RECLAMATION SUCCESS AT AN ABANDONED DEEP COAL MINE SITE NEAR STAUNTON, ILLINOIS[1]

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Abstract.--Reclamation activities began in 1976 on the 13.8-ha site of an abandoned deep coal mine near Staunton, IL. An area of about 9.3 ha was severely eroded, devoid of vegetation, and received little use by wildlife. Reclamation procedures included grading and recontouring the coal refuse (gob) pile and slurry area, covering exposed refuse material with soil, liming the soil, seeding with selected plant species, and creating a pond to receive runoff from the site. To evaluate reclamation, soil depth (30 and 60 cm) and liming rate (112 and 224 t $CaCO_3$ equivalent/ha) were experimentally manipulated in plots on top of the gob pile. Studies were conducted annually from 1977 to 1982 and again in 1987. After reclamation activities were completed, vegetation quickly became established over most of the site, except for some areas on the slopes of the gob pile. Vegetative cover was greatest on plots with 60 cm of soil and a 224 t/ha liming rate. Soil depth appeared to be more important than liming rate in determining vegetative cover. Wildlife used the site following reclamation, especially those areas with the greatest habitat diversity.

INTRODUCTION

The success of reclamation activities at an abandoned deep coal mine was evaluated approximately 10 years after initial reclamation efforts were made. Reclamation began in 1976 at the abandoned Consolidated Coal Company Mine No. 14 in Macoupin County, IL, near the town of Staunton (Jastrow et al. 1984). The site covered 13.8 ha and included a 9.3-ha area that had been affected by past mining and coal refuse disposal operations that had taken place from 1904-1921. The steep, 25-m-high refuse (gob) pile covered 1.8 ha and was highly eroded and devoid of vegetation. Vegetation was also lacking from areas that received acid runoff from the pile. Most drainage from the gob pile was impounded during mine operation behind a dam that had been constructed across a ravine near the edge of the property. After mining ceased, this impoundment continued to receive runoff and sediment from the gob pile, and sediment accumulated to a depth of approximately 9 m. In the early 1940's, the dam was breached and the 4.5-ha slurry area began to erode and contribute acidic runoff and sediment to nearby Cahokia Creek. This slurry area was also largely devoid of vegetation when reclamation activities began in 1976.

Reclamation work began with the excavation of a borrow pit adjacent to the gob pile (Jastrow et al. 1984). From the borrow pit, B and C soil horizon material (weathered Illinoian glacial till) was removed and stockpiled for use as cover material. Material from the gob pile was used to fill the borrow pit, and the pile was graded. The recontoured pile was one

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fifth of its original height and covered an area more than twice its original size (fig. 1). The remainder of the area was also graded, and a new 0.5-ha sediment retention pond was created in the slurry area. Neutralizing agents were applied to the refuse and slurry areas at 170 t/ha $CaCo_3$ equivalent and incorporated to a depth of 15 cm using a disk harrow. Agricultural limestone was used as a neutralizing agent on the gob pile and "Code L Alkali", a fine-textured mixture of calcium oxide and calcium carbonate, was used on the slurry area to stabilize as well as neutralize the fines. Stockpiled soil material was then placed to a depth of 30 cm over the gob pile and slurry areas. The top of the gob pile was graded flat to prevent runoff and erosion of cover material from the area. Agricultural limestone (11.2 t/ha 75% $CaCO_3$ equivalent) was applied to the entire site and incorporated to a depth of 10 cm. Next, the site was fertilized with nitrogen, phosphoric acid, and potash (135 kg/ha each) and, in April 1977, seeded with a mixture of legumes and grasses (table 1). Bare areas totaling 2 ha were reseeded in August and September 1981 with additional species.

Sixteen revegetation research plots were established on 0.73 ha of the top of the gob pile and were prepared and treated in a different manner from that described in the preceding paragraph (Jastrow et al. 1984). A factorial experimental design was used to determine the effects of four different soil cover material depths (0, 15, 30, and 60 cm) and two liming rates (112 and 224 t/ha) on revegetation of the limed gob pile. Two replicate plots (21.3 by 21.3 m) were used for each treatment combination. Plots were seeded with species listed in table 2. Due to difficulties in soil cover application, the 15-cm soil depth plots actually had 30 cm of soil cover and were, therefore, considered with other 30-cm plots in the analysis. Extremely poor plant establishment occurred on the 0-cm soil depth plots, and these were later covered with soil material and seeded; these plots were eliminated from the analysis.

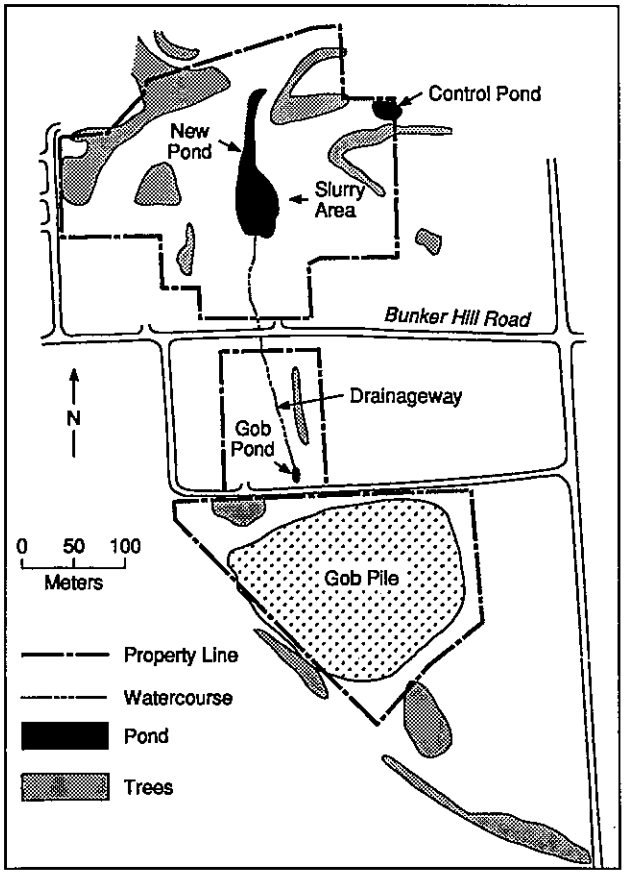

Figure 1.--Staunton Reclamation Site.

Table 1.-- Seed mixture used to revegetate the Staunton Reclamation Site in April 1977 (Jastrow et al. 1984).

Species	Application Rate (kg/ha)
Reed canarygrass (*Phalaris arundinacea*)	11.2
Tall fescue (*Festuca arundinacea* cv. Kentucky-31)	16.8
Birdsfoot trefoil (*Lotus corniculatus*)	13.5
Ladino clover (*Trifolium repens*)	5.6
Cereal rye (*Secale cereale*)	22.4

The results of research to determine the success of reclamation activities in promoting revegetation and wildlife use of the site from 1977 to 1981 has been reported elsewhere (Pentecost and Stupka 1979; Jastrow et al. 1984). Most of the results indicated that reclamation had been a success on these accounts although some areas of the gob pile had begun to develop acid seeps by 1981 (Jastrow et al. 1984). The objective of the current research effort was to evaluate the site 10 years after initial reclamation activities took place.

MATERIALS AND METHODS

Experimental Revegetation Plots

Revegetation was evaluated in research plots with 30-cm and 60-cm soil cover depths in August 1977, June and August of 1978 through 1981, June 1982, and July 1987. Within each plot, five parallel, evenly spaced, east-west transects were

Table 2.--Seed mixture used on revegetation research plots on the Staunton Reclamation Site, April 1977 (Jastrow et al. 1984).

Species	Application Rate (kg/ha)
Little bluestem (*Andropogon scoparius* cv. Camper)	6.3
Smooth brome (*Bromus inermis* cv. Lincoln)	8.3
Orchardgrass (*Dactylis glomerata* cv. Potomac)	8.3
Tall fescue (*Festuca arundinacea* cv. Kentucky-31)	12.2
Deertongue (*Panicum clandestinum* cv. Tioga)	4.4
Switchgrass (*Panicum virgatum* cv. Blackwell)	11.1
Reed canarygrass (*Phalaris arundinacea*)	6.6
Birdsfoot trefoil (*Lotus corniculatus*)	8.3

established. The point-intercept method was used along these transects to estimate plant cover (Mueller-Dombois and Ellenberg 1974). Four sampling sites were chosen at random within each transect and areal cover was estimated with a 1-m-tall, 10-pin point frame with pins 10 cm apart. Three transects in each plot were used in 1987 to estimate areal cover. Areal cover for each species in a plot was estimated by determining the percentage of pins that were touched by that species during a sampling period. Thus, if a species touched 100 of 200 pins in a plot (200 pins = 10 pins/frame x 4 frames/transect x 5 transects/plot), the estimated areal cover for that species was 50%. Total cover was estimated in a similar fashion, but the percentage of pins in contact with any plant was used to calculate cover. Data from 1977 to 1981 were reported in Jastrow et al. (1984). The entire data set from 1977 through 1987 is re-evaluated in this report to determine the long-term effects of the soil treatments used.

Wildlife Studies

In 1987 surveys of bird and mammal use of the site were conducted over a five-day period. Three areas were surveyed for birds--the gob pile, slurry area, and drainageway between the gob and slurry areas (fig. 1). Both qualitative (species lists) and quantitative (relative numbers and use) data were collected for each of these areas. All bird and mammal (including tracks) species seen in these areas during the course of field work on the site were recorded to develop a list of species using the site in 1987. In addition, systematic counts of birds were made during morning hours (0530 to 0830 CST) while walking slowly through each area. Records were kept of the amount of time spent in each area (an estimate of effort expended) and the number of each species seen on or flying over each area. Small mammals were live-trapped on three consecutive nights using collapsible Sherman live traps (9 cm by 9 cm by 23 cm). Rectangular trap grids were established on top of the gob pile (4 by 5 grid), at the base of the gob pile (4 by 5 grid), and in the slurry area (4 by 6 grid). Distances between traps on the gob pile top, slurry area, and gob pile base were 21 m, 10m, and 10m, respectively. Traps were baited with a mixture of peanut butter and rolled oats each evening near dusk and checked the following morning. Trapped individuals were identified, sexed, and toe-clipped for later identification. The results of these surveys and similar wildlife studies conducted on the site during the summer months of 1977 and 1978 (Pentecost and Stupka 1979) were compared to determine if changes in species use had occurred since initial reclamation efforts were made.

RESULTS AND DISCUSSION

In general, vegetative cover over the entire site was well established in 1987. Excellent cover was attained in the slurry area and areas with at least 30 cm of soil cover on top of the gob pile. Only areas where acidic gob material was exposed due to erosion of slopes or where acidic drainage occurred were devoid of vegetation. These areas were concentrated on the slopes of the gob pile (especially the south slope) and in the drainage area between the gob pile and the slurry area pond. Erosion problems and lower cover in these areas were noted in 1978 (Jastrow et al. 1984). As water penetrates the soil cover material, it flows over the relatively impenetrable gob material and acidifies, and then discharges near the bottoms of slopes (Drake 1983b). The acidic water issuing from these seeps results in the death of nearby plants and subsequent erosion of the exposed soil. Because of the extremely low pH (approximately 2.5; Vinikour et al., elsewhere in these proceedings) of water in the drainageway and the slurry area pond, no emergent vegetation was present in 1987 despite the early establishment of cattails after initial reclamation activities were completed in 1976. Most cover present on the site was provided by species that were originally planted, but several other plants including common reed (*Phragmites communis*) and several tree species (mostly cottonwood, *Populus deltoides*; willow, *Salix* sp.; and black locust, *Robinia pseudoacacia*) had become established, especially in the slurry area.

Experimental Revegetation Plots

Vegetative cover was high (mean of 75% or more) for all treatments (fig. 2). However, differences among years and treatment (soil depth and liming rate) were apparent (table 3). Areal cover in the first year following reclamation was high (> 90%) in all experimental plots. Differences between treatments were apparent in subsequent years, especially in the drought years of 1979 and 1980. Soil depth appeared to have a greater effect on vegetative cover than did lime application rate (table 3; fig. 2). Plots with 60 cm of soil cover had the highest percentage of plant cover; the amount of lime used did not affect cover in these plots. For plots with 30 cm of soil, lime rate was important; plots with 224 t/ha of lime had greater plant cover than did plots with 112 t/ha.

Soil depth has been shown in other studies to affect the growth and establishment of plants on acidic mine refuse (McGinnies and Nicholas 1980; Drake 1983a, 1986). Increased soil depth serves to increase the distance between the acidic gob material and the roots of plants and it also increases the amount of water available to plants. This latter point was made especially apparent during the drought years of 1979 and 1980 when plant cover on 30-cm-deep soil was considerably less than that on 60-cm-deep soil. Although the amount of lime applied to the plots had less of an effect than soil depth on plant growth, increased lime did serve to promote vegetative cover. The effect of lime was more apparent in 30-cm-deep soil than in 60-cm soil presumably because of the reduced distance between plant roots and the acidic gob material in the 30-cm soil and thus, the greater need for neutralizing agents.

Invading (nonplanted) species dominated revegetation plots only during the first year, and were almost completely replaced by species that were planted in 1976 (fig. 2). Drake (1983a) also reported that foxtail (*Setaria* sp.) was dominant

Table 3.--Analysis of variance for the effects of lime application rate, soil depth, and year on percent areal cover of vegetation on the Staunton Reclamation Site.

Source	d.f	F	P > F	
Lime Rate	1	4.7	0.04	*
Soil Depth	1	27.0	0.0001	*
Year	6	61.4	0.0001	*
Lime x Depth	1	3.6	0.06	
Lime x Year	6	0.2	0.97	
Depth x Year	6	4.7	0.001	*
Lime x Depth x Year	6	0.2	0.98	

*Significance at the 0.05 level.

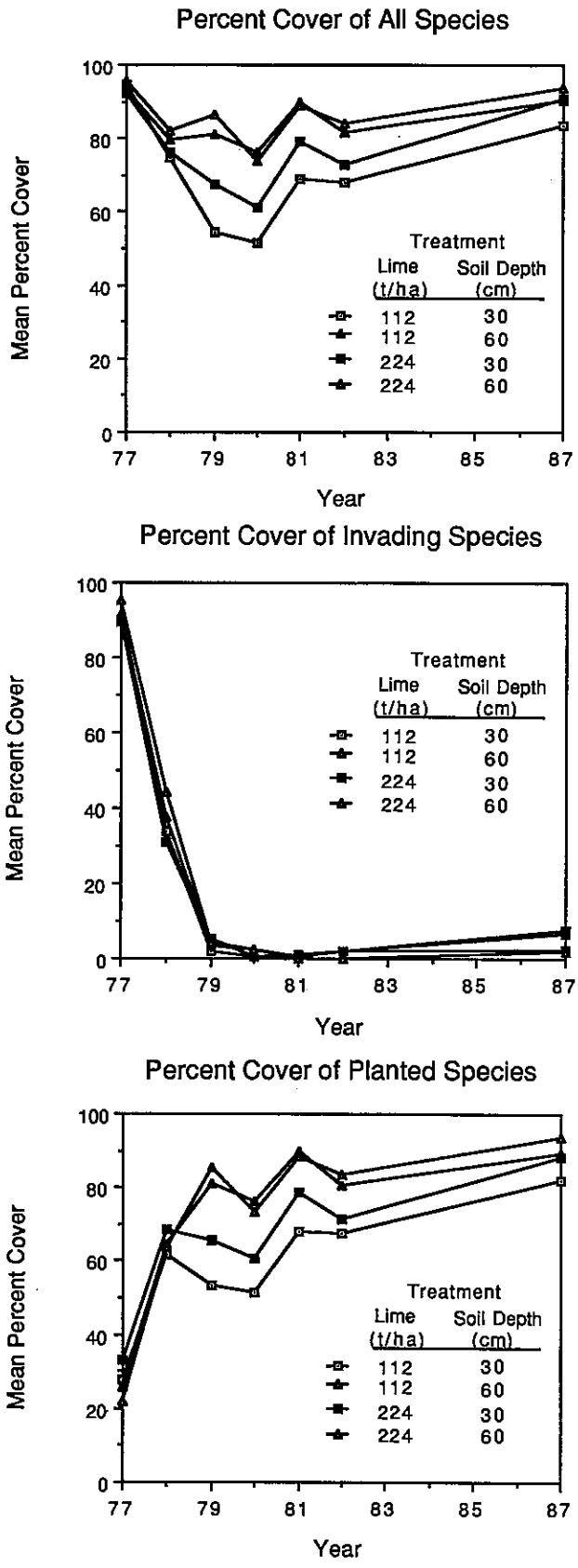

Figure 2.--Percent areal cover of vegetation according to soil depth and lime application rate on the Staunton Reclamation Site, 1977 to 1987.

during the first years following reclamation, but was rapidly replaced by perennial grasses. Representation of the planted species varied through time, and some species were almost completely eliminated (deertongue, orchardgrass, reed canarygrass). Switchgrass and little bluestem, both relatively drought-tolerant, were most abundant in 1987. These two species were found to be particularly suitable for the revegetation of acid mine spoils in Iowa (Drake 1983b).

Wildlife Studies

Thirty four species of birds were observed on the site during field work conducted in July 1987 (table 4). The most common species included the European starling, house sparrow, barn swallow, chimney swift, and eastern meadowlark. Species observed on the site were similar to those recorded for adjacent areas in 1977 and 1978 (Pentecost and Stupka 1979).

The total number of birds observed per hour of survey was greatest for the drainage area and least for the gob pile, although values were relatively similar (table 4). Differences between areas can be explained by differences in the availability of different habitats and ecotones (edges) within each study area. The drainage area was fairly narrow and bordered on one side by trees and on the other by an overgrown fencerow. The slurry area was predominantly an oldfield community, but there were stands of small trees along several drainages within the area that increased habitat diversity. The slurry area was surrounded by oldfield and forest communities. If the pond created in the slurry area had not acidified and retained some emergent vegetation, bird numbers and diversity in this area would probably have been higher. The gob pile, dominated by a grassland community, had little habitat diversity; it was approximately rectangular in shape with forest and oldfield along its borders.

Table 4.--Bird species seen on the gob pile, slurry area, and drainage area of the Staunton Reclamation Site, July 1987. Numbers presented are birds observed per hour of surveying.

Species	Survey Area		
	Gob	Slurry	Drainage
Bobwhite (*Colinus virginianus*)	r	2.3	1.9
Killdeer (*Charadrius vociferus*)	4.2	4.5	0
Mourning Dove (*Zenaidura macroura*)	1.4	4.5	1.9
Chimney Swift (*Chaetura pelagica*)	12.7	16.5	13.1
Common Flicker (*Colaptes auratus*)	0.7	r	0
Downy Woodpecker (*Picoides pubescens*)	0	r	0
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	0	0.8	0
Eastern Kingbird (*Tyrannus tyrannus*)	0	0.8	0
Eastern Phoebe (*Sayornis phoebe*)	r	0	0
Eastern Wood Pewee (*Contopus virens*)	0	0.8	0
Barn Swallow (*Hirundo rustica*)	12.7	3.0	13.1
Rough-winged Swallow (*Stelgidopteryx ruficollis*)	r	0	0
Purple Martin (*Progne subis*)	4.9	2.3	1.9
Carolina Chickadee (*Parus carolinensis*)	0.7	1.5	0
Tufted Titmouse (*Parus bicolor*)	1.4	0	0
White-breasted Nuthatch (*Sitta carolinensis*)	0	0.8	0
House Wren (*Troglodytes aedon*)	0.7	0	0
Northern Mockingbird (*Mimus polyglottus*)	0	r	0
Brown Thrasher (*Toxostoma rufum*)	1.4	0	1.9
American Robin (*Turdus migratorius*)	7.1	3.0	5.6
European Starling (*Sturnus vulgarus*)	10.6	24.0	28.1
Warbling Vireo (*Vireo gilvus*)	1.4	1.5	0
Common Yellowthroat (*Geothlypis trichas*)	0	2.3	1.9
Yellow-breasted Chat (*Icteria virens*)	r	0	0
House Sparrow (*Passer domesticus*)	10.6	12.8	18.8
Eastern Meadowlark (*Sturnella magna*)	10.6	6.8	1.9
Red-winged Blackbird (*Agelaius phoeniceus*)	0.7	6.8	7.5
Common Grackle (*Quiscalus quiscula*)	0.7	1.5	0
Brown-headed Cowbird (*Molothrus ater*)	0.7	0	0
Northern Cardinal (*Richmondena cardinalis*)	0.7	0	5.6
Indigo Bunting (*Passerina cyanea*)	0	0	1.9
American Goldfinch (*Spinus tristis*)	0.7	0	0
Field Sparrow (*Spizella pusilla*)	1.4	0	0
Song Sparrow (*Melospiza melodia*)	0	0	5.6
Total Birds Observed/hr	86.1	96.0	110.6

r = indicates that the species was observed, but not counted during the surveys.

Evidence of nesting was observed for two species although the surveys were conducted outside of the nesting season and an intensive search for nests was not conducted. A covey of bobwhite consisting of mother and several chicks were flushed occasionally while doing field work in the slurry area. An unhatched killdeer egg was seen on an exposed patch of soil on the top of the gob pile. Singing males of a variety of species were observed and many of the species probably nest on the site or in the vicinity.

Trapping, direct observation, and observation of sign in July 1987 resulted in the recording of seven species of mammals for the site (table 5). The prairie vole was abundant on the site and had a higher density in the slurry area than on the gob pile (4 captures in the two 20-trap grids on the gob pile; 12 captures in the 24-trap grid in the slurry area). The house mouse was the only other species captured in the live traps (one captured in slurry area). The deer mouse (*Peromyscus maniculatus*) was not captured in 1987 although this species is often abundant on abandoned mined lands (Sly 1976; Hansen and Warnock 1978). Hanson and Warnock (1978) found an inverse relationship between the abundance of the deer mouse and the abundance of grasses; the dense grass cover present in all areas of the site may not have provided suitable habitat for this species. Of the species recorded in 1987, only the gray squirrel had not been recorded in 1977 and 1978. The muskrat (*Ondatra zibethica*) was not seen in 1987 despite its being recorded in previous years. This can undoubtedly be attributed to the acidification of the pond and the subsequent die-off of emergent vegetation (Perry 1982; Allen and Hoffman 1984).

SUMMARY AND CONCLUSIONS

The results of the experimental revegetation studies indicate that soil depth is more important than the rate of lime application in determining the amount of vegetative cover on acidic gob material. It appears that 60 cm of soil is adequate for establishing cover of 80% or more. Once initial reclamation practices are complete and the area is seeded with perennial grasses, especially drought-tolerant species, the community can become self-sustaining. The low-relief slurry area on the site had excellent plant growth and essentially 100% cover with only 30 cm of soil cover.

Seepage of acidic water from the gob material and erosion of areas devoid of vegetation is one unresolved issue that needs further consideration. Drake (1983b) suggests several designs for directing acid throughflow that could prevent plant loss and erosion. The type of lime material may also be important in preventing acidification of the soil cover. On the gob pile, agricultural limestone was used. This material was fairly coarse and the large chunks became coated with iron precipitates, thus limiting its neutralizing capabilities. A finer textured neutralizing material is recommended.

Despite the problems in establishing complete vegetative cover and preventing erosion, the site was used by a variety of wildlife species. Habitat diversity appears to be the most important factor at this point in determining the use of the site by wildlife. A diverse wildife population can be obtained by properly planning the area for a variety of habitat types.

Table 5.--Mammals recorded on the Staunton Reclamation Site, July 1987.

Opossum (*Didelphis marsupialis*)
Raccoon (*Procyon lotor*)
Cottontail (*Sylvilagus floridanus*)
Gray Squirrel (*Sciurus carolinensis*)
House Mouse (*Mus musculus*)
Prairie Vole (*Microtus ochrogaster*)
White-tailed Deer (*Odocoileus virginianus*)

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