 10 m by 10 m plots were randomly located on each site, and cover, density, and stem diameter of all woody plant species were measured. Herbaceous and plant litter cover were also estimated in square-meter quadrants within each 10-m^2 plot. Total tree cover was significantly different among sites on Pittsburgh and Kittanning coal mined sites, but not among Freeport sites. Among coal beds, Kittanning sites had the lowest tree cover (33% avg), Pittsburgh had an average of 67%, while Freeport sites had a multilayered tree cover averaging >100%. A total of 29 tree species were found on these sites. No tree species occurred on all 15 sites, but black cherry *(Prunus serotina* Ehrh.) and red maple *(Acer rubrum* L.) were found on 13 sites. Clustering produced three distinct plant communities including (i) an herbaceous community, (ii) a tree community dominated by red maple, and (iii) another tree community of primarily black birch *(Betula lenta* L.). Herbacious communities were found on sites with soil pH >5.0, while tree communities occurred on sites with pH <5.0. On disturbed sites with high soil pH, herbacious plants rapidly invaded and formed an almost complete cover. On low-pH sites, the invasion of plant species from adjacent undisturbed sites was initiated in favorable microsites where minesoil or environmental conditions were ameliorated.

APROXIMATELY 34 000 ha of coal mined land in West Virginia have been designated as abandoned mine land (USDA-SCS, 1979). Abandoned mine land (AML) sites are coal mining disturbances that were not adequately reclaimed before the passage of the Surface Mining Control and Reclamation Act (SMCRA) on 3 Aug. 1977, and where no company or individual has any reclamation responsibility under state or federal laws. Most of this AML area has undergone some natural revegetation with various grass and tree species. Many AML sites revegetate in relatively short time (i.e., 10-20 yr) because they have fertile minesoils with few physical and chemical properties that limit plant establishment and growth. A much smaller AML land area has one or more edaphic properties that severely limit reinvasion by plant species from adjacent undisturbed sites. These sites may take much longer (decades to centuries) before natural processes create a site habitable by most plant species.

The natural plant invasions observed on AMLs in Wisconsin (Kimmerer, 1984) and Texas (Skousen et al., 1990) were similar to those observed on old fields (Ashby and Weaver, 1970). For example, abandoned fields in Illinois (Bazzaz, 1968) were dominated for the first 10 yr by one or two pioneering species such as goldenrod *(Solidago nemoralis* Ait.), broomsedge *(Andropogon virginicus* L.), or white heath aster *(Aster pilosus* Wild). Tree species of mature forests such as tuliptree *(Liriodendron tulipifera* L.), redbud *(Cercis canadensis* L.), and shingle oak *(Quercus imbricaria* Michx.) were only found in fields abandoned for over 40 yr. Likewise, invading plant species of AMLs are often weedy species tolerant of extremes in temperature, moisture, and light. Later, the site may be inhabited by trees that establish and become conspicuous after amelioration of harsh conditions (Skousen et al., 1990).

Invading species on AMLs are often those with effective seed dispersal mechanisms, high seed production rates, local availability, and tolerant of minesoil conditions (Ashby, 1984). Coal minesoils in Pennsylvania (Bramble and Ashley, 1955; Schramm, 1966) and England (Hall, 1957) were colonized by plant species of surrounding areas having efficient seed dispersal mechanisms. The species composition of AML sites in Oklahoma (Gibson et al., 1985) were determined by (i) the species' geographical distribution, and (ii) the species' propagule dispersal ability. In New Mexico, plant community diversity on disturbed sites was related to the distance from undisturbed areas, and species with long-range seed dispersal mechanisms were found on these disturbed areas (Wagner et al., 1978).

Invasion on AMLs is uneven (Ashby, 1984), and often produces irregular islands or patches of vegetation from plants of surrounding undisturbed areas (Bramble and Ashley, 1955). Plant succession on disturbed areas can manifest itself by the development and expansion of these vegetation islands through time. Vegetation aggregation and patch dynamics were studied by Game et al. (1982) on AMLs in Missouri. Vegetation development was observed to pass through three stages. Stage 1 involved rapid colonization of microsites by plant propagules from the surrounding undisturbed land that formed small islands of vegetation. In Stage 2, existing patches grew in size with only a few new islands establishing. In Stage 3, the patches coalesced.

Substrate conditions of AML sites sometimes dictate species composition (Hulst, 1978) in that species most adapted to specific minesoil conditions establish and contribute rapidly to the plant community. Plant community composition was not greatly affected by site age or time since abandonment in England (Hall, 1957; Roberts et al., 1981) and Illinois (Lindsay and Nawrot, 1981) be-

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Abbreviations: AML, abandoned mine land; SMCRA, Surface Mining Control and Reclamation Act; IMPV, importance value.

cause acid soil conditions made the sites uninhabitable for most species for decades.

Schramm (1966) observed the effects of a *nurse-log* or a fallen tree on barren parts of minesoils. The area around the log was the only place where sweet fern [*Comptonia peregrina* (L.) Coult] vegetative shoots and bigtooth aspen (*Populus grandidentata* Michx.) seedlings emerged and thrived. Keeney (1980) studied this tree fall phenomenon on West Virginia minesoils, hypothesizing that the tree debris provided moderate shade, reduced wind velocity, and trapped snow, leaves, and seed. Soil moisture conditions under the debris improved, enhancing seedling survival. In addition, light intensity was reduced by 90% under the debris compared with no shade.

The objective of this study was to evaluate tree species cover and composition on 15 AML sites in northern West Virginia. Similarity among plant communities on these sites was determined by cluster and soil analyses to assess the effects of parent material and age since disturbance. The evaluation may help revegetation specialists know which tree species show promise for planting on disturbed sites, and elucidate the mechanisms whereby plant species invade and establish on disturbed lands.

METHODS

Site Selection

Fifteen AML sites in northern West Virginia were sampled from 1989 to 1990. The AML inventory list of the West Virginia Division of Environmental Protection was used as the pool of available sites for selection. This pool was reduced to sites with south and west facing highwall aspects (Hicks and Frank, 1984). Geology maps were used to identify the coal mined on each site, and five sites each from the Pittsburgh, Freeport, and Kittanning coal beds were randomly selected (Fig. 1). These three coal beds were chosen because they produce about one-third of the coal mined in the state. Furthermore, these coal beds account for about 8000 ha of disturbed land in West Virginia, and are known for their potential to produce acid minesoils and sparsely vegetated areas. The date of site abandonment was determined by interviews with the landowner or adjacent landowners, and also by extracting tree cores from the largest trees and adjusting for the species' reinvasion and growth rate. The approximate age of the site was then calculated. Each site was named by the letter of the coal mined and its age (e.g., P30 is a Pittsburgh site mined 30 yr ago). Our 15 AML sites ranged in age from 13 to 35 yr.

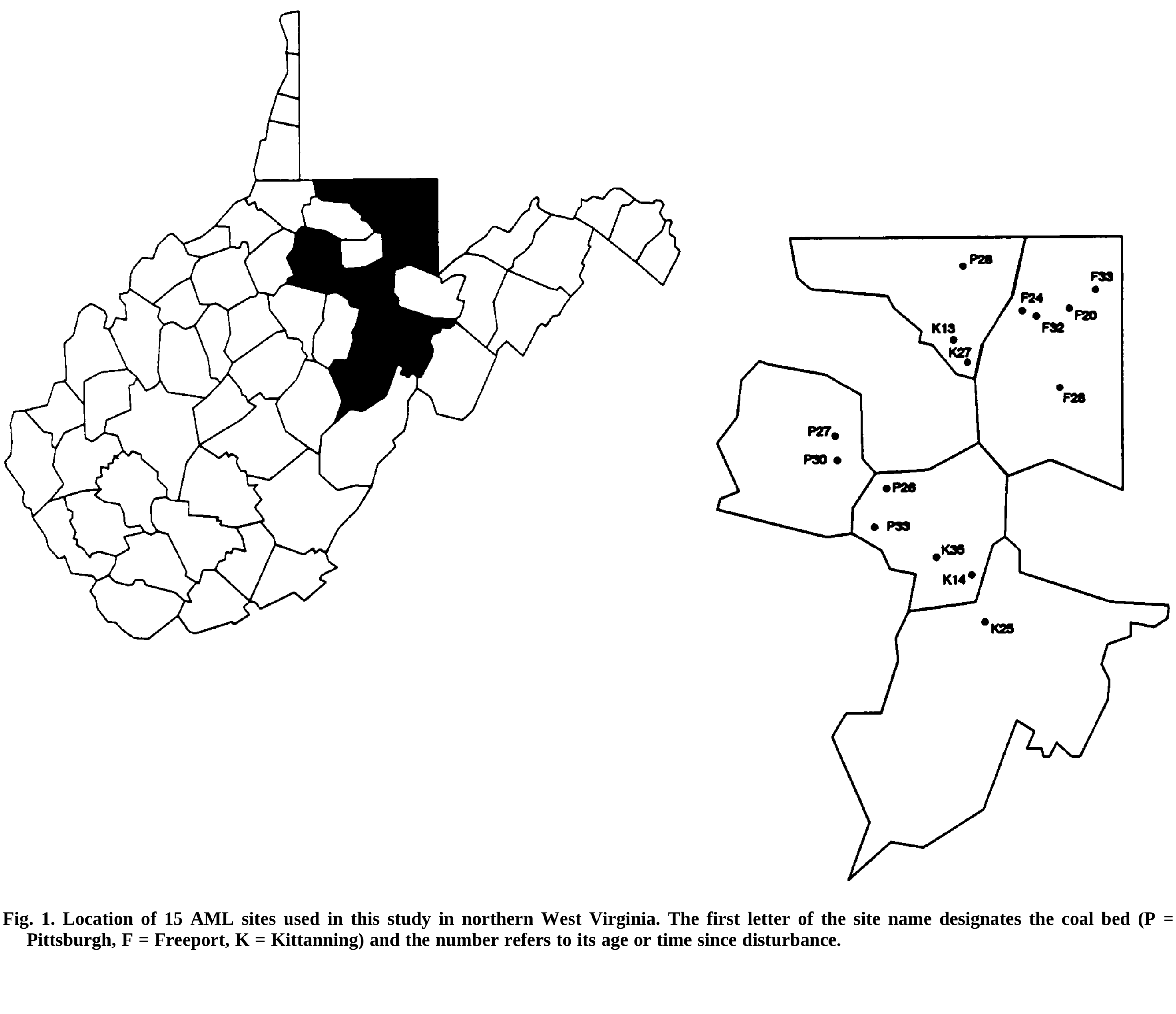

Fig. 1. Location of 15 AML sites used in this study in northern West Virginia. The first letter of the site name designates the coal bed (P = Pittsburgh, F = Freeport, K = Kittanning) and the number refers to its age or time since disturbance.

Vegetation Sampling

Vegetation was sampled at each AML site in three 10 m by 10 m plots. Plots were located by placing a grid over a map of each site and randomly selecting the plots using a computer random coordinate generator. All trees in each 10 m by 10 m plot were identified by species and their stem diameters measured at (i) 2.5 cm aboveground for trees under 1.4 m tall, or (ii) 1.4 m for trees taller than 1.4 m. Stem diameter was recorded to obtain the basal area of each species. Canopy cover of each tree was estimated by the line intercept method on the southern side of each 10 m by 10 m plot. Canopy cover was recorded in cm/l000 cm for each species and then summed to determine total canopy cover. Next, these totals were divided by 1000 and multiplied by 100 to get percent total cover. Thus, a value of O% indicated no canopy cover, 100% indicated a complete canopy, and >l00% indicated an overlapping canopy.

An importance value (IMPV) for each tree species on each site was calculated by the following formula (Curtis and McIntosh, 1951; Smith, 1974):

$$\text{IMPV} = \text{Relative density} + \text{Relative dominance} + \text{Relative frequency}$$

where

$$\text{Relative density} = (\text{Density of a species} \times 100\%)/\text{Total density of all species}$$

$$\text{Relative dominance} = (\text{Basal area of a species} \times 100\%)/\text{Total basal area of all species}$$

$$\text{Relative frequency} = [(\text{No. of plots containing a species} \times 100\%)/\text{Total no. of plots}]/\text{Total frequency value of all species}$$

Herbaceous, lower vascular plant (fungi and algae), and plant litter cover were estimated in three 1 m by 1 m plots randomly located (using a computer random coordinate generator) within each 10 m by 10 m plot. Herbaceous cover was estimated using a modified Daubenmire cover class technique (Skousen et al., 1988). A herbaceous IMPV was calculated for each site by multiplying total herbaceous cover by 3 so the herbaceous IMPV could be used in clustering.

Results of tree species cover and cover values for herbaceous species, lower vascular plants, and plant litter were analyzed by ANOVA to determine significant differences ($P \leq 0.05$) among sites within each coal. When significant differences were found, the cover values were separated among sites within each coal by the Student Newman Keul's multiple comparison test.

To detect complex patterns of similarity among all 15 sites based on vegetation, a cluster analysis was performed using Ward's minimum variance method (Ward, 1963). Clustering is an agglomerative procedure. Each observation (a vegetation plot) begins by itself. Similar observations are joined to form clusters, which are then joined with other similar clusters to form larger clusters. This process continues until only one cluster remains (SAS Inst., 1985). The clusters were then printed as a dendrogram with each vegetation plot as the roots (Johnson, 1967).

Soil samples were collected at the northeast corner of each vegetation plot to a depth of 10 cm. The <2-mm fraction was obtained by weighing rock fragments >2 mm and soil material <2 mm. A percentage of each was then calculated. Soil pH was measured with a Fisher Scientific Accumet pH meter on a 1:1 soil/water paste (Sobek et al., 1978). Exchangeable acidity was determined by 1 *M* KC1 extraction followed by NaOH titration to pH 7 (Soil Survey Staff, 1984). Exchangeable bases (Ca, Mg, Na, and K) were extracted by 1 *M* ammonium acetate at pH 7 (Soil Survey Staff, 1984) followed by analysis with atomic absorption spectrophotometry. Cation exchange capacity was determined by summing exchangeable bases plus exchangeable acidity, and base saturation was calculated by total bases divided by cation exchange capacity.

Table 1. Average cover values of total tree, herbaceous, lower vascular plant, and plant litter on 15 AML sites in northern West Virginia. First letter of the site designates the coal bed (P = Pittsburgh, F = Freeport, and K = Kittanning) and the number refers to the age or time since disturbance.

Site (coal bed and age)	Total tree cover	Total herb cover	Lower vascular plant cover	Plant litter cover
			%	
P26	117a†	26b	8b	47a
P27	17ab	61a	16b	55a
P28	84a	1b	1b	36ab
P30	0b	82a	48a	3b
P33	115a	33b	9b	75a
F20	214a	4b	0a	97a
F24	90a	93a	1a	98a
F28	143a	2b	11a	53a
F32	97a	12b	1a	71a
F33	183a	6b	1a	98a
K13	0b	93a	11a	36a
K14	0b	77a	31a	66a
K25	27ab	30b	2a	25a
K27	70a	5b	13a	52a
K35	70a	4b	1a	36a

† Values within columns for each coal with the same letter are not significantly different ($P < 0.05$) by the Student Newman Keul's multiple comparison test.

RESULTS AND DISCUSSION

Total tree cover was significantly different among sites within each of the Pittsburgh and Kittanning coal beds (Table 1). Kittanning sites as a whole had the lowest amount of tree cover (avg. of 33%, range of 0-70%) while Freeport sites had the highest amount (avg. of 145%, range of 90-214%). Kittanning sites had a younger average age of 22 yr compared with 27 yr for Freeport and 29 yr for Pittsburgh. Total herbaceous cover was significantly different among sites of all three coals. Pittsburgh sites also differed in lower vascular plant and plant litter cover. The P30 site had no tree cover and was dominated by grasses and lower vascular plants. The F24, and K13 and K14 sites also had greater than 75% herbaceous cover.

Ten tree species were common on at least one site on all three coal beds (Table 2). Of those 10, red maple, black birch, tuliptree, bigtooth aspen, black cherry, red oak *(Quercus rubra* L.), and black locust *(Robinia pseudoacacia* L.) occurred on seven or more sites. No tree species was common on all 15 sites, but black cherry occurred on 14 sites and red maple occurred on 13 sites. A total of 29 tree species were found on our 15 sites.

The contribution of each species to the plant community of each site was analyzed by both the species' canopy cover and IMPV. Canopy cover was estimated by the amount of tree cover overlaying one border of each 10 m by 10 m plot. Importance value was calculated based on density, dominance, and frequency of all sizes of trees (seedlings, saplings, and mature trees) inside the plot. Furthermore, more species were detected using IMPV since IMPV recorded all trees in a 100-m^2 area

Table 2. Average canopy cover (CC, %) and importance value (IMPV) of tree species common on at least one site in each coal on 15 AML sites in northern West Virginia. First letter of the site name refers to the coal bed and the number refers to the age or time since disturbance.

Site (coal bed and age)		Red maple	Black birch	Tulip tree	Sour wood	Aspen	Black cherry	Red oak	Black locust	Sassafras	Slippery elm
P26	CC	•†	•	•	•	•	10	•	4	•	43
	IMPV	13	•	12	•	•	42	•	15	•	77
P27	CC	2	•	1	•	•	•	•	•	3	•
	IMPV	30	•	4	•	•	4	3	28	9	9
P28	CC	21	24	1	1	25	5	1	•	•	•
	IMPV	73	82	12	55	22	11	8	•	2	•
P30	CC	•	•	•	•	•	•	•	•	•	•
	IMPV	•	•	•	•	•	88	•	•	•	13
P33	CC	54	•	28	•	•	12	•	•	•	•
	IMPV	74	•	50	•	•	55	5	47	•	•
F20	CC	54	99	5	•	17	5	•	34	•	•
	IMPV	63	121	7	•	11	15	16	26	2	•
F24	CC	•	•	10	•	51	•	•	28	•	•
	IMPV	71	15	11	•	94	3	6	12	•	11
F28	CC	34	66	•	7	5	1	•	26	•	•
	IMPV	65	115	5	51	9	9	18	20	2	•
F32	CC	5	9	•	•	•	37	•	47	•	•
	IMPV	32	15	•	14	•	66	•	173	•	•
F33	CC	16	1	•	•	23	87	•	8	•	•
	IMPV	43	12	•	•	29	57	7	27	•	•
K13	CC	•	•	•	•	•	•	•	•	•	•
	IMPV	•	•	25	•	•	•	•	•	•	•
K14	CC	•	•	•	•	•	•	•	•	•	•
	IMPV	46	•	•	29	•	38	•	•	•	•
K25	CC	2	4	•	1	5	15	1	•	•	1
	IMPV	87	57	9	44	23	23	18	•	•	6
K27	CC	20	33	1	•	1	7	•	8	•	•
	IMPV	114	55	8	24	40	21	•	29	•	•
K35	CC	15	13	4	•	•	11	5	•	•	•

† The dots refer to zero values

vs. tree canopies intercepting a 10-m line. A tree may have contributed to the canopy cover but not been inside the 10 m by 10 m plot. On the other hand, a tree may have been inside the plot but not contribute to canopy cover because of its small size.

Pittsburgh tree communities were generally composed of red maple, tuliptree, black cherry, hawthorn *(Crataegus* spp.), and sycamore *(Plantanus occidentalis* L.) (Tables 2 and 3). Black cherry was the only tree common to all five Pittsburgh sites (Table 2). Black cherry plants on P27 and P30 were small and no canopy cover of the seedlings was measured. On the P30 site, no tree canopy cover was measured and only three other tree species besides black cherry had IMPVs on this site. Red maple, tuliptree, and sassafras *[Sassafras albidum* (Nuff.) Nees] provided tree canopy cover on the P27 site, with nine other tree species being present (Tables 2 and 3).

Freeport sites were generally composed of red maple, black birch, aspen, cherry, and black locust (Tables 2 and 3). Canopies of the F20 and F28 sites were dominated by red maple, black birch, and black locust. The F24 site also had high IMPVs for red maple but no measured canopy. The older F32 and F33 sites were dominated by cherry with either black locust (F32) or Hercules'

Table 3. List of less common tree species, and the sites where each species occurred on 15 AML sites in northern West Virginia.

	Coal bed and age of sites where species occurred		
Species	**Pittsburgh**	**Freeport**	**Kittanning**
Acer negundo (boxelder)	P26, P27		
Alnus serrulata (smooth alder)		F20	K35
Aralia Spinosa (Hercules' club)	P28	F20, F33	
Betula alleghaniensis (yellow birch)		F20, F33	
Carya ovata (shagbark hickory)	P28, P30		K35
Castanea dentata (chestnut)			K27, K35
Cercis canadensis (redbud)	P27		K35
Cornus spp. (dogwood)	P28	F24, F33	
Crataegus spp. (hawthorn)	P26, P27, P28, P33	F28	
Elaeagnus umbellata (autumn olive)		F20, F33	
Fagus grandifolia (American beech)	P28		
Juglans nigra (black walnut)	P26, P33		
Kalmia latifolia (mountain laurel)		F20	
Magnolia tripetala (umbrella tree)		F20, F33	
Platanus occidentalis (sycamore)	P26, P27, P28, P30		K13, K14
Quercus alba (white oak)		F20, F33	K25, K27, K35
Quercus palustris (pin oak)			K35
Quercus velutina (black oak)			K35
Rhus glabra (smooth sumac)	P26 ,P27		

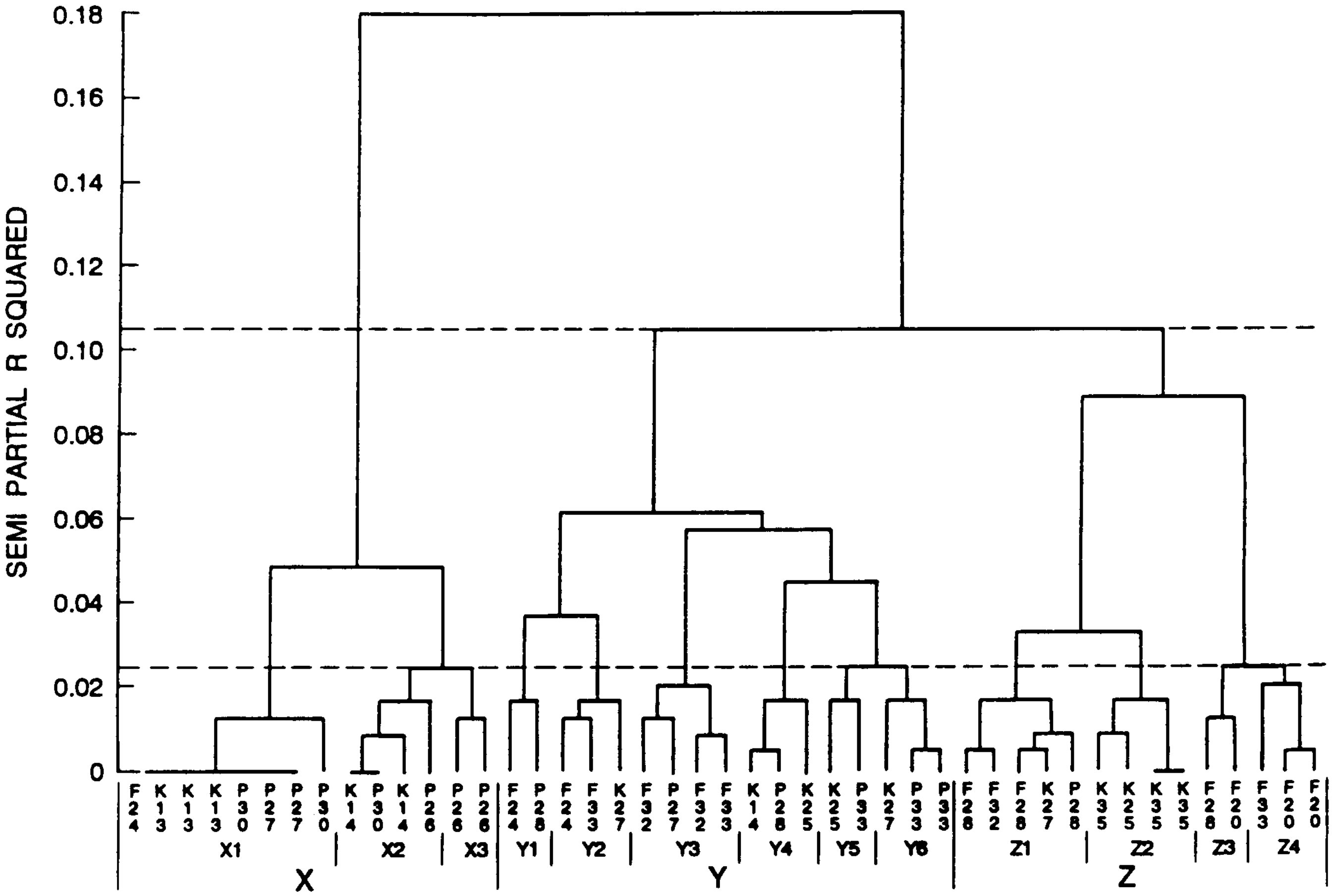

Fig. 2 Cluster dendogram of vegetation parameters from three plots on each of 15 AML sites (45 total plots) in northern West Virginia. The cluster analysis used all tree and herbaceous vegetation data to generate the dendogram. The first letter of each site designates the coal bed and the number refers to its age or time since disturbance.

club *(Aralia spinosa* L.) (F33 had 47% Hercules' club cover). The F20 and F24 sites had 5 and 10% tuliptree cover, respectively, while the F28 site had small IMPVs for tuliptree, red oak, and sassafras. The F33 canopy had a small contribution from red oak, white oak *(Quercus alba* L.), dogwood *(Cornus* spp.), and umbrella tree *(Magnolia tripetala* L.).

In Kittanning plant communities, the two youngest sites had no measured tree canopy cover and the three older sites (K25, K27, and K35) had tree cover composed of red maple, black birch, tuliptree, black cherry, and white oak (Tables 2 and 3). The cover of red maple, black birch, and black cherry was statistically the same among these older sites. The K25 and K35 sites had red oak, K27 and K35 had some tuliptree, and the K25 site also had some slippery elm *(Ulmus rubra* Muhl.). K35 had several less common tree species (Table 3), all less than 22 IMPV.

The cluster dendrogram of each vegetation plot on each site based on tree species and total herbaceous IMPV (Fig. 2) produced two distinct clusters (semipartial r^2 = 0.18, the dendrogram's highest value). The small cluster was named plant community type *X*, and the larger cluster was then divided into two smaller clusters (semipartial r^2 = O.10), which were named plant community types *Y* and *Z*.

Plant community type *X* (Table 4) always had an herbaceous plant component, and either sycamore, black cherry, slippery elm, or no trees. Plant community type *Y* had a variable herbaceous component (from barren to high), and always had red maple with various other tree species (except black birch unless aspen was also present). Plant community type *Z* had zero to low herbaceous plants, and always had black birch with various tree species (low red maple and no aspen). These three plant community types *(X, Y,* and *Z)* were then subdivided into more discrete plant community types as summarized in Table 4.

Parent material played a small role in plant community development. Plant community type *X* was dominated by Pittsburgh and Kittanning vegetation plots while type *Z* was dominated by Freeport and Kittanning plots. Plant community type *Y* was composed of six Pittsburgh, six Freeport, and five Kittanning vegetation plots (Table 4).

The P26, P27, and P30 sites all showed minesoil pH > 6.0 (Table 5), while the F24, K13, and K14 sites had pH >5.0. These sites with pH greater than 5.0 had low acidity (<6 $cmol_c\,kg^{-1}$), high Ca (>9 $cmol_c\,kg^{-1}$), and >50% base saturation. The high pH and low acidity is reflected in the amount of herbaceous cover on these sites (avg. of 72%, range of 26-93%). Tree cover averaged 37% on these same sites (range of 0-117%). Conversely,

Table 4. Cluster summary of tree species and total herbaceous importance values (IMPV) on 15 AML sites in northern West Virginia.

Cluster	Veg plot (coal bed-no. of plots)	Sites	Total herbaceous IMPV	Tree species IMPV
X1	P-4	P27,P30	High (240-290)	None
	K-3	K13		
	F-1	F24		
X2	P-2	P26,P30	Mod low (80-120) to high (250)	Mod to high (120-300) sycamore
	K-2	K14		
X3	P-2	P26	Low (60-70)	Low (40-120) black cherry and elm
Y1	P-1	P28	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
	F-1	F24		
Y2	F-2	F24:F33	Barren (0-10) to high (290)	Low to mod (70-150) aspen and low to mod low (50-140) red maple
	K-1	K27		
Y3	F-3	F32,F33	Barren (6-20) to high (260)	Low (30-80) red maple and low to high (60-300) black locust
	P-1	P27		
Y4	K-2	K14,K25	Barren to high (3-280)	Mod high (150-220) red maple and low to mod low (80-120) sourwood
	P-1	P28		
Y5	P-1	P33	Low (30-90)	Mod low (100) red maple, low (30) black cherry, low to mod low (30-90) tulip
	K-1	K25		
Y6	P-2	P33	Barren to low (0-90)	Mod low (80-100) red maple, low (30-80) black cherry and black locust, low (30-50) tulip
	K-1	K27		
Z1	F-3	F28,F32	Barren to low (0-60)	Low to mod high (30-200) birch and red maple, low to mod low (30-110) sourwood
	P-1	P28		
	K-1	K27		
Z2	K-4	K25,K35	Barren (0-30)	Mod to high (140-300) birch
Z3	F-2	F20	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
24	F-3	F20,F33	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

sites with pH <5.0 and high acidity had total herbaceous cover ranging between 1 and 33% (avg. of 11%) and tree cover varying between 27 and 214% (avg. of 111%). Clearly, the soil's chemical properties dramatically influenced the composition of the plant community.

An examination of site ages showed no obvious species replacement trends as determined by IMPV or cover between younger and older sites on any coal bed. Only a few species had significant ANOVA *F* values and high correlations (*r* values) of IMPV with age. For example on Pittsburgh sites, tuliptree and hawthorn increased in IMPV with age (r = 0.53 and 0.63, respectively). On Freeport sites, no species had significant ANOVA *F* values and high correlations with age, while only black birch increased in IMPV with age (r = 0.93) on Kittanning sites. Two factors contribute to the reason no trends were observed. First, our sites only differed by 22 yr from youngest to oldest and, secondly, the life spans of many of these species are >50 yr. Therefore, insufficient time had passed since disturbance on these sites to determine invasion, growth, and mortality of trees, and then to distinguish the replacement of initial colonizers by other developing species.

In this study, three sites had no measured tree canopy cover. Two of these, K13 and K14, were young sites and the absence of a mature tree canopy may not be particularly surprising. The other site without a tree canopy, P30, was old and its community structure was markedly unlike other older sites in this study. This site seems to be a classic example of *inhibition* (Connell and Slayter, 1977), given that grasses covered the site, effectively delaying invasion by woody species. Woody species now appear to be invading the P30 site, particularly seedlings of black cherry. However, this phase generally occurred 20 yr ago at other sites.

In general, the data presented here support an individualistic model of succession (Gleason, 1926) rather than a Clementsian autogenic process (Clements, 1936). These data suggest that the natural revegetation of these sites can best be characterized as one of aggregation similar to that described by Game et al. (1982). On sites with favorable minesoil properties (i.e., high pH and low acidity), herbaceous species rapidly invaded and covered the ground providing little opportunity for tree establishment. However, on minesoils of low pH and high acidity, the favorable microsites sparsely distributed throughout the site were colonized by acid-tolerant grasses and tree species from the surrounding forest. The identity of these initial colonizers was a function of the species available,

Table 5. Selected mined properties of the surface 10 cm on 15 AML sites in northern West Virginia. The first letter of the site designates the coal bed and the number refers to its age or time since disturbance.

Sites (coal bed and age)	<2mm	pH	Acidity	Calcium	Cation exchange capacity	Base saturation
	%		$cmol_c\,kg^{-1}$			%
P26	42	6.1	0.3	14	18	97
P27	30	6.9	0.1	19	22	99
P28	61	3.3	11.3	1	13	11
P30	73	6.6	4.3	18	27	88
P33	44	4.4	5.2	2	47	9
F20	28	4.2	3.9	1	6	35
F24	31	5.2	5.9	9	16	55
F28	39	3.8	6.7	1	8	13
F32	43	3.9	8.4	1	10	15
F33	9	3.9	8.9	1	10	11
K13	34	5.3	0.8	11	14	92
K14	41	5.3	3.2	9	15	74
K25	55	4.3	7.8	2	10	30
K27	43	4.1	9.9	1	12	18
K35	36	3.8	13.1	1	14	3

the distribution of seed from the forest, and the nature of the favorable microsite. The importance of the composition of the surrounding forest can be seen in this study by the absence of quaking aspen *(Populus tremuloides* Michx.) from any of the sites. Quaking aspen has a very restricted distribution in West Virginia (although it is found sparsely in northern West Virginia) and is a dominant species on Pennsylvania AML sites in association with bigtooth aspen, black birch, and black cherry (Hedin, 1988). The fact that quaking aspen is absent on West Virginia AML sites while bigtooth aspen, birch, and cherry are present indicates the importance of the surrounding forest.

The nature of favorable microsites is not obvious from this study. They could be nurse-logs, brushpiles, or simply patches of soil with low acidity, high nutrients, or improved moisture suitable for establishment of invading woody species. Small ridges or depressions in the surface could easily capture and accumulate leaves and/or seed, or collect water to improve seed germination and seedling establishment. For a more complete understanding of the developmental history of a naturally reclaimed site, it would be necessary to conduct a study in which the spatial relationships between the individuals on the site were also taken into consideration.

The results of this study have important implications for reclaiming AMLs. If the objective of the reclamation is to provide the landowner with quick economic returns through haying or grazing and complete erosion control, the landowner should choose a cover crop of herbaceous plants. The herbaceous crop must be maintained by the landowner with lime and fertilizer, or a delayed invasion of the site by woody species will gradually occur. If the purpose of the reclamation is to restore the land to its previous land use (forest in the case of West Virginia), then the planting of forages that provide rapid competitive cover is probably not the best approach. At site P30, forest regeneration seems to have been delayed by the presence of an herbaceous community. Disturbed sites without a dominant herbaceous community and with nontoxic minesoil conditions will be invaded by trees leading to the establishment of a native forest. An approach using nurse-logs, tree debris, or soil ridges may be useful for erosion control and certainly be more effective in promoting forest regeneration on these sites than a complete cover of herbaceous species. If a good source of tree seed is nearby, another revegetation approach could plant less competitive herbaceous species and/or using less seed and fertilizer to encourage establishment of invader tree species on AML sites.

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