Effects of topsoiling and other reclamation practices on nonseeded species establishment on surface mined land at Colstrip, Montana

by Lyle Andrew King

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Range Science
Montana State University

Abstract:
The purpose of this study was to determine the extent to which reclamation practices, especially topsoiling, aided nonseeded species establishment on revegetated mined land. Nonseeded species are desirable because of their potential to increase diversity with species not readily available from commercial sources. Fifteen topsoiled, thirteen nontopsoiled, and one native range study area were sampled at or near a coal strip mine at Colstrip, Montana, in May and June 1979, using frequency data and Domin-Krajina cover-abundance estimates .

Results indicated that properly handled topsoil, especially direct-take, increased numbers of total species and numbers and frequency of nonseeded native species on mined land. Perennial native species in the 0-20 percent frequency range and in the rare, less than I percent, and 1-5 percent cover classes were increased if smooth bromegrass (Bvomus inermis) was not abundant. Topsoiling also increased numbers and frequency of warm season perennial grasses and warm season forbs if smooth bromegrass was not abundant.

The exclusion of aggressive perennial grasses, especially smooth bromegrass from seeding mixtures was a major factor in encouraging nonseeded species establishment.

Proper grazing of revegetated mined land communities also increased total numbers and cover of nonseeded species.

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A thesis submitted in partial fulfillment
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of

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ABSTRACT

The purpose of this study was to determine the extent to which reclamation practices, especially topsoiling, aided nonseeded species establishment on revegetated mined land. Nonseeded species are desirable because of their potential to increase diversity with species not readily available from commercial sources. Fifteen topsoiled, thirteen nontopsoiled, and one native range study area were sampled at or near a coal strip mine at Colstrip, Montana, in May and June 1979, using frequency data and Domin-Krajina cover-abundance estimates.

Results indicated that properly handled topsoil, especially direct-take, increased numbers of total species and numbers and frequency of nonseeded native species on mined land. Perennial native species in the 0-20 percent frequency range and in the rare, less than 1 percent, and 1-5 percent cover classes were increased if smooth bromegrass (*Bromus inermis*) was not abundant. Topsoiling also increased numbers and frequency of warm season perennial grasses and warm season forbs if smooth bromegrass was not abundant.

The exclusion of aggressive perennial grasses, especially smooth bromegrass from seeding mixtures was a major factor in encouraging nonseeded species establishment.

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INTRODUCTION

Montana's Strip and Underground Mine Reclamation Act of 1977 requires "a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area" to be established on coal strip mined land before it is legally reclaimed. The Montana reclamation regulations require each operator to establish at least one unmined reference area in good range condition, based on Soil Conservation Service range condition guides, for each native plant community type to be mined. Success of revegetation is determined at the end of a ten year bond period by comparing revegetated areas to unmined reference areas. At that time, revegetated areas must be composed of at least 51 percent native species (based on production and canopy cover) with diversity (the number of species with more than one percent ground cover) comparable to that of reference areas. In addition, revegetated areas must be comparable to reference areas in current annual production, ground cover for each morphological class, and seasonality of species. Revegetated areas must be grazed during the last two bonding years. To meet these criteria, it will be necessary to understand the modified successional patterns resulting from cultural attempts to speed up plant succession on coal mined areas.

Montana reclamation regulations require topsoil to be spread on graded and contoured spoil prior to seeding. Topsoiling has potential to encourage native species establishment, but the degree of such establishment has not been adequately documented (Howard and Samuel, 1979). Proper handling, stockpiling, and spreading of topsoil are important in determining its ability to add nonseeded native species to revegetated plant communities. However, ambiguous regulatory definitions of topsoil have resulted in the mixing and dilution of soil horizons, often destroying soil structure, microorganism populations, seed reservoirs, and other reproductive plant parts (Miller, 1978; Robbins, 1980).

Regulations require the use of genotypically adapted seed and seedlings when available in sufficient quality and quantity. Since commercial sources of native plant species are limited or nonexistent, topsoiling is a potential source of species that cannot be obtained commercially (Beauchamp et al., 1975). It is important to identify which nonseeded species can be established by topsoiling and to identify their ecological roles.

The purpose of this study was to determine the extent to which topsoil aids nonseeded species establishment in revegetated mined land communities. Other reclamation practices were also investigated to determine their effect on nonseeded species establishment. This research project is associated with an existing study on surface mined land in eastern Montana (Sindelar and Plantenberg, 1977, 1978, 1979).

Objectives of this study on mined land were to:

1. Determine the role of topsoil in establishment of nonseeded species.
2. Determine the effects of cultural practices on nonseeded species establishment.
3. Identify successfully established nonseeded plant species and define their ecological roles.

LITERATURE REVIEW

FACTORS INFLUENCING SEED NUMBERS AND GERMINATION IN TOPSOIL

The number and type of viable seed present at any one time in the soil depends on many factors. Major and Pyott (1966) examined a California bunchgrass type and found grazed plots to have higher numbers of seed (12,290 seed/m^2) than ungrazed plots (8,230 seed/m^2). Brown (1943) measured seed yield in central North American grasslands and found considerable variation within each type over a three year period. In blue grama-buffalograss *(Bouteloua gracilis-Buchloe dactyloides)* dominated grassland seed yields were 720-53,200 mg/m^2, while little bluestem *(Schizachyrium scoparium)* and big bluestem *(Andropogon gerardi)* grassland seed yields varied between 4,510-40,100 mg/m^2 and 0-118,900 mg/m^2 respectively. Rabotnov (1955) reported smooth bromegrass meadowland in the USSR to have between 280-2,450 seed/m^2. Blake (1935) and Lippert and Hopkins (1950) observed low numbers of buried viable seed in the Great Plains, with native perennial grasslands yielding 300-800 seed/m^2. The majority of seed were annual grasses or forbs.

Because of their methods of dispersion, reproductive outputs, and seed longevities, colonizing and pioneering species tend to leave large seed reserves in the soil (Harper, 1977). However, a large number of seed in the soil does not insure a reliable source of potential plant material. Many factors affect the number and type of seed that will germinate. Weaver and Clements (1938) stated that certain characteristics of the seed or of the embryo itself can cause germination failure even under favorable external conditions.

McMinn (1952), May et al. (1971), and Dwyer and Aguirre (1978) found moisture to be the most critical factor limiting germination in arid and semiarid land. Weaver and Himmel (1931) found water content of the soil and air humidity to be major influencing factors in the prairie environment. Soil moisture in the surface 15 cm of unplowed soil often varied ten percent or more during a single week. Moore and Wein (1977) stated that numbers of seed present in the soil were much greater than numbers germinating. Knipe and Springfield (1972) found natural reproduction from seed of alkali sacaton *(Sporobolus airoides)* in New Mexico subject to high loss by wind, water, and unfavorable conditions for seedling establishment, thus limiting natural reseeding of disturbed land. Roberts (1972) found that viable seed could be lost from a site by germination, predation, and fungal pathogens.

The number of seed remaining viable in a soil depends on the species, length of time seed are buried, number of seed produced, durability of the seed coat, and the seed's response to moisture (Bookhout, 1958). Hull (1973) reported that some seed will remain viable up to several hundred years. Hard-coated seed (especially legumes) retain their viability longer than soft-coated seed. Longevity of most seed is greatest when stored at low temperatures, low moisture content, low humidity, and in the absence of oxygen (Crocker, 1945; Barton, 1953 and 1961; Hafenrichter, et al., 1965; Windle et al., 1966).

Rate of germination is a species characteristic, but within a species, younger seed emerge faster than older seed (Hull, 1973). Deeply buried seed are generally older and have a lower germination rate than those from upper soil layers. Rabotnov (1958) found that deep burial induced seed dormancy and decreased viability. He found 64.0-99.6 percent of all seed in a pasture to be in the top 10 cm of soil. In the type he classified as "meadow", the number of seed buried 2 to 10 cm deep was greater than the number of seed at depths less than 2 cm.

Excessive litter accumulations can retard both seedling germination and the development of established plants (Heady, 1975; Redmann, 1975). Successful germination and establishment occurs at proper soil depths. Seed must be covered with soil to permit germination and establishment (Weaver and Clements, 1938). When seeds germinate in the litter of dry environments, seedlings are suspended above the moisture supply of mineral soil. Their survival depends on rapid elongation of the radicle because the porous litter and duff dry out rapidly. Thick surface layers of organic debris restrict the number of species, contributing to floristic simplification (Daubenmire, 1968).

Both Olmsted and Curtis (1947) and Weaver and Rowland (1952) found excessive accumulations of litter and duff to reduce soil temperature to levels which inhibit seedling germination and growth. Weaver and Rowland found these conditions to favor dominance by a single species. Blake (1935) found that seed falling in dense vegetation were caught and held in crowns of old plants, inhibiting placement in proper seed beds.

Beauchamp (1973) found the season of seed collection affected the number and type of seed germinating in a greenhouse study. Grass seed are generally better able to respond to available moisture and germinate faster than forb seed (Major and Pyott, 1966; Dwyer and Aguirre, 1978).

Prince and Hodgdon (1946) and Lippert and Hopkins (1950) found that seed buried in soil does not necessarily bear a close relationship to compostion of the vegetation present. Of ten perennial species found on a site by Prince and Hodgdon, none had germinable seed in the soil.

Golubeva (1962) working on a meadow-steppe found only two percent of the viable buried seed to be those of dominant, perennial grass species. He attributed this small number to yearly variations in fruiting, rapid seedling germination, and short viability in most perennial species.

Harper (1965 and 1977) suggested the availability of suitable microsites on a soil surface may regulate the number of plants establishing from seed because the surrounding environment determines whether proper environmental conditions, resources, and stimuli are received for germination. Because species' germination requirements for "safe sites" showed a considerable subtlety, he concluded the ability of the ecosystem to provide microsites can determine the number and variety of seedlings that are recruited from a seed bank into a population of growing seedlings.

SOURCES OF NONSEEDED SPECIES ON MINED LAND

Topsoil

Literature dealing with the potential of topsoil to provide viable seed and vegetative parts is limited. Kohnke (1950) found species volunteering on overburden to be predominantly those with seed which are easily carried by wind or introduced in the original topsoil. In a study conducted in southwestern Wyoming, Beauchamp (1973), after one growing season, found seedling density on overburden seeded with crested wheatgrass *(Agropyron cristatum)* greater (290 seedlings/m^2) than nonseeded overburden left to naturally revegetate (11 seedlings/m^2). In greenhouse studies involving seed collected from the top 5 cm of topsoil at various native range sites in Wyoming, he found it not advisable to depend solely on viable seed in the soil for revegetation. Although each sample contained enough viable seed to revegetate an area much greater than his original quadrat size, lack of precipitation limited germination. Of those species germinating, most were common to early secondary succession in the area (Beauchamp et al., 1975).

Studies conducted in Wyoming and Colorado by Howard and Samuel (1979) showed several species present in nonseeded topsoiled plots after 14 months of treatment, despite drought conditions. They concluded that direct-take topsoil spread in early spring can be an important source of rhizomes and other vegetative parts from useful reclamation plants in arid regions. In North Dakota, Wali (1980) found that regardless of species seeded, initial vegetation was determined by the diversity of viable seed present in the topsoil.

Natural Migration

The primary factor influencing a species' migration is its means of mobility (Praeger, 1923). Mobility is determined by size, weight, surface characteristics, and amount of disseminules produced. The fertility of seed is greatest in typical "polyanthous" species which produce one seed per flower as observed in grasses, composites, and other achene bearing families. This is shown by the large number of successful invaders (weeds) produced by these groups. The perfection of the migratory device and the distance of migration determine which pioneer species will enter, as well as when other species will appear (Clements, 1916). Daubenmire (1968) stated, "survival of pioneer species depends on their ability to produce highly mobile disseminules in great quantities and at an early age, permitting them to avoid intense competition by taking advantage of newly created bare areas." In contrast, climax plants have heavier disseminules and spread slowly into new territory. Salisbury (1942) and Daubenmire (1968) found seed size increased in higher successional stages, while the number of viable seed per plant decreased. Rice et al. (1960) showed that seed of prairie threeawn *(Aristida oligantha)*, an early successional plant, were carried long distances by wind, whereas fruits of little bluestem, a species of later successional stages, were carried only short distances from parent plants. Although natural migration would eventually supply invading plant species on seeded mine spoil, one potential value of topsoil may be its ability to supply these heavier, less mobile disseminules of climax species earlier.

OLD FIELD SUCCESSION ON GRASSLANDS

Once present, the potential of a species to establish itself is influenced by many environmental factors. Succession studies quantify this potential and relate it to predictable patterns. Old field succession has been thoroughly researched in much of the United States (Haug, 1970). Although not totally applicable to succession on seeded mine spoil, some aspects of the patterns, functions, and interactions of "normal" successional stages apply.

Bazzaz (1975) described secondary succession as "a process of systems repair through which the attributes of a mature ecosystem are restored, including: high species diversity, structural complexity, closed mineral cycling, balance between community productivity and respiration and perhaps, system stability."

Several authors have documented the general pattern of old field succession (Smith, 1940; Booth, 1941; Costello, 1944; Keever, 1950; Bazzaz, 1975; Tramer, 1975). It is initiated with an annual forb invasion by species adapted for migration because of tumbling habits, spines and prickles on fruits, prodigious seed production, early germination, and a short life cycle (Smith, 1940; Costello, 1944).

Several adaptations aid the competitive advantage of pioneering species, including earliness of taproot penetration, ability to garner nutrients in short supply, and ability to withstand drought or poor soil aeration. In addition, pioneers tend to be xerophytic, light demanding, heat demanding, frost hardy, deep rooting, and not exacting as to soil. They are generally intolerant of conditions that arise as a dense plant cover develops so their tenure is usually limited to one generation (Daubenmire, 1968).

First year communities consist of scattered individuals of pioneer species, which become more uniform in distribution the second year. Soon after, these pioneers begin to die due to competition for soil moisture and decreased production of viable seed (Booth, 1941; Costello, 1944).

With normal weather, perennial forbs replace annuals and become progressively more important through time. They dominate the community earlier and more completely each successive year (Costello, 1944; Tramer, 1975). The perennial forb stage is followed by either annual grasses or short lived perennial grasses, depending on climate and other environmental factors. The final stage is dominance by more permanent, long lived perennials.

General tendencies of old field succession on a mixed prairie grassland in northeastern Colorado were summarized by Costello (1944):

1. Replacement of annuals by perennials.
2. Gradual reduction in percent compositon contributed by forbs.
3. Increased abundance of grasses.
4. Increased density of ground cover as climax associations are approached.
5. Increased numbers of species as climax is approached.

Most species were retained throughout several seral stages but in differing amounts as each sere reached maximum development (Costello, 1944). Smith (1940) found 30 percent of the species listed in early stages to be present through all stages of succession. The later in succession a species appeared, the greater its chance of surviving in the climax vegetation.

Keever (1950) suggested that because of life cycle event timing of early invaders, the season of the year that secondary succession was initiated influenced the eventual dominant species more than environmental changes brought on by those invaders. Although the influence of a species on its environment may produce conditions which keep it from surviving, those conditions do not always favor the next invader. Secondary invaders may attain dominance in spite of and not because of changes in environment brought about by the first dominant (Keever, 1950). The habitat determines both when the seed will germinate during the season and if dormant seed will remain viable (Clements, 1916).

ROLE OF COMPETITION IN ESTABLISHMENT

Odum (1971) defined interspecific competition as an interaction between two or more species' populations which adversely affect their growth and survival. Competition was defined by Weaver and Clements (1938) and Harper (1977), as changes in the environment that are brought about by the proximity of individual plants.

Competition begins early in succession. In herbaceous species, danger arises from excess competition immediately after germination (Clements, 1916). Clements found that once a seedling became established it was fairly certain to develop, especially with herbaceous plants. When dense stands of seedlings of several species start growth at the same time, any initial advantage may lead to a lasting superiority in growth (Daubenmire, 1968; Mueller-Dombois and Ellenberg, 1974). In sparse stands, competition becomes noticeable later in the life cycle. Braun-Blanquet (1951) observed competition in the early life history of many species to be so drastic that few individuals survived. Competition among mature plants was of secondary importance so far as survival of a taxonomic unit in an ecosystem was concerned.

Life form duration (annual versus perennial), rapid growth rate, efficient uptake of nutrients, rate and amount of germination, vegetative reproduction, a species' capacity to maintain its presence, and genetic variability and plasticity all help a plant to accommodate a severe condition (Clements et al., 1929; Braun-Blanquet, 1932; Daubenmire, 1968).

The competitive exclusion principle between closely related species results in equilibrium adjustments in which one species replaces another or forces it to occupy another space and yields ecological separation of related species (Odum, 1971).

It is characteristic of competition in all plant communities to increase along with increases in population numbers until the climax or subclimax is reached (Clements, 1916). The inherent capacity of plants for growth and reproduction leads to competition for available niches in each habitat, resulting in a tendency for all plant communities to become closed. Closed plant communities with established stands of vegetation fully utilizing the habitat are not readily invaded. Plant communities populated by few species are more readily invaded because plants are unable to monopolize the limiting factor, usually moisture, through the entire growing season (Clements, 1916; Robertson and Pearse, 1945). The number of stages of succession is largely determined by this increasing difficulty of invasion as the area becomes stabilized (Clements, 1916). Stabilization results when the entrance of invaders capable of influencing community structure is no longer possible (Clements et al., 1929).

FACTORS INFLUENCING FLUCTUATIONS IN STABLE PLANT COMMUNITIES

Humphrey (1958) found radical changes in plant community floristics to be dependent on: (a) developmental changes in endemic or nearby exotic vegetation which is usually too slow a process to consider on a short term basis for plant community change; (b) introduction of new species or varieties; (c) marked changes in such environmental factors as climate, grazing, and plant competition. Strip mining can also be added. Robertson and Pearse (1945) found that marked departures from normal patterns in arid or semiarid climates can open communities to invasion.

Species composition of natural grasslands fluctuates much more in response to environmental influences than does that of woody shrublands and forests. Seasonal fluctuation of relative species abundance in grassland increases with degree of fluctuation in the environment.

Yet, it is probable that homogeneity of plant cover as a whole is increased by environmental fluctuation as species which are not adapted to surviving extremes are excluded from the community (Coupland, 1974).

Because the ecological response of a species also depends upon that of its competitors, the response cannot be constant. Wherever main competitors differ in the range of a species, its ecological or sociological response will differ also. Therefore, ecological behavior and competitive ability of a plant species are rather complex. They are the result of both morphological structure and physiological requirements as matched with the environmental resources available in the habitat and modified by competing plant species (Mueller-Dombois and Ellenberg, 1974).

Competition is keenest when individuals are most similar. Therefore competition among plants of different species varies directly with their similarity in growth or life form. This is of primary importance in competition arising between occupants and invaders in different stages of succession. Invaders so unlike the occupants that they enter with a clear advantage or disadvantage establish themselves readily, in one case as a result of reaction, in the other by taking a subordinate position (Clements, 1916). The tendency to limit species to a group with matched abilities under a particular type and intensity of competition makes competitive elimination a major unifying force responsible for much of the similarity among stable vegetation units in similar habitats. As succession advances and competition intensifies, a species may be eliminated from certain habitats where in early seral stages it grew well, if not at its best, and the areas characterized by its success or failure become more sharply differentiated (Daubenmire, 1968).

Because soil texture and surface topography are not uniform, vegetation patterns are created along moisture gradients. Working in the northern Rocky Mountains, McMinn (1952) found distinct differences among plant associations in the amount of soil drought they could tolerate, with soil drought being earliest and deepest in grassland communities. He concluded that the spread of plant associations into dry areas was prevented because of soil drought. If this idea is extended to include the spread of individual species then drought will also be limiting in revegetated mined land communities.

POTENTIAL SPECIES INVASION AND SUCCESSION ON STRIP MINED SPOIL

Wali (1980) stated that succession on topsoiled strip mined spoil will resemble secondary succession more than primary succession because topsoil provides organic matter, nutrients, seed, and propagules from original vegetation. Old field succession patterns differ from that on strip mined land in that spoil areas are often seeded. Competition from seeded species becomes a primary factor in determining which species will be able to establish in a mined land plant community. Nonseeded native species have several inherent disadvantages:

1. There are generally more seed of seeded species properly placed for ideal germination in the prepared seedbed. Nonseeded species may be found at any depth or location.
2. Seeded introduced species gain a competitive advantage by germinating and establishing faster, making use of available nutrients and moisture before natives (Depuit et al., 1978).

Research dealing with succession and species invasion of strip mined spoil in the arid and semiarid West has been limited. Hall (1957) and Leisman (1957) found that pioneer vegetation invading strip mined areas was usually determined by characteristics and configuration of the spoil, nature of adjacent vegetation, and habitat requirements of the vegetation. Hodder et al. (1970) claimed that slope exposure significantly affected invading species on spoil, with north and east exposures having more surface moisture for establishment. Meyn et al. (1976) found that weedy invaders offered some degree of protection to seeded species from wind and water, but if allowed to grow without competition, probably increased the length of time necessary to establish diverse and self-sustaining plant communities. Sindelar and Plantenberg (1978) found that competition resulted in population replacement and structural changes in most seeded communities on mined land. Life forms characteristic of early succession were seldom abundant for more than two years following seeding. Golley

(1965) found that rate of change within or between seral stages of a community may be influenced by size of the disturbed area and invasion ability of species on adjacent land. Old, naturally revegetated level spoil communities at Colstrip generally had greater species diversity than seeded mine spoil; their diverity was equal to or greater than diversity of grazed native range (Sindelar and Plantenberg, 1978). On steep seeded spoil in North Dakota, Williams (1978) concluded diversity was affected by age and was much lower on mined land than on unmined land, regardless of age.

DePuit et al. (1978) found competitive inhibition of native species when they are seeded in mixtures containing even a low proportion of naturalized introduced species. They concluded that adequate and diverse native species establishment may be enhanced if naturalized introduced species, especially crested and tall wheatgrasses *(Agropyron elongatum)* are eliminated from seeding mixtures.

In a study of native species best adapted to seeding and establishment on coal strip mined land in southeastern Montana, Eddleman (1978 and 1979) determined that initial seedling survival, rates of root and shoot growth, and resistance to moisture stress determine the degree of success exhibited by a species. He found a wide variety of germination requirements and ideal seed ages in the native species he investigated. It is probable that there is no ideal length of time for topsoil storage or treatment for all native species.

Sindelar and Plantenberg (1978) found plant establishment and succession on seeded spoil to be influenced by species seeded, weather conditions, cultural practices and postmining management. Although advanced life forms such as perennial grasses, forbs, and shrubs were readily established by seeding, the use of aggressive introduced species, especially smooth bromegrass, had limited community diversity and native species invasion. The inability of native species to establish and become dominant on seeded sites was due to unsuitability of cultural practices and the often limited ability of native species to become established by seeding. The eventual effect was dependent upon the type of cultural practice, climate, and degree of management. They concluded that topsoiling as a cultural practice has great potential to increase species numbers and diversity on seeded mined land but improper use of topsoil has limited its effectiveness.

METHODS AND PROCEDURES

SITE SELECTION

Site selection was based on availability of historical information from research reports and coal company records and was completed during late April and early May of 1979.

To determine how cultural practices affected presence and abundance of nonseeded species on revegetated mined land communities, as many site treatments and ages as possible were included. Fifteen topsoiled sites and thirteen nontopsoiled sites were chosen. In addition, one native range area in good condition was sampled for comparative purposes.

SAMPLING PROCEDURES

Frequency

Sites were sampled within a short time to minimize environmental variability. Frequency was chosen as a fast method of determining differences among sites. It is not an absolute measure because results obtained depend in part on quadrat size and shape. Proper quadrat size is a function of plant size and species richness per unit area (Mueller-Dombois and Ellenberg, 1974). Daubenmire (1968) regarded ideal quadrat size as consistently yielding two or three species at or near 100 percent frequency.

A review of the previous year's data from an associated study on six of the sites (Sindelar and Plantenberg, 1979) indicated that a 2x5 dm rectangular quadrat (Daubenmire, 1959) approached Daubenmire's criterion. However, a few sites had greater than three species at or near 100 percent frequency. This relatively large quadrat size was chosen over a point frequency method in order to maximize the area covered within a minimum number of samples. Species area curves indicated that 20, 2x5 dm quadrats per site was an efficient sample number, with all but three sites leveling in species numbers with 20 or fewer quadrats.

Sampling was conducted early in the 1979 growing season (May 1 to May 16) to give consideration to early maturing species, especially forbs, which might have been overlooked with later sampling dates.

A central location was chosen on each site and each sample quadrat was located by pacing northward or southward from this center point. The direction and number of steps were determined from a random numbers table. Frequency was recorded for all species, alive or dead, which were overhanging or rooted in the quadrat. In addition, species lists were made for each site to record species not encountered in frequency data.

Cover

Because frequency does not reveal dominance of a site, cover-abundance estimates were made for each species on each site using the Domin-Krajina method. These estimates were made two to four weeks after frequency sampling to allow for additional growth of early and midseason species. This is a quick, visual estimate of cover which is not accurate on absolute scales, but good for relative comparisons among sites (Mueller-Dombois and Ellenberg, 1974).

Six sites were simultaneously monitored in a mined land succession study. Extensive species lists had been constructed for these sites and detailed cover estimates had been made using a modified Daubenmire technique (Daubenmire, 1959; Sindelar and Plantenberg, 1977, 1978, and 1979). In addition, detailed cover estimates and species lists were made for the native range area by Munshower et al. (1978) and DePuit (unpublished data, 1979). Cover data derived from the Daubenmire procedure were classified into Domin-Krajina categories (Table 1), but included only those species encountered in 40, 2x5 dm quadrats per site. Therefore, these are minimum estimates of the number of species present on these sites.

Frequency and cover were compared among sites to determine effects of reclamation practices on nonseeded species establishment. Cover estimates provided a basis for comparing percent composition of individual species and groups of species among sites. Differences in species ecological roles as a result of site treatments were evaluated.

Table 1. Domin-Krajina cover-abundance categories

Category Number	Percent Cover	Description
10	100	–
9	>75	–
8	50-75	–
7	33-50	–
6	25-33	–
5	10-25	–
4	5-10	–
3	1-5	–
2	<1	Scattered individuals with cover under 1/20
1	0.1	Seldom present, with insignificant cover
+	Rare (R)	Solitary individual with insignificant cover

The Chi-square test of significance was used to determine differences in frequencies among sites. Analysis of variance and Student t-tests were used for determining site differences in species numbers and cover values. All statistical tests were made at the 0.05 level of significance.

Cluster analysis used similarity indices determined from frequency data (Sokal and Sneath, 1963) to look for groupings of sites by species similarity.

STUDY AREA

COLSTRIP AREA

The Colstrip area has been strip mined for coal since the early 1920's. Early mined areas were left to revegetate naturally. Since 1968 mined areas and old spoil ridges have been reshaped and seeded. Vegetation in the Colstrip area is primarily mixed prairie grassland interspersed with ponderosa pine *(Pinus ponderosa)* on scattered sandstone outcrops.

The growing season extends from April to October with a frost free period of 120-140 days. Summers are hot, dry, and often windy. Annual precipitation averages 40 cm with most falling as rain in April, May, and June (Sindelar and Plantenberg, 1978). Several detailed descriptions of vegetation, topography, climate, physiography, soils, and geography have been previously reported (Sindelar et al., 1974; Meyn et al., 1976; Sindelar and Plantenberg, 1978; Skilbred, 1979).

Precipitation for 1979 was 14.8 cm with 11.0 cm falling during the growing season. Although one of the driest years on record, stored soil moisture from the previous fall allowed near normal spring growth.

SITE DESCRIPTIONS

Twenty-eight study sites were located on revegetated spoil at Western Energy Company's Rosebud Mine and Peabody Coal Company's Big

Sky Mine near Colstrip (Figures 1 and 2). In addition, one native range area near Colstrip was sampled for comparison. Except for native range and Cape Oliver, topsoiled and nontopsoiled sites were further divided by smooth bromegrass abundance as described in results and discussion. These categories were used for assigning names to 27 revegetated mined land sites. Complete species lists for each site and percent frequency and cover of each species from 1979 data appear in the appendix. In addition, a summary is given of seeded species, native species, and seasonality of species present.

Topsoiled Sites

I-A. This site was located on the Peabody Big Sky Mine approximately 9.6 km south of Colstrip. It was mined in February, then reshaped and topsoiled during the spring of 1974. Although the area was a nonseeded study plot for Arnold and Dollhopf (1977), it is probable the site was seeded to an eight species mixture along with the adjacent area in January of 1975. It is difficult to tell if the abundance of those species in 1979 was the result of seeding or invasion from the adjacent seeded area (Figure 3).