DEVELOPMENT OF NATURAL AND PLANTED VEGETATION ON SURFACE MINES IN SOUTHEASTERN KENTUCKY[1]

by

Ralph L. Thompson[2], Willis G. Vogel[3], Gary L. Wade[4], and Barbara L. Rafaill[5]

Abstract. Descriptive studies were made of the flora and vegetation on five 17- to 20-year old surface mines that originally had been partly or entirely planted with herbaceous and woody species. A rich flora was found on these mines as a result of natural secondary succession and artificial plantings. Certain similarities in vegetation were evident at all sites; yet, distinct differences existed that appeared to be influenced by site and minesoil characteristics, planted species, and contiguous plant communities. Plantings of sericea lespedeza (Lespedeza cuneata), tall fescue (Festuca arundinacea), and black locust (Robinia pseudoacacia) were being replaced by native and naturalized flora characteristic of various seral stages of secondary succession. Important invading trees included Virginia pine (Pinus virginiana), red maple (Acer rubrum), yellow-poplar, (Liriodendron tulipifera), sweetgum (Liquidambar styraciflua), white ash (Fraxinus americana), river birch (Betula nigra), sourwood (Oxydendrum arboreum), blackgum (Nyssa sylvatica), and black locust. A Virginia pine-mixed hardwoods stand at one site and mixed hardwoods stands at four sites were the major vegetation types present. All of the sites were floristically rich; 350 and 360 taxa were documented at two of the sites. At a third mine, site indices of 18-year old planted trees were similar to those of trees in adjacent unmined forest. Results of these studies indicate that potentially productive forests are reestablishing on older surface-mined sites in southeastern Kentucky.

Additional Key Words: flora; tree species; herbaceous species; secondary succession; minesoils

Introduction

Approximately 109,000 hectares of land were surface-mined for coal in eastern Kentucky before passage of the Surface Mining Control and Reclamation Act (PL 95-87) in 1977. Many of the areas mined just prior to this law have been vegetated primarily with seeded herbaceous species, whereas many of the older mined areas, especially those mined before 1970, have been revegetated naturally or by a combination of artificial plantings and natural plant succession. Traditionally, attention has been focused on the environmental problems caused by surface mining, but relatively little effort has been made to study, document, and report on the vegetational status of older mined areas. The purpose of this paper is to report on results of studies and observations of the flora and vegetation on five older surface-mined sites in southeastern Kentucky.

[1]Paper presented at the 1986 National Meeting of the American Society for Surface Mining and Reclamation, Jackson, Mississippi, March 17-20, 1986.

[2]Botanist, Department of Biology, Berea College, Berea, Kentucky 40404.

[3]Range Scientist, U. S. Forest Service, Northeastern Forest Experiment Station, Berea, Kentucky 40403.

[4]Botanist, U. S. Forest Service, Northeastern Forest Experiment Station, Berea, Kentucky 40403.

[5]Graduate Student, Department of Botany, Southern Illinois University, Carbondale, Illinois 62901.

Proceedings America Society of Mining and Reclamation, 1986 pp 145-154

DOI: 10.21000/JASMR86010145

https://doi.org/10.21000/JASMR86010145

Sites and Study Methods

Four surface-mined sites in Bell County and one in Laurel County, Kentucky, were selected for this report. These sites are in the Eastern Kentucky Coal Field Region of the Cumberland Plateau. The climate is continental, characterized by warm, humid summers and moderately cold winters. Mean annual precipitation is about 120 cm with distribution fairly uniform throughout the year. Mean annual growing season is 180 to 190 days. The sites were mined in the early to mid 1960s and were partly or entirely planted and seeded as part of the reclamation process. The vegetation growing on these sites was evaluated 17 to 20 years after the initial revegetation effort. Selected features and the methods used to study the flora and vegetation at each site are described in the following sections and in Table 1.

Lily

The Lily site is a 14.0 ha area-type coal surface mine located 3.5 km east of Lily in southeastern Laurel County, Kentucky. The terrain in the vicinity of the study site consists of gently to moderately rolling hills with broad undulating valleys. Differences in elevation usually are less than 40 m from ridgetop to valley floor. Mixed hardwoods-pine forests are interspersed among agricultural land in the immediate vicinity. Native vegetation in this portion of the Cumberland Plateau belongs to the Pine-oak Forest type of the Mixed Mesophytic Forest Region (Braun 1950).

Surface mining was terminated in 1964, after which the site was graded and partially leveled. Steep slopes were formed on most of the perimeter and a 1.5 ha body of water was created by the final mining cut. The minesoils (spoils) were derived mainly from acidic gray and black shales intermixed with siltstones, sandstones, and local soils. Texture of the soil-size (< 2mm) fraction is mainly silty clay loam. The pH of the minesoils sampled in 1965 ranged from 2.7 to 6.7 with a median of 4.1. A similar analyses in 1981 showed a pH range from 3.3 to 5.7 with a 4.4 median.

In 1965 and 1966, personnel from the USDA Forest Service, Northeastern Forest Experiment Station, Berea, Kentucky, planted 110 woody and herbaceous species on outslopes and in selected experi-

Table 1. Description of Study Sites

Characteristic	Sites				
	Lily	Log Mountain	Henderson Fork Road	Brownies Creek	Fonde
Type of Mine	Area	Contour	Contour	Contour	Contour
Size of Study Area (ha)	14.0	14.2	2.0	1.8	7.3
Elevation (m)	350	870	682	503	580
Aspect	N/A	W-NW	SW-W	SW	NW-NE
Geologic Formation	Breathitt	Bryson	Hignite	Hance	Mingo
Coal Bed Mined	Lily	Red Springs	Hignite	Puckett Creek	Mingo
Minesoil pH, median	4.1	6.4	4.8	4.6	4.0
range	2.7-6.7	4.8-7.7	4.2-5.3	4.4-4.8	2.8-5.9
Regional Vegetation	Pine-Oak Forest	Mixed Hardwoods Forest	Mixed Hardwoods Forest	Mixed Hardwoods Forest	Mixed Hardwoods Forest
% of Area Planted	25	100	100	100	80
Year Planted	1965-66	1964-65 1971	1963	1965	1965
Species Planted	110	25	3	3	24
Trees					
Native	26	11	1	1	11
Non-indigenous	15	4	0	0	2
Herbs					
Native	9	0	0	0	5
Non-indigenous	35	8	2	2	5
Shrubs					
Native	9	0	0	0	0
Non-indigenous	16	2	0	0	0

mental plots covering about 25 percent of the mined area. Most of the unplanted portion of the site and some of the planted area were subsequently vegetated by natural processes.

In 1981 and 1982, a descriptive study was made of the flora and vegetation. Belt transects (2 m x 100 m) were used to sample trees, shrubs, and vines in the natural plant communities and two nested quadrats (1 m x 1 m) within each transect were used to sample herbaceous vegetation. Plant collections were made twice weekly during the growing season from April 1981 through September 1982 (Thompson et al. 1984). In September 1983, an assessment was made of the success of trees and shrubs in the planted experimental plots (Wade et al. 1985).

Log Mountain

The Log Mountain site is a 14.2 ha contour-type surface mine located 18 km west of Middlesboro in southwestern Bell County, Kentucky. The site is near a ridgetop in steeply sloping mountainous terrain where narrow ridgetops rise as much as 595 m above the narrow floor of the valleys. The native vegetation in this vicinity is classified as Mixed Hardwood Forest and is in the center of the Mixed Mesophytic Forest Region of the Deciduous Forest Formation (Braun 1950).

Surface mining at this site was done at two different times. A 9.1 ha area on the Red Springs coal bed was mined in 1963. The bench portion of the mine was graded and gently sloped toward the highwall with a steep outer slope remaining along the length of the mine. Mining of a rider seam in 1971 produced an additional mined area of 5.0 ha above part of the original mine. The bench on this area was graded level and a steep outslope extended down to the bench of the original mine below. The minesoils consisted of various sizes of fragments of predominantly siltstones and shales with some sandstones and local soils intermixed. The soil-size fraction was mostly silty clay loam. These minesoils recently have been classified as the Fairpoint soil series (J. D. Childress, U. S. Soil Conservation Service, personal communication). The pH of the minesoils samples in 1985 ranged from 4.8 to 7.7 with a median of 6.4. Some of the minesoil samples contained carbonates.

The area mined in 1963 was seeded to Kentucky-31 tall fescue (Festuca arundinacea) and Korean lespedeza (Lespedeza stipulacea) in the spring of 1964. A fair to good ground cover was established in the first year on all but some of the steep outslope. In 1965, this area was selected by a Federal-State Interagency Research Coordinating Committee for demonstrating reclamation planting for a forestry postmining land use. Five hardwood and six conifer tree species and two shrub species were planted. Blocks of tree species with potential commercial value were planted on the bench; nitrogen-fixing trees and shrubs were planted mostly on the outslope. The area mined in 1971 was seeded with a mixture of tall fescue, sericea lespedeza (L. cuneata), and black locust (Robinia pseudoacacia). A dense ground cover developed within one year and a black locust overstory developed within eight years. In 1984, several small plots of hardwood tree species were planted.

In 1984 and 1985, a floristic study was made of the entire mined area. All trees on the 1963 mined area were counted and recorded in DBH size classes. Plant collections were made biweekly during the growing season from April through October 1985. A detailed report of this study is being prepared by R. L. Thompson et al.

Henderson Fork Road and Brownies Creek

The Henderson Fork Road site is a 2.0 ha segment of a contour-type surface mine located 2.3 km northwest of the Log Mountain site and is on a lower coal seam at about a mid-slope position. Brownies Creek is a 1.8 ha segment of a contour-type surface mine located about 30.0 km east of Middlesboro near the Bell-Harlan County line. The surrounding terrain and vegetation at both sites are similar to Log Mountain.

These two sites were mined in the early 1960s. A minimal amount of postmining grading was done; the surface of the bench areas is somewhat irregular and contains several seasonally wet depressions. The minesoils are derived from fragments of siltstones, sandstones, and shales intermixed with coal waste and local soils. Texture of the soil-size fraction varied from clay loam to sandy clay loam. The pH of minesoils samples in September 1982 ranged from 4.2 to 5.3 with a median of 4.8 at Henderson Fork, and from 4.4 to 4.8 with a median of 4.6 at Brownies Creek.

Following mining, the entire areas were seeded to tall fescue and sericea lespedeza and planted to black locust by personnel of the Kentucky Reclamation Association. Lime and fertilizer were not applied. Vegetation establishment from the seeding and planting effort was reported to be successful (C. K. Spurlock, Kentucky Reclamation Association, personal communication). The rows of planted black locust are still evident today.

A study was made in 1982 and 1983 to describe the vegetation at the Henderson Fork Road and Brownies Creek sites and two other mined sites in the region. Trees and saplings present in 5 m x 20 m plots were counted and measured, and herbaceous species and woody seedlings less than 1.0 m tall were sampled by the vertical point-quadrat method along two transect lines within the plots. A complete inventory of the vascular flora was not attempted as was done at Lily and Log Mountain. Results of this study will be presented in a Ph.D. dissertation by B. L. Rafaill.

Fonde

The Fonde site is a 7.3 ha contour-type surface mine on a north-facing mid-slope position. It is located 1.5 km southeast of Fonde in southwestern Bell County and about 9.0 km south of the Log Mountain site. The mountainous terrain and native mixed hardwoods forest in the area are similar to that described for the Log Mountain site.

This site was initially mined in 1959 and remined in 1963. This site was chosen by the Kentucky Strip Mine Research Coordinating Committee to demonstrate methods recommended at that time for water control and revegetation on surface-mined areas. In 1964 and 1965, a dam, two siltation ponds, and associated spillways and water courses were constructed to control onsite runoff and intercept runoff from a 7.0 ha area above the mine.

A minimal amount of grading was done to direct surface runoff toward the highwall and then to settling ponds with controlled outlets. Some of the acid-forming coal wastes and shales were buried, but several small areas of acidic materials were left uncovered and exposed to weathering. Besides coal wastes, the minesoils were derived from a mixture of sandstone, siltstone, and shale fragments and forest soils. The pH of the minesoils samples in August 1965 ranged from 2.8 to 5.9 with a median of 4.0.

The revegetation demonstration project in 1965 consisted primarily of planting trees on selected areas for forestry and wildlife habitat uses. Those areas considered too acid to support vegetation were not planted. Minesoils considered marginal for plant growth were planted to acid tolerant species such as pitch pine (Pinus rigida), Virginia pine (P. virginiana), loblolly pine (P. taeda), and black locust. Mixtures of hardwoods were planted on the least acid minesoils. Bicolor lespedeza (L. bicolor), a nitrogen-fixing shrub, was planted along spillways and in selected patches. Herbaceous species were seeded on the dam, in spillways, on some outslope areas, and in several of the shrub plantings. Lime and fertilizer or fertilizer only was used to help establish seedings on the dam and in several small plots on the outslope.

The pine and mixed hardwood plantings were evaluated in 1983 to 1985 (Wade et al. 1986). Height and DBH of dominant trees were measured, and site indices were estimated using age-height data and site index curves developed by Hampf (1965). Tree age at time of measurement was 18 years, but age 20 was used for site index calculations. Dominant and codominant trees of northern red oak (Quercus rubra) and yellow-poplar (Liriodendron tulipifera) in the secondary forest above and below the mine were selected for measurement, and site index determinations were made in the same manner as in the mined area plantings. Tree age was estimated by counting rings on extracted cores and adjusting for 1.3 m core height (Hampf 1965). A floristic inventory was not done at this site.

Results and Discussion

Certain similarities in the development of vegetation were evident at all sites; yet, distinct differences were noted that seemed to be influenced by site and minesoil characteristics, planted species, and the contiguous natural plant communities.

Species Richness

Of special interest was the large number of species at these sites. A total of 350 taxa was recorded at Lily and 360 at Log Mountain, the two sites where complete floristic inventories were made. Only 75 species were recorded at Brownies Creek and 55 at Henderson Fork Road, but these values do not indicate the true number of species because only a preliminary inventory was made of the flora. The number of native and non-indigenous species in several floristic components are shown in Table 2.

At Lily, 272 of the 350 recorded taxa were invading species and 78 were persisting from the 110 species planted. Twenty-two percent of all recorded taxa and 56 percent of the surviving planted taxa were non-indigenous species. The Log Mountain flora included 338 volunteer species and 22 survivors from the 25 species planted; 22 percent of all recorded taxa were non-indigenous. The flora at Lily included one threatened species and at Log Mountain three threatened species listed for Kentucky by Branson et al. (1981). The 360 species found on only 14.2 hectares at Log Mountain compared favorably with the 566 species found in the nearby 8,170 ha Cumberland Gap National Historical Park by Hinkle (1975). Furthermore, 119 species of the Log Mountain collection were Bell County records not listed by Hinkle (1975) or Braun (1943).

Plant Succession

All five sites had advanced to the seral stage of perennial herb and woody plant communities similar to normal secondary successional assemblages in the surrounding environs. Important invading tree species were mainly those with small easily dispersed fruits and seeds and with varying degrees of shade-intolerance. Volunteer seedlings of some of the larger-fruited species such as oaks (Quercus spp.) and hickories (Carya spp.) were present, but they were not yet an important component of the naturally developing forest communities. Important invading tree species common to all or most of the sites were red maple (Acer rubrum), sourwood (Oxydendrum arboreum), blackgum (Nyssa sylvatica), yellow-poplar, and Virginia pine. Black locust was planted at all sites and remains an important species, though some of the plants are a result of natural regeneration. Invading tree species important at one or two sites included white ash (Fraxinus americana), white dogwood (Cornus florida), sycamore (Platanus occidentalis), and sugar maple (Acer saccharum). Several other species were also locally important (Table 3). Nearly all of these species are recommended for planting on coal minesoils in the eastern United States (Vogel 1981).

Most important of the shrubs and vines were blackberry (Rubus spp.) and greenbriar (Smilax spp.) found at all sites. Other shrubs and vines important at two or more sites were sumac (Rhus spp.) and virgin's bower (Clematis virginiana) (Table 3). These woody plants are indicator species of various seral stages of old-field succession.

The herbaceous flora consisted mainly of perennial composites, grasses, legumes, sedges, and rosaceous species (Table 2). Important herbs present at all or most of the sites were goldenrod (Solidago spp.), microstegium (Microstegium vimineum), white snakeroot (Eupatorium rugosum), and pale jewelweed (Impatiens pallida)(Table 3). None of the originally seeded reclamation species, including tall fescue and sericea lespedeza, ranked high in overall importance.

At three of the sites, stands of sericea lespedeza and tall fescue that initially developed from seedings made concurrently with the planting or seeding of black locust have been largely replaced by native and naturalized flora. The black locust overstories represented an important component of a seral stage where shade-tolerant species were becoming established. Their understories contained a number of herbs, vines, shrubs, and tree

Table 2. Taxonomic summary of flora at four sites

Floristic Components	Lily		Log Mountain		Henderson Fork Rd[1]		Brownies Creek[1]	
	Native	Non-Indigenous	Native	Non-Indigenous	Native	Non-Indigenous	Native	Non-Indigenous
Trees	51	16	34	7	9	0	19	0
Shrubs & Vines	26	12	14	4	8	0	10	0
Herbs, Total	196	49	233	68	35	3	41	4
Graminoids	50	16	45	15	3	1	10	3
Grasses	31	16	23	15	1	1	6	3
Sedges	14	0	16	0	1	0	2	0
Rushes	5	0	6	0	1	0	2	0
Forbs	146	33	188	53	32	2	31	1
Legumes	19	14	20	12	1	0	0	0
Composites	34	4	49	12	13	0	17	1
Rosaceous	15	6	11	4	1	0	0	0
Ferns	7	0	10	0	11	0	4	0
Other	71	9	98	25	15	2	10	0
Total Species	273	77	281	79	52	3	70	5
Families	84		82		30		35	
Genera	210		230		46		58	

[1]A complete inventory not made at these sites.

Table 3. Important trees, shrubs, vines and herbs at four sites

Lily[1]	Log Mountain[2]	Henderson Fork Road[2]	Brownies Creek[2]
Trees			
Pinus virginiana*	Fraxinus americana	Acer rubrum	Acer rubrum
Liquidambar styraciflua	Liriodendron tulipifera*	Robinia pseudoacacia*	Robinia pseudoacacia*
Acer rubrum	Acer saccharum	Liriodendron tulipifera	Liriodendron tulipifera
Betula nigra	Robinia pseudoacacia*	Oxydendron arboreum	Betula lenta
Cornus florida	Acer rubrum	Quercus velutina	Oxydendrum arboreum
Robina pseudoacacia*	Alnus glutinosa*	Nyssa sylvatica	Nyssa sylvatica
Nyssa sylvatica	Pinus virginiana*	Platanus occidentalis	Magnolia acuminata
Oxydendrum arboreum	Platanus occidentalis*		Cornus florida
Shrubs & Vines			
Rhus copallina	Rubus spp.	Rubus spp.	Rubus spp.
Smilax glauca	Clematis virginiana	Hydrangea arborescens	Sambucus canadensis
Rubus spp.	Smilax rotundifolia	Clematis virginiana	Rhus copallina
Toxicodendron radicans	Smilax glauca	Parthenocissus quinquefolia	Vaccinium pallidum
Lonicera japonica	Hydrangea arborescens	Smilax spp.	Smilax spp.
Spiraea tomentosa	Vitis cinerea		Clematis virginiana
Herbs			
Andropogon virginicus	Eupatorium rugosum	Microstegium vimineum	Eupatorium rugosum
Solidago spp.	Solidago spp.	Solidago spp.	Microstegium vimineum
Aristida dichotoma	Impatiens pallida	Eupatorium rugosum	Solidago spp.
Senecio smallii	Microstegium vimineum	Impatiens pallida	Phytolacca americana
Panicum lanuginosum	Polygonum cuspidatum	Polygonum cristatum	Aster spp.

[1]Includes only volunteer species outside of planted plots.
[2]Includes both planted and volunteer plants.
(*) = Species planted on the site.

seedlings present in mixed mesic hardwoods forests. Our findings concur with results of a study of a 16-year old planting in Breathitt County, Kentucky, where more species were volunteering under black locust than under other planted trees (Foster and Henry 1985).

On the unplanted portions of the Lily and Fonde sites, the predominant invading species was Virginia pine. Understories in pine-mixed hardwoods communities had fewer species than in the black locust-grass-legume planted communities. A major difference between the pine-pioneered and legume-pioneered sites is that the pines are site occupiers while the legumes are site developers. Secondary succession appeared to be progressing more slowly within the pine communities.

Planted Species

A number of native and non-indigenous planted species had persisted and contributed significantly to overall vegetational development. Some grasses and herbaceous legumes such as weeping lovegrass (Eragrostis curvula), tall fescue, Korean lespedeza, and sericea lespedeza provided relatively quick initial cover but were being replaced by native and exotic invaders from outside the mined areas or from other plantings on the mined areas. Native warm-season perennial grasses, big bluestem (Andropogon gerardi) and switchgrass (Panicum virgatum), seeded at Lily and Fonde have persisted and spread into open areas. At Lily, two non-indigenous legumes, flatpea (Lathyrus sylvestris) and crownvetch (Coronilla varia), have spread from the original plots into adjacent areas and have excluded invading species (Thompson et al. 1984).

Black locust is probably the most important planted native tree species on all the mined sites. This tree contributes to site stabilization, soil enrichment, and soil development (Ashby et al. 1985). European black alder (Alnus glutinosa), also a nitrogen-fixing tree, has grown well at Lily, Log Mountain, and Fonde where it has enhanced soil enrichment and development, and promoted invasion of other plants. Black locust and black alder have begun to decline as trends of succession have progressed.

Many of the planted woody species survived and grew well at the Lily site in spite of the predominance of extremely acid minesoils. Some of the native trees and shrubs were pin oak (Quercus palustris), bur oak (Q. macrocarpa), sweet birch (Betula lenta), pitch pine, loblolly pine, and silky dogwood (Cornus amomum). Successful non-indigenous trees and shrubs were mimosa (Albizia julibrissin), European white birch (B. pendula), Japanese crabapple (Pyrus zumi), autumn olive (Elaeagnus umbellata), and bicolor lespedeza (Thompson et al. 1984; Wade et al. 1985).

Planted trees that have grown well at Log Mountain are Scotch pine (P. sylvestris) and Norway spruce (Picea abies), though there is no evidence of regeneration of either species. Planted native hardwoods, red oak, yellow-poplar, and sycamore were only moderately successful. More impressive was the development of naturally-seeded individuals of these species, especially where they invaded into stands of black locust and black alder. The shrubs, autumn olive and bicolor lespedeza, have thrived at this site.

Site Productivity

Productivity of planted trees was determined at the Fonde site (Wade et al. 1986). Tree densities and basal areas indicated that the site was very productive, but the plantations were greatly overstocked because of close spacing and high survival (Table 4). The hardwood stands need to be thinned to about 300 trees per hectare, and the pines to about 750 trees per hectare.

Growth of pine, especially loblolly, was impressive, particularly when the initial quality of the minesoils was considered. The site index for loblolly pine was 27.0 m. The index of 22.1 for pitch pine was a medium quality rating for this species. The site index of 27.0 for Virginia pine was at the low end of the good site rating (Table 5). However, these site indices for pine may be somewhat misleading because they are based on age 50. Rotation ages for pine are often less than 50, so productivity at optimum rotation period may be less than these site indices indicate.

Site indices for yellow-poplar in the mixed hardwoods plantations were in the medium to good site quality rating, but were below indices calculated for yellow-poplar on undisturbed soils adjacent to the mined site (Table 5). Calculated site indices for northern red oak on the mined site were likewise lower than the offsite indices, but the oaks in the mixed hardwoods plantations on the site were overtopped by competing species such as yellow-poplar and sycamore; thus the calculated site indices are lower than acutal growth potential. Site index comparison curves by Hampf (1965) and Ostaff et al. (1982) were used to calculate oak site indices based on the growth of yellow-poplar and Virginia pine. These oak site indices were determined to be equal to or better than the pre-mining condition (Wade et al. 1986).

It should be noted that site index curves used in this study were developed for stands on natural soils. Tree growth at Fonde was on relatively undeveloped soils. An A_1 horizon whose properties are considered important to growth of several species planted was not initially present. This suggests that a developed soil with an A_1 horizon is not absolutely necessary for tree establishment and growth on mine spoils. Assumedly, other properties of spoil compensate for the lack of the A_1 horizon. Rates of tree growth may be altered as soil horizons and ecosystems develop on minesoils.

Table 4. Mean tree density and basal areas in plantations at Fonde Demonstration Area

Plantation Type	Trees/ha	m^2/ha
Mixed Hardwoods	2192	16.7
Loblolly Pine	1808	43.8
Pitch Pine	3745	32.6
Virginia Pine	4920	51.5

Table 5. Site indices for tree species on Fonde Demonstration Area

Species	Mean d.b.h. (cm)	Mean height (m)	Mean S.I.
Loblolly Pine	23.4	15.3	27.0
Pitch Pine	14.2	10.6	22.1
Virginia Pine	15.2	13.0	27.0
Yellow poplar	16.3	15.1	27.0
off site	27.4	22.7	32.7
Red Maple	14.6	13.4	24.4
Sycamore	15.1	15.2	-
Northern Red Oak[1]	10.4	10.3	18.2+
off site	41.4	23.3	21.2
White Oak[1]	11.7	9.7	17.9+
Black Oak[1]	11.2	10.3	19.1+

[1]Oaks on the mined site were overtopped by other species. Actual site indices are probably greater.

Environmental Diversity

Results of these studies suggest that the large number and variety of plant species found on these sites are related to the overall environmental diversity created by surface mining. Instead of destroying the environment, older mining practices sometimes converted homogenous premining forest environments to several new and diverse postmining environments. Figure 1 illustrates where a homogenous premining environment was converted to five new environments: seasonally wet bench, pond, mesic bench, xeric outslope, and rock outcrop. This once common method of contour mining resulted in the cutting of a bench with spoil piled on the bench and outslope. Seasonally wet depressions, and sometimes small ponds, were left on part of the bench, usually next to the highwall. On the rest of the bench, habitats varied from mesic at the pond edge to xeric at the top of the outslope. On the outslope, habitats could vary from xeric at the top to the mesic or xeric condition of the undisturbed forest below. The highwall and associated rock surfaces provide small, specialized rock outcrop habitats. Each of these environments may provide physical niches for entirely different plant and associated animal communities. The contour mine sites provided most or all of these environments, and the rich flora present 20 years after mining reflected this environmental diversity. The presence of threatened species on some of the sites suggests that environments created by the old methods of mining are potential or actual refugia for some of our endangered, threatened, and rare species.

Soils developing from mine spoils may not be radically different chemically from the unmined soils. Minesoil (spoil) is the shattered and mixed parent material of the original premining soils. The fertility of the new soil may eventually be comparable to or better than that of the original soils unless their quality is degraded by pyritic materials. The development of soils from mine spoils varies in response to the vegetation type at each site. The O-horizon decomposes more rapidly and an A-horizon develops better under mixed hardwoods than where pine litter predominates. Black locust, black alder, and other nitrogen-fixing species have provided significant acceleration in soil development through nitrogen fixation and humus formation.

Hydrology of mined sites is different from the premining condition. The bench intercepts downslope water flow and holds some of it onsite for an indeterminate amount of time. Some of this impounded water will recharge bench and outslope water tables. The minesoils piled on outslopes and benches provide a deeper rooting zone and allow more water to be held than occurs in the usually shallow mantle of unmined forest soil. This greater water availability eventually makes the site more mesic than the original conditions. Productive plantings of sycamore, hybrid poplar (Populus spp.), cottonwood (Populus deltoides), and pin oak, species normally found in mesic habitats, have been observed on surface mines on ridge and upper slope positions. Because of better hydrologic conditions and greater soil volume, prelaw mined sites have the potential to be more productive than unmined sites.

Summary and Conclusions

Results of vegetational studies at five 17- to 20-year old surface-mined sites in the eastern Kentucky coalfields have revealed the successful establishment of vegetation at all sites. Regardless of the species or amount of area initially planted and seeded, these older-mined areas supported plant communities representative of seral stages of secondary succession. Even the planting of the commonly-used mixture of Kentucky-31 tall fescue, sericea lespedeza, and black locust has not prevented secondary succession from occurring.

A rich flora has resulted from both planted and volunteer species. A total of 360 taxa were documented at one site where minesoils are moderately acid to neutral; 350 taxa were collected at a second site where most of the minesoils were strongly to extremely acid. Important invading species common at all or most of the sites were red maple, yellow-poplar, black locust, sourwood, blackgum, Virginia pine, blackberry, greenbriar, sumac, microstegium, white snakeroot, and jewelweed.

Planted black locust was an important component of a seral stage of secondary succession that included many of the herb, vine, and shrub species found in mixed hardwood forest understories. The black locust has gradually declined and is being replaced by shade tolerant tree species. Where Virginia pine was the predominant invading species, understories contained fewer species than did black locust-grass-legume planted communities.

The old methods of surface-mining in the eastern Kentucky coal fields produced a wide diversity of environments that appears to contribute to

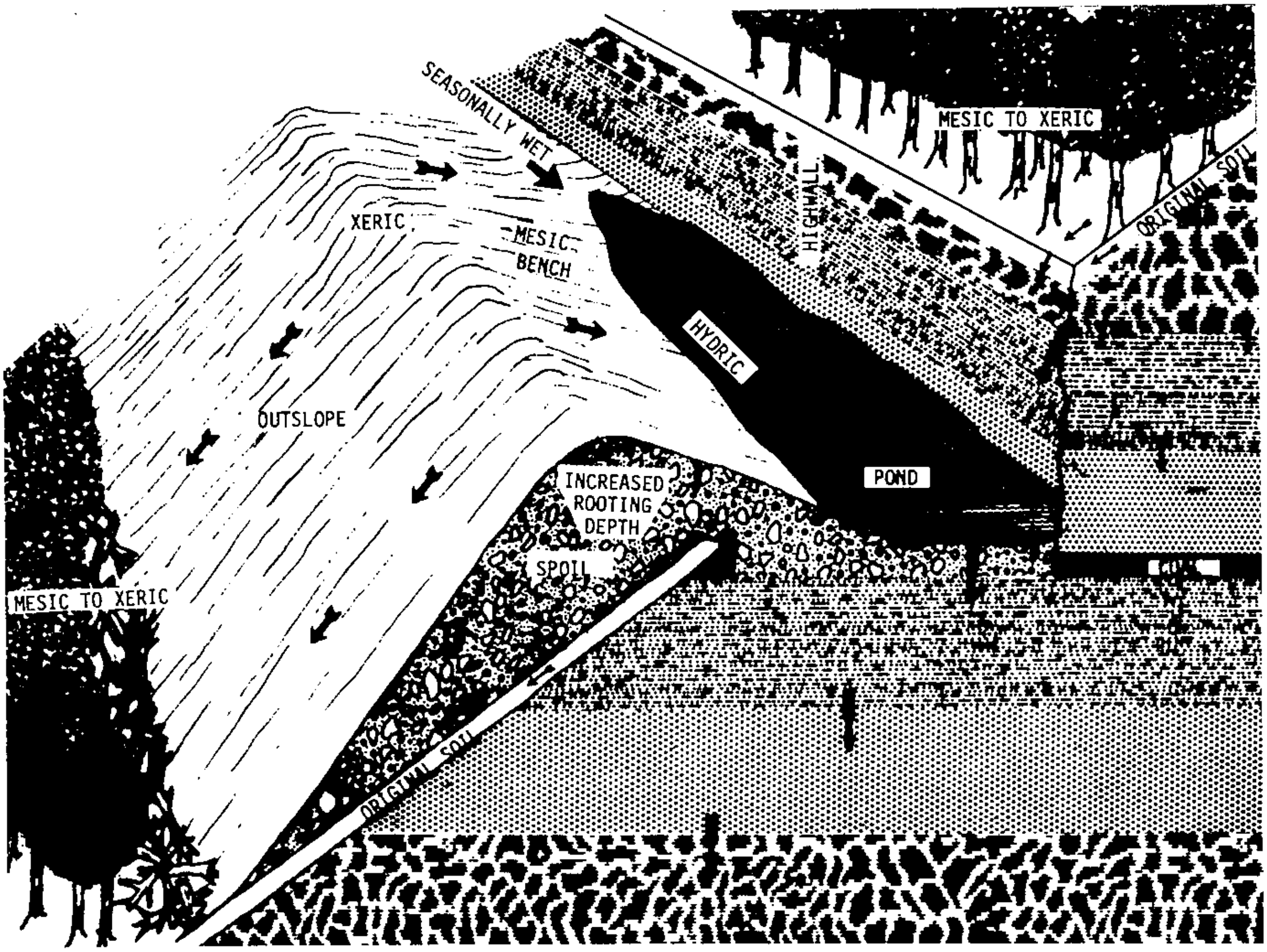

Figure 1. Representation of the environmental diversity created by pre-law contour mining techniques.

on-site species diversity. Changes in hydrology and rooting depth associated with old mining practices have created forest site conditions that are sometimes more mesic and potentially more productive than the premining condition.

Potentially productive forest ecosystems are reestablishing on some of the older surface-mined sites in southeastern Kentucky. These sites should be studied to determine the characteristics that have made them productive. Incorporating those characteristics into current and future mining and reclamation practices should be considered. Older revegetated sites also need to be reevaluated for their potential and future value as managed forests and as specialized habitats to increase local species diversity.

Literature Cited

Ashby, W. C., W. G. Vogel, and N. F. Rogers. 1985. Black locust in the reclamation equation. USDA Forest Service, Northeastern Forest Experiment Station, General Technical Report NE-105. 12 p.

Branson, B. A., D. F. Harker, Jr., J. M. Baskin, M. E. Medley, D. L. Batch, M. L. Warren, Jr., W. H. Davis, W. C. Houtcooper, B. M. Monroe., Jr, L. R. Phillippe, and P. Cupp. 1981. Endangered, threatened, and rare animals and plants of Kentucky. Trans. Ky. Acad. Sci. 42:77-89.

Braun, E. L. 1943. An annotated catalog of spermatophytes of Kentucky. J. S. Swift Co., Inc. Cincinnati, Ohio. 161 p.

Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner Press. New York. 596 p.

Foster, C. A. and D. S. Henry. 1985. Sixteen year's evolution of woody plants on surface mines in eastern Kentucky. Southern Section, Soil Conservation Society of America Meeting, February 4, 1985, Biloxi, Mississippi. 11 p.

Hampf, F. E. 1965. Site index curves for some forest species in the eastern United States, Revised. USDA Forest Service, Eastern Region, Upper Darby, Pennsylvania. 43 p.

Hinkle, C. R. 1975. A preliminary study of the flora and vegetation of the Cumberland Gap National Historical Park, Middlesboro, Kentucky. M.S. thesis. The University of Tennessee. 236 p.

Ostaff, W. S., K. L. Carvell, and H. V. Wiant, Jr. 1982. Comparative site index of eight hardwood species on the West Virginia University Forest. W. Va. For. Notes 9:18-20.

Thompson, R. L., W. G. Vogel, and D. D. Taylor. 1984. Vegetation and flora of a coal surface-mined area in Laurel County, Kentucky. Castanea 49:111-126.

Vogel, W. G. 1981. A guide for revegetating coal minesoils in the eastern United States. USDA Forest Service, Northeastern Forest Experiment Station, General Technical Report NE-68. 190 p.

Wade, G. L., R. L. Thompson, and W. G. Vogel. 1985. Success of trees and shrubs in an 18-year-old planting on mine spoil. USDA Forest Service, Northeastern Forest Experiment Station, Research Paper NE-567. 10 p.

Wade, G. L., J. T. Crews, and W. G. Vogel. 1986. Development and productivity of forest plantations on a surface mine in southeastern Kentucky. In: Proceedings, Better Reclamation with Trees Conference, June 5-7, 1985. Southern Illinois University, Carbondale, Illinois.