HISTORICAL PERSPECTIVE OF ECOLOGICAL RECLAMATION

by

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Abstract. Dissatisfaction with the problems and quality of orphan minespoil left after early surface mining activity stimulated interest in reclaiming newly mined land to some level of productivity and stability. Before reclamation became mandatory, scientists began studying the ecology of abandoned minespoils. Individuals also initiated efforts to seed or plant trees on orphan spoils. The relationship of development and growth of new flora and fauna to the environmental factors following mining was one of the first ecological principles intensively studied. Environmental factors limiting reclamation potential were low and irregular precipitation, high temperatures, high evaporation/transpiration rates, and adverse soil/spoil properties such as high or low pH, high sodium and/or salt content, low nutrient content, excessively fine or coarse textures, lack of soil structure, and excessive soil compaction. Various grass, forb, shrub, and tree species were better adapted to specific environmental conditions encountered after mining than other species. Succession was the second important ecological principle studied in relationship to reclamation. Application of various treatments accelerated natural successional processes. Future research needs to develop a better understanding of the function and interrelationships within individual ecosystems and how these individual ecosystems integrate to influence the environment of the earth. This knowledge will be the scientific key to maintaining and improving the world's environment.

Additional Key Words: Succession, ecosystem, rehabilitation, restoration, environmental quality

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Introduction

Ecosystems and landscapes are often disturbed and damaged by the activities of mankind or by natural catastrophic events. Disturbances and the successional recovery from disturbances are part of any natural ecosystem because ecosystems are dynamic, not static. Early distur-

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bances or damage caused by mankind's activities were considered of little consequence because of limited human population and the vast acreage of unused land and resources still available. However, in current times, the world community is concerned about excess human population, deterioration of the world's environment, and natural and mankind caused environmental disturbances. World leaders and societies try to address these concerns while providing jobs, food, clothes, shelter, and specific cultural values.

Three terms often used to describe the efforts of mankind to abate environmental disturbances are restoration, rehabilitation, and reclamation. Restoration is defined as "the process of restoring site conditions as they were before the land disturbance" (ASSMR 1983). Rehabilitation "implies that the land will be returned to a form and productivity in conformity with a prior land-use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values" (ASSMR 1983). Reclamation is "the process by which land disturbed by mining activities is returned to its former or other productive uses" (ASSMR 1983). Readers desiring more information are alerted to a recent discussion of these and other similar terms by Jordan III (1992).

Most post 1970 experience with the abatement of environmental disturbances has been gained world wide in our efforts to reclaim land disturbed by mineral extraction. The purpose of this paper is to review the role ecology and ecological processes have played in reclamation of mined land.

Stages of Reclamation Development

During the early 1800s, resource development was generally completed with little concern for the future of the resources or land. In the late 1800s and early 1900s, concerns were raised about preserving unique natural areas as parks, forest, and preserves. Mineral development was still conducted with little thought of the safety, utility, or stability of the land after mining was complete. Areas of disturbed land left after mineral extraction became known as orphan spoils. Orphan spoils were generally unsightly and often caused off site air and water pollution. As early as 1918, revegetation of spoils by planting trees was started in the eastern United States. Some of the plantations were successful and tree planting became a common reclamation practice in the northern Appalachians and the Midwest. Three eastern States initiated legislation between 1937 and 1954 concerning the reclamation of surface mined land and often required the establishment of trees.

In the early 1970s, the need for energy independence fostered the development of the large coal reserves in the United States. Increased surface mining and the dissatisfaction with the problems and quality of earlier orphan spoils stimulated interest by "Society" in reclaiming newly mined lands to some level of productivity and stability after the coal was extracted. Other State governments passed laws controlling mine development and reclamation. Interest in reclamation after mineral development also increased around the world.

Public Law 95-87 "Surface Mining Control and Reclamation Act of 1977 [SMCRA]" (U.S. Congress 1977) was enacted and became the first "National" legislation concerning mining and reclamation in the United States. Section 515 (b) (2) states: "restore the land affected to a condition capable of supporting the uses which it was capable of supporting prior to any mining,....." and Section 515, (b) (19) "establish on the regraded areas, and all other lands affected, a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area; except, that introduced species may be used in the revegetation process where desirable and necessary to achieve the approved postmining land use plan".

The importance of ecological processes were emphasized in the 1977 Federal law by requiring diversity, permanence, self-regeneration and plant succession. The law also required productive post-mine land use(s) and stablility of land after reclamation. Rules and regulations to implement the 1977 Federal law were written, discussed, and finalized. These actions have resulted in the development of an integrated process of premine planning, mining, and reclamation for orderly and effective mineral extraction and land reclamation.

Ecological Reclamation

Grandt (1985) and Dodd et al. (1989) provide a good review of the historical development of reclamation in the United States and North Dakota, respectively. These papers provide insight into early reclamation research and legislation for those wanting more detailed information.

Ecology is "the science that deals with the mutual relation of plants and animals to one another and to their environment" (ASSMR 1983). Succession, an important principle of ecology, is "the process whereby one association of species replaces another; the progressive change in plant species over time on an area" (ASSMR 1983). This has been a significant part of reclamation research for a long time. McDougall (1918) discussed plant succession at a surface coal mine near Danville, Illinois. Croxton (1928), a student of Professor McDougall, reported on the reclamation of mined lands from the standpoint of natural revegetation.

Wali (1980) provided an excellent discussion of ecological principles and succession in relationship to mineland reclamation. He pointed out that "succession is considered primary when it is initiated on new land masses never before inhabited, on bare rock, after a volcanic activity, etc.". A similar situation exists when spoils left after mining are parent materials, never inhabited and not yet weathered into soil. Wali considered that secondary succession "commences with the natural plant establishment on plowed fields that have been abandoned, in areas where intense fires have swept through, or after logging activities or heavy grazing have ceased." A situation similar to this exists when spoils are covered by replaced subsoil and topsoil when mining is complete.

Schafer and Nielsen (1979) reported their findings after studying fifty-year-old mine spoils. They found old spoils can develop vegetation resembling undisturbed sites if soil/spoil properties approximate native soils. Soil development processes that occur on undisturbed soil also occur in 50-year-old mine soil/spoil; however, only a small amount of change occurred in 50 years.

Sindelar (1979) also studied natural succession of vegetation and soil development on surface-mined land in Montana. He found the speed of revegetation was influenced by seed sources and soil/spoil quality. Both plant succession and soil development were slow. Evidence from revegetated spoils nearly 50 years old indicated considerable potential for reclamation success, provided spoil materials have adequate water holding capacity and are not over grazed.

Jonescu (1979) studied natural revegetation of mined land in southeastern Saskatchewan. She found a contrast between the vegetation on the spoil ridges and the vegetation in the spoil interridge. Spoil ridge slopes were only 50% or less covered with vegetation after 40 years. The vegetation was dominated by pioneer, weedy species. Interridge areas contained a greater variety of vegetation and showed greater change in dominant species. Evidence of decreasing concentration of dominance (and increasing diversity) in older areas was interpreted as evidence of juvenile populations being succeeded by increasingly stable vegetation.

Fisser and Ries (1975) ecologically characterized a proposed coal lease in the Powder River Basin in Wyoming. The characterization was made using the quantitative ecology techniques of range site and condition described by Dyksterhuis (1949). This premining characterization suggested reclamation techniques and potential for reclamation success. Hodder (1975) also discussed soil/plant/water problems encountered during reclamation in Montana and proposed remedial techniques to overcome them.

Early 1970 reclamation research concentrated on the ecologial relationship of plants and plant growth to post mine environmental conditions. Soil/spoil chemical and physical characteristics and climatic conditions were the primary environmental factors studied.

In the Midwest and East, the response of tree establishment and growth was studied in relation to fertilizer and lime amendments (Plass 1969 and 1972). Tree species were evaluated for revegetation suitablility for strip-mined lands (Hart and Byrnes 1960). Johnson and Skousen (1990) reported tree species composition, canopy coverage, and importance on seven abandoned mine land sites in West Virginia. They found tree canopy coverage and forest community structure increased as surface minesoil pH decreased from 7.0 to 4.5.

In the West, May et al. (1971) evaluated the response of various shrub and grass species to fertilization, mulch and snow fencing for increased water accumlation, irrigation, and various mechanical soil treatments in southwestern Wyoming.

Wali and Freeman (1973) studied the composition of plant species in western North Dakota relative to soil and spoil characteristics such as sodium content, soil/spoil texture, salinity, and elemental content. Farmer et al. (1974) used different grass mixtures, fertilizer, mulch, irrigation, and replacement of topsoil as treatments to revegetate mined land near Decker, Montana. Irrigation was a critical treatment for revegetation in the arid regions of the Southwest (Aldon 1978). Barker et al. (1977) evaluated the establishment and production of 36 grasses and legumes seeded on North Dakota minespoil and minespoil covered with topsoil. Munshower and Neuman (1979) measured the elemental content in plants growing on revegetated mined lands in Montana. Bjugstad (1984) discussed tree and shrub establishment on coal mine spoils in the high plains. Power et al. (1975) reported the findings from several experiments they conducted on spoil, or spoil covered with topsoil, in the Fort Union region of North Dakota.

All these studies found that certain environmental factors limited revegetation; whether natural or when seeded or planted. The primary limiting environmental factors were low and irregular precipitation, high temperatures, high evaporation/transpiration rates, and adverse soil/spoil properties such as high or low pH, high sodium and/or salt content, low nutrient content, excessively fine or coarse textures, lack of soil structure, and excessive soil compaction. As expected, different grass, forb, shrub, and tree species performed better in response to specific environmental conditions.

Wali (1980) pointed out that our understanding of successional processes is paramount to devising ways to hasten revegetation and reclamation of surface mined lands. Reclamation research, since about 1976, has investigated successional processes on mine land. Of all the treatments tried in reclamation, the replacement of topsoil or a suitable replacement has been the best single treatment related to successful revegetation. The replacement of a suitable soil material over poor quality spoil or parent material resulted in plant establishment and development similar to secondary succession rather than primary succession.

There are examples in the reclamation literature that show human manipulation and natural succession together can speed and direct the recovery of disturbed ecosystems. Hedin (1988) found some mined sites that were planted with trees before abandonment had forest composition in various stages of development. Tree planting followed by natural plant succession speeded forest recovery and as these stands aged, bare soil disappeared and litter increased.

DePuit et al. (1980) discussed methods available to establish diverse native plant communities on surface mined land. Williamson (1981) found that selective grazing intensities and time periods could improve species composition and seasonal variety on reclaimed mineland. Williamson (1984) also reported that grass stands with a greater warm-season grass species component could be established on topsoiled and regraded mineland by seeding and various other cultural practices. Nilson and Hirsch (1989) reported the use of native hay mulch helped improve stand diversity and increase warm-season grasses on reclaimed minelands. Nilson (1989) reported the importance of understanding the topography and environment of woody draws before disturbance in order to redesign and establish woodlands after mining.

Many other research examples show the great variety of eoclogical approaches used in reclamation research and technology development for natural ecosystems. Krabbenhoft et al. (1991) reported on the type and importance of plant diversity on reclaimed rangeland in North Dakota. Schuman et al. (1982) discussed competition between crested wheatgrass, an introduced species, and other native grasses in a seed mixture. The importance and functioning of soil microorganisms on reclaimed mined land have been investigated (Fresquez et al. 1987, Harris and Birch 1990, and Cordell et al. 1991). Ireland et al. (1990) reported on the reinvasion of small mammals, reptiles, amphibians, and insects on mined land. Studies to restore and rehabilitate disturbed areas in Teton and Yellowstone National Parks have been reported

(Cotts and Redente 1991 and Williams and Smith 1991). Alpine tundra rehabilitation was discussed by Brown et al. (1978).

Reclamation research and technology development has also focused on replacement of agroecosystems. The reclamation of prime agricultural land in the midwestern United States was discussed (Dancer 1982). Soil structure and associated rooting depth on reclaimed minesoils as it relates to crop production in Illinois was studied by McSweeney and Jansen (1984). Halvorson and Bauer (1984) discussed the yield and composition of a grass-legume pasture on reclaimed land as affected by nitrogen and phosphorus fertilizer.

Most of the reclamation research reported so far in this paper relates to the study of one or two environmental factors and their relationship to flora and fauna establishment and growth on mined land. This approach generally follows Liebig's law of the minimum which states "that crop yields are determined by the quantity of the element that is present in least abundance" (Bear 1942). While Liebig's law applies to nutrient effects on crop yield, the principle has been used advantageously in ecological reclamation research by isolating factors most limiting the reestablishment and growth of flora and fauna on disturbed mineland. This has made research and reclamation approaches less complex and more manageable. This approach has also resulted in effective and successful reclamation.

However, reclaimed flora and fauna communities are more complex and interrelated. Wali (1975) addresses this complexity. The complexities arise from the interrelationships found in any ecosystem "a community, including all the component organisms, together with the environment, forming an interacting system" (ASSMR 1983). Natural ecosystems are expected to provide for multiple and sustained use with limited or no outside inputs. Ecological factors should be considered when determining suitable post-disturbance land use. Proper matching of ecological conditions with post-disturbance land uses determines the potential long term success of the reclamation/restoration of man-caused or natural disturbances (Ries 1992).

Harthill and McKell (1979) and Sindelar and Murdock (1985) discussed the importance of reestablishing a functioning ecosystem before the reclamation of natural ecosystems can be considered successful. Several recent papers ask new questions and suggest new approaches to the reclamation/restoration of disturbed, damaged or altered ecosystems that address their complexity and interrelationships.

Bengson (1990) discussed ecosystem restoration on copper tailings in the southwest. Birch et al. (1991) reported on soil microbial ecosystems in relationship to effective restoration of mined lands. An ecorestoration model for surface mined lands was presented and discussed by Soni et al. (1990). At the 1990 National Meeting of the American Society for Surface Mining and Reclamation in Charleston, West Virginia, a symposium exclusively addressed the ecological considerations in evaluating reclamation success (Chambers and Wade 1992). Finally, a recent paper entitled "Restoration research in the Alligator Rivers Region, Australia" (Ashwath 1992) discusses many important ecological concerns and approaches to mineral development and restoration within Kakadu National Park.

Future of Ecological Rehabilitation/ Reclamation/Restoration

Natural ecosystems including land types such as tundra (arctic and alpine), forests, deserts, rangelands (grasslands and shrublands), and wetlands will continue to be disturbed and damaged by use and natural catastrophic events. If mankind does not intervene, ecological processes (climatic, topographic, and edaphic factors interacting with flora and fauna) will determine the post-disturbance ecosystems. These natural ecosystems will be the product of their environments and may, or may not, be similar to the ecosystems before disturbance. The time required to reach the final specific outcome of these ecological processes (primary and/or secondary succession) may be long.

Increased world population requires more of the land area be dedicated to producing jobs, food, clothing, and shelter; thus, limiting the space within which, ecological processes unaffected by mankind, can function. Human preference and need for speedy recovery, limited off site pollution, and desire for specific land use(s) often precludes reliance solely upon natural ecological processes for recovery.

The science of restoration/ rehabilitation/reclamation will be very important in the future. Rehabilitation and reclamation as defined above can be achieved with various methods and varying degrees of success. Restoration in terms of its most strict definition of restoring ecosystems to their physical state before damage or disturbance is not attainable at the present time and may never be possible. Therefore, important, unique ecosystems require protection. However, restoring an ecosystem to a functioning, self-regenerating system appears possible.

Regardless of whether damaged or disturbed ecosystems are restored, rehabilitated, or reclaimed; understanding the interactions of flora, fauna, and their environment and the application of sound ecological principles are crucial to success. Research needs to develop a comprehensive understanding of the function and interrelationships within individual ecosystems and how these individual ecosystems integrate to influence the environment of the earth. This knowledge will be the scientific key to maintaining and improving the world's environment.

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