that point would be narrowed, and state regulation might be the only solution.

Fortunately, we feel that the interim solution has been received with tacit acceptance by policy makers, environmental groups and most importantly, the landowner. We are encouraged that the integrated and interdisciplinary approach to resolving this major social issue will prevail.

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Plant Succession on Surface Mined Lands in the West

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Editor's Note: A paper on this subject, " 'Native' vs. 'Exotic'—The Dilemma of Ecological Mine Waste Revegetation" by Stuart A. Bengson, appeared in *Rangelands* 8(2):65-67, 1986.

Succession is a natural process of plant community development. On abandoned spoil, succession to a stable community may take from tens to hundreds of years. Reclamation is important in shortening the time period of succession. However, even under the best reclamation technology it is not possible to immediately establish communities that are as diverse or as stable as native communities. Consequently, succession will be important in further development of communities following initial plant establishment. Succession may initially increase species diversity, allow establishment of microbial populations, and promote soil development.

Plant succession will also be important in meeting requirements of the Surface Mining Control and Reclamation Act of 1977. This law requires that plant communities be established that are permanent, effective, diverse, and of the same seasonal variety as those native to the area or that will support the approved post-mining land use. When the proposed post-mining land use is grazing land, the goal of reclamation is essentially to establish diverse and stable plant communities which will sustain livestock grazing and wildlife use. To accomplish this goal within a short time frame, techniques which will accelerate succession must be used.

Natural Succession on Abandoned Mine Spoil

Geologic material removed from above a mineral deposit during surface mining is commonly referred to as spoil. Spoil varies considerably in physical and chemical properties because of the different geological formations from which it originates, and may contain high concentrations of soluble salts or acid-forming materials.

The process of succession on spoil can be better understood through an analysis of the factors that affect it. There have been many descriptions of these factors and one of the most simple and yet one of the most complete is the model used by Major (1951) to describe the interrelationship of plants to their environment. The model includes the effects of regional climate, parent material, relief, organisms and time. This model is compatible with most climax-oriented successional theories including Daubenmire's (1968) and Odum's (1971). In this model, organisms include soil biota, vascular plants, animals, and man.

Climate and time can be considered independent factors since they can not be greatly influenced during the reclamation process. Therefore, the remaining three factors (organisms, parent material, and relief) become especially important in the design of reclamation practices to induce succession on mined lands. These are also factors which have been emphasized in recent studies of succession on orphaned spoil in the West.

Organisms

Soil Biota

Cundell (1977) in his review of the role of microorganisms in revegetation of strip-mined lands stated that the first microorganisms to inhabit abandoned spoil are those with the capacity to fix atmospheric nitrogen. Free nitrogen in the spoil in turn stimulates invasion and establishment of other microorganisms and the first plants. Researchers report that as spoil age increases, microbial activity becomes similar to that in native soils. Stroo and Jencks (1982) working in West Virginia, reported that after 20 years, microbial activity in the surface 10 cm of spoil was less than in native soils. They also

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found that while the presence of vegetation was essential for recovery of microbial activity, it did not always guarantee recovery. Nitrogen cycling and retention also appeared important in recovery of microbial activity. Biondini et al. (1985) postulated that as the plant community develops and late successional plant species become established, there may be a successional shift in the microbial composition from species that depend on free nutrients in the soil to plant dependent species which function in the root zone.

Vascular Plants

Revegetation of abandoned spoil is a developmental process. Plants capable of invading and becoming established on spoil are key elements of the initial community. Wagner et al. (1978), working on untreated spoil in northwestern New Mexico, ranging in age from 1 to 13 years, found that species diversity showed no correlation with site age. However, species diversity did appear to be related to site size. It was believed that this relationship of diversity to site size might be a reflection of the limited number of species with sufficiently effective dispersal mechanisms to allow quick colonization of the larger areas.

Sindelar and Plantenberg (1978) studied naturally revegetated mine spoil in southeastern Montana. The spoil was deposited in 1930 by truck and leveled around several hilltops, thereby leaving "islands" of native vegetation within the site. The authors reported that the site was successfully revegetated with productive and diverse vegetation in less than 47 years by natural processes. Important factors contributing to this rapid establishment were the proximity and nature of the seed source. Plants available to colonize an area are important to the types of communities that become established. Skilbred (1979) reported that one reason several plant communities on 50-year-old spoil were dominated by undesirable species was because of the availability of these plants to invade from adjacent overgrazed areas.

Animals

Grazing animals can greatly influence the process of succession through selective consumption of forage species and dispersal of seeds. Sindelar and Planteberg (1978) reported that one of the reasons spoil leveled in 1930 had more desirable vegetation cover than spoil leveled in 1928 was because the vegetation in 1930 spoil had been grazed less. Some level of grazing may be beneficial while heavy use will retard succession or cause retrogression. Judd (1940) found succession to be hastened on abandoned fields adjacent to virgin prairies because of moderate grazing, while heavy use inhibited succession. It has been suggested that small mammal populations may decrease diversity of plant communities on reclaimed lands through their concentrated feeding on less abundant forbs and shrubs (Hingtgen and Clark 1984).

Soil (Parent Material)

Pedogenesis or soil development is a slow process, which would be expected to advance prior to and concurrently with plant succession. Barker (1979) studied pedogenesis on 16- and 40-year-old abandoned spoil in south central Wyoming, and found indications of soil development in both age groups. Schafer and Nielsen (1979) studied soil development and plant succession on abandoned spoil and reclaimed areas in southeast Montana. They found that soil development processes characteristic of undisturbed soils were also occurring in 50-year-old spoil; however, pedogenesis had advanced only slightly over 50 years. In many cases, the authors were unable to distinguish trends in soil development from inherent variability among spoil materials.

The effect of soil texture on plant species composition and life forms growing in a particular area is well-known. In their studies of plant succession, Schafer and Nielsen (1979) found that perennial grass production increased on finer textured spoil while half-shrub production was higher on coarse textured spoil. Wali and Freeman (1973) examined mine spoil from 0 to 53 years of age throughout western North Dakota. They concluded that moisture availability was a major factor limiting plant establishment. Inadequate percolation of water through the upper spoil layers contributed to this problem because of high clay and sodium contents.

Relief

Relief or topography influences plant community development through its effects on microclimate and pedogenesis. Slopes which have a southern aspect are generally warm and dry while those having a northern aspect are cool and moist. These microclimatic conditions cause a divergence in soil development and plant succession leading to divergent plant communities.

Jacoby (1968) examined some of the factors influencing natural revegetation of 3-, 8-, and 15-year-old mine spoil in southwestern Wyoming. He concluded that moisture availability was the primary factor limiting plant establishment. Steep slopes did not allow water infiltration and level tops did not favor snow capture. Jonescu (1979) studied succession on spoil ridges placed from the 1930's through the 1960's in southeastern Saskatchewan. Her analysis showed that interridge areas were more successionally advanced than spoil slopes because of more mesic conditions.

Reclamation Techniques

A number of reclamation techniques can be used to accelerate and direct plant community succession on mined lands. In essence, such techniques are applied to modify the major factors (organisms, parent material and relief) that control succession.

Grading

The primary goals of a grading or contouring plan are to provide mass stability, control erosion and allow vegetation establishment (Verma and Thames 1978). Techniques such as benching, terracing and creating undulating surfaces help attain these goals and also provide the varied habitats required for landscape diversity. Studies in southeast Montana, showed that contour terracing provided microtopography which increased establishment of nonseeded native species (King 1980). Shaping to create concave sites allowed collection of slope runoff and produced optimal areas for survival of woody species in North Dakota (Wollenhaupt and Richardson 1982). Schafer (1984) reported that mine soils in the Powder River Basin were less variable over an entire landscape than natural soils. To create reclaimed sites that favor vegetation diversity, Schafer suggested establishing distinct landscape slopes and aspects. In their soil-plant diversity relationship studies, Stark and Redente (1985) found that plant production and diversity were inversely correlated. They postulated that by modifying the land surface to create varied microclimates diversity could be increased without radically affecting area-wide production.

Topsoil Replacement

Topsoil replacement is the act of distributing the upper layers of soil material, generally consisting of the A and B horizons and at times the C horizon, over graded spoil materials. Topsoil is usually superior to spoil as a plant growth medium due to the presence of plant propagules, higher organic matter content, and presence of microorganisms.

If topsoil is immediately reapplied after salvage, much of the pre-existing microbial populations may be maintained and reproduction from plant parts and seeds may be stimulated. Volunteer growth from viable seeds and plant parts within the replaced topsoil may help add diversity to the plant community (King 1980). Fresquez et al. (1985) found that soil microbial populations in 4-year-old topsoiled sites were similar to those of undisturbed soils, suggesting that the microbial community was beginning to stabilize only 4 years after topsoil replacement and revegetation. However, if topsoil is stored for long periods prior to application, much of the potential for rapid microbial recovery will be lost. Miller and May (1978) showed storage of topsoil for up to two years was more damaging to the microbial population than initial impacts of topsoil removal. Loree and Williams (1984) indicated that the infective potential of vesicular-arbuscular mycorrhizae in stored topsoil was negatively correlated with stockpile age.

Selective replacement of topsoil materials differing in texture, thickness, percent coarse fragments or organic matter content has been suggested as a method to enhance plant community diversity by creating varied habitats on reclaimed areas (Redente et al. 1984, Schafer 1984).

Species Selection

The selection of plant materials for reclamation must be based on the proposed post-mining land use, adaptation to the site specific environmental conditions and synecological relationships. Overly aggressive species have often been noted to slow invasion and thus succession. It has often been reported that cover of invading species increased in communities seeded to native species and decreased in areas where aggressive introduced species established closed communities. DePuit et al. (1980) noted declines in diversity over time even on mined lands seeded exclusively to native species, due to progressively greater dominance of the most vigorous native species in the mixture. Redente et al. (1984) found that after six growing seasons the effects of fertilization, irrigation, seeding method and manipulation of seeding ratios among life forms were no longer influential in plant community composition. Instead, it appeared that only species composition of the initial seed mixture and environmental factors such as soils and climate were the most important variables.

This illustrates that if succession is to play a role in the species enrichment of a planted community, the species used should be considered carefully. Species that are aggressive and may form closed communities, whether introduced or native, should be used with caution.

Mulching

Mulching has two basic purposes as a cultural practice on reclaimed lands: to prevent wind and water erosion, and to aid vegetation establishment by providing a more favorable environment. It may also re-inoculate the soil with microorganisms: however, research has shown that providing a carbon source (such as a mulch) is more beneficial to stimulating microflora populations than is supplying an inoculant source (Fresquez and Lindemann 1982, Lindemann et al. 1984).

Additionally, Ries et al. (1980) believed that use of native hay mulch could potentially increase community diversity and provide a supplemental seed source of species not commercially available. This practice should be used with caution, however, because it can lead to an influx of undesirable species.

Planting Methods

There are several methods of establishing plants on disturbed areas including direct seeding and transplanting. Drill and broadcast seeding are by far the most common methods of planting reclaimed areas. Drill seeding is considered to provide the best microenvironment for seedling establishment. However, DePuit et al. (1980) suggested that to achieve a balance between initial establishment, productivity and diversity, diverse seed mixtures should be broadcast seeded. Doerr and Redente (1983) found no significant difference in grass production between drill and broadcast seeding when broadcast seeding was performed with twice the quantity of seed, but found forb biomass was greater on broadcast seeded plots. Redente et al. (1984) reported that after six growing seasons, differences between seeding methods were no longer important.

Some species are not readily established by direct seeding methods. Transplanting methods may allow establishment of such species. These methods may also supplement natural invasion of advanced successional species which are slow to colonize disturbed areas.

Irrigation

Most researchers support the concept that irrigation should be used only temporarily to aid in plant community establishment. For this reason, irrigation generally has not been considered important in the long-term community development process. Doerr et al. (1983) found that irrigation during the first two growing seasons shortened the time required for grasses and forbs to establish and reach high production levels. However, this gain was only short-term, and after 4 years there was no significant difference in aboveground biomass production and canopy cover between irrigated and nonirrigated treatments. Additionally, irrigation reduced shrub biomass and densities throughout the study period.

Recent work in Montana and North Dakota indicates that irrigation may be used to establish warm-season grass species which are difficult to establish under ambient precipitation. Ries (1980) found that supplemental irrigation would permit planting later in the growing season and that applica-

Fig. 1(*Top photo) 35-year-old abandoned coal mine spoil in north central Wyoming showing poor plant community development.*
Fig. 2.(*Middle photo) Seeding of regraded and topsoiled coal mine spoil in Colorado.*
Fig. 3.(*Bottom photo) Successfully reclaimed coal mine spoil in northwest Colorado.*

tion of different amounts of water could allow control of species composition in newly established stands.

DePuit et al. (1982) concluded that one year of supplemental summer irrigation stimulated first-year productivity of seeded perennial grasses, promoted warm-season perennial grass development, and increased stand diversity. However, a second year of irrigation promoted highly irrigation-responsive species and reduced evenness of cover among seeded species. Williamson (1984) reported that a balanced grassland with both warm-season and cool-season grasses was produced when seeding was completed in late spring, irrigation was used during the first growing season, and seed mixtures were weighted in favor of warm-season species.

Irrigation, through its effect on the developing plant community, may also have a beneficial effect on the below-ground portion of the ecosystem. Klein et al. (1984) reported that irrigation during the first two growing seasons showed a significant positive effect on microbial activity because of increased organic matter production.

Post-Reclamation Management

Post-reclamation management plays an important role in achieving stability and permanence of the developing plant community (Sindelar 1984). Careful management is needed to encourage succession in the intended direction. Overgrazing may set the developing community back to an earlier successional stage. In many cases, however, proper grazing may be important in accelerating succession and increasing diversity. DePuit and Coenenberg (1980) concluded that varied grazing systems may have great potential as management tools in manipulating mined land vegetation to achieve reclamation goals. They found that proper spring, summer, and fall grazing of a mined land plant community dominated by introduced species was generally beneficial in stimulating productivity; reducing excessive standing dead biomass and ground litter accumulations; and increasing plant species composition evenness and floristic richness. However, their results also showed that grazing did not induce diversities equal to that of native rangeland, indicating that grazing alone can not be relied on to achieve high diversity over short time periods. Other techniques such as prescribed burning, haying, fertilization, herbicide treatment and interseeding have potential in manipulating the vegetation. However, research concerning such management practices on reclaimed land is minimal (Sindelar 1984).

Conclusion

Vegetation established on mined lands must meet land use needs, and must be self-perpetuating unless the land is to be returned to crop production. In areas of the West where annual precipitation and agronomic potential are low, it is usually proposed to return mined lands to their historic use as grazing land. Native plant communities of these regions have evolved under herbivory and contain a variety of species which provides permanent ground cover and often season-long forage. Plant communities established on reclaimed lands should be similar to indigenous communities to provide a similar utility unless the land use is altered.

It is not feasible to rapidly establish stable and diverse plant communities on mined lands. Ultimately, however, stable ecological systems will develop as products of succession. Succession is the process of change in vegetation over time, and may require tens to hundreds of years for full expression. Data on plant succession for semiarid and arid mined lands are limited. Because of this lack of information, many questions remain concerning the successional process and controlling factors.

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Reseeding Almost Complete Following Wildfires in the West

Reseeding of vegetation is almost complete on about 20,000 acres of private land in the West burned by wildfires this summer, according to the U.S. Department of Agriculture.

Wilson Scaling, chief of USDA's Soil Conservation Service, said $917,000 in SCS's Emergency Watershed Protection (EWP) funds have been allocated to California, Oregon, Idaho, Utah and Nevada since Sept. 1 to restore fire damaged areas now vulnerable to wind and water erosion. EWP funds will pay up to 80 percent of the cost, with the remainder split between state and local jurisdictions. In some instances, EWP funds will pay the entire cost of reseeding.

According to Scaling it is important to quickly reseed into the ash after a fire before rain soaks the ash and cakes it. "Even before the fires were put out, we were working with inter-agency teams to pinpoint areas that would be vulnerable to erosion. We then recommended the vegetation that would provide the best cover and protection against soil erosion," he said.

Scaling said that reseeding recommendations are made by consulting SCS field office technical guides that take into account such factors as climate, elevation and soil conditions. The main concern is immediate short-term help. "The first two years are critical in preventing erosion following a disaster like this," he said. "That is why everyone must act quickly to reseed these burned-over areas."

Reseeding of both federal and private lands damaged by fire is usually conducted under a contract administered by USDA's Forest Service. EWP funds are then used to reimburse the Forest Service for the cost of reseeding private land. Most of the reseeding work is done by aerial spraying, though in some places, the job is done mechanically or by hand.

An interagency effort to clear channels and trap sediment from streams to prevent downstream damages has also been conducted in the five states.—USDA *News*