Nonseeded species invasion of twelve revegetated surface mined sites at Colstrip, Montana
by Donna Stangohr Lovell

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation
Montana State University

Abstract:
In 1977 the Surface Mining Control and Reclamation Act (SMCRA) was passed requiring surface mining companies to "establish ...a diverse, effective, and permanent vegetative cover of the same seasonal variety. .. capable of self regeneration and plant succession at least equal in extent of cover to the natural vegetation of the native area." Nonseeded species play an important role in revegetation by increasing community diversity. Their voluntary encroachment onto revegetated minesoils is desirable to the mining industry since final bond release depends upon reclamation success.

The primary objective of this study was to identify factors that significantly affect nonseeded species invasion. Some factors known to affect encroachment of nonseeded species have already been established: direct hauling topsoil provides a live seed bank, excluding aggressive species from seed mixes limits competition, and properly utilizing management tools, such as grazing, reduces litter accumulation.

Analyses indicated that significant variables affecting nonseeded species invasion were the age of the reclaimed sites and the ratio of edge to interior of a field. Seeding mixtures and seeding rates also appeared to influence the number of invading species on these sites. Other variables analyzed were: topsoil depth, total soil depth, size of the field, season of planting, and distance from undisturbed, windward seed sources.

Subsampling was used in analyses instead of true replication. Statistical inferences should be limited to this project site. Nevertheless, the factors which revealed an influence on the invasion of reclaimed lands at Western Energy’s Rosebud Mine warrant further investigation.

NONSEEDED SPECIES INVASION OF TWELVE REVEGETATED SURFACE MINED SITES AT COLSTRIP, MONTANA

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Donna Stangohr Lovell

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Land Rehabilitation

MONTANA STATE UNIVERSITY
Bozeman, Montana

December 1992

APPROVAL

of a thesis submitted by

Donna Stangohr Lovell

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency and is ready for submission to the College of Graduate Studies.

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Date 1-13-93

ACKNOWLEDGEMENTS

I wish to thank the many people who provided assistance during the course of this project. Dr. Frank Munshower and Bill Schwartzkoph arranged funding for data collection through Western Energy Company (WECO). Peter Martin and Dana Nile of WECO provided logistical support and collection of field soil samples. Dr. Bret Olson and Dennis Neuman provided valuable writing criticism and assistance with data interpretation. Katherine Olson-Rutz guided me patiently through the SAS data analyses. Curt Strobel, Bryce Romig, and Dawn Major clipped vegetation for this project. Finally, I would like to thank Jim Lovell for his support, in every way.

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ABSTRACT

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INTRODUCTION

In 1977 the Surface Mining Control and Reclamation Act (SMCRA) was passed. It requires that surface mined lands be returned to equal or higher land uses than those which existed prior to mining. An interest-free bond sufficient to cover the cost of reclamation must be posted before mine development; the bond is forfeited if the mine operator fails to complete reclamation. As various phases of reclamation are completed, such as recontouring of the landscape and topsoil replacement, parts of the bond can be released to the company.

Montana falls under the category of reclaimed areas receiving less than twenty-six inches of annual precipitation and is required to have a ten year bonding period after revegetation. Under SMCRA guidelines "a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area" must be established. Satisfactory revegetation, as described under this SMCRA guidline, is often the bottleneck in the bond release process.

In addition to requirements for a diverse, permanent cover, SMCRA also requires the establishment of grass species of the "same seasonal variety" (e.g. cool season or warm season) on the disturbed site. Seeding should occur during the spring and fall when moisture conditions are most favorable for seedling establishment. The seeding mixtures used at the Rosebud mine contain cool and warm season grasses;

consequently, the schedule of planting may affect seasonal dominance of grasses in the reclaimed stands.

Reclamation laws require the construction of landscapes which promote plant succession and sustain stable, productive plant communities. Secondary succession, as defined by Odum (1971) is influenced by previous plant growth and modified by environmental factors such as soil substrate. To enhance production and growth and to speed succession, the subsoil and topsoil are salvaged before mining and redistributed after regrading of the spoil material.

Redistributing direct haul topsoil to the regraded spoil area increases the total number of plant species as well as the frequency and numbers of nonseeded native species on mined land (King 1979). Nonseeded species are important in revegetation because they may establish on the reclaimed site thereby increasing community diversity and aiding in the successful reestablishment of plant communities.

Clements (1916) noted that, "From the very nature of migration, invasion is going on at all times and in all directions." This invasion, or encroachment, is affected by a number of other factors. For example, Van Zalingen (1987) found that the distance between revegetated sites and undisturbed areas is significant in the invasion of windborne, nonseeded species in alpine stands. Other physical factors affecting the encroachment of native species include soil conditions, slope stability, and aspect (Van Zalingen 1987).

Encroachment is also affected by management practices. For example, native species are inhibited when seeded in mixtures containing even a low proportion of aggressive, introduced or naturalized species (DePuit et al. 1978).

The age of a reclaimed site may also affect species diversity. Sindelar (1980) found a decline in species diversity after year three as the initial flush of weedy and nonadapted seeded species disappeared. Another study showed an increase in diversity over time as unseeded species migrate onto mined lands (Sindelar and Plantenburg 1977).

This study examines factors affecting the invasion of nonseeded species onto twelve sites seeded with native species. Six sites were seeded in the spring and six were seeded in the fall. Seeding rates, mixes, methods, ratio of edge to interior, and size of reclaimed fields are factors which may influence the invasion of species on reclaimed minelands. Some of these factors can be manipulated by the reclamation specialist to enhance diversity, thereby improving the probability of obtaining final bond release.

Objectives of this study on surface mined land were to:

1) determine the effects of management practices on the invasion of nonseeded species onto sites seeded with native species.
2) provide recommendations for promoting the invasion of desirable nonseeded species.

LITERATURE REVIEW

Succession of Plant Communities on Mined Lands

Under the guidelines of SMCRA, soil salvage is required prior to mining with soil replacement occurring after resource extraction. This promotes secondary succession which approaches a climax community more rapidly than primary succession (Odum 1971). During secondary succession, communities begin to develop with weedy pioneer species appearing first. These early pioneers are replaced by a series of more mature communities until a relatively stable community is reached. This general pattern of old field succession is well documented (Golly 1965, Bazazz 1975, Odum 1971).

Pioneer species have many adaptations that increase their initial competitive advantage. Pioneers tend to be xerophytic, frost hardy, light and heat tolerant, and to have extensive taproots to withstand droughty conditions. In addition, they produce large quantities of seed that are adapted for long range dispersal. They also have a short life cycle (Smith 1940). By the time succession has reached a stage of dense vegetative cover, as early as the second year after disturbance, conditions no longer favor the establishment of small fast-growing seedlings (Daubenmire 1968).

Pickett and Bazzaz (1978) showed that early successional annuals had broad responses to moisture gradients supporting the utilization of broad, overlapping niches. With the presence of annual grasses such as Bromus japonicus (Japanese brome) on younger sites, Romo and Eddleman (1987) theorized that this brome could limit growth and establishment of seeded perennials which have narrower niches. They found that emergence of native bunchgrasses, Agropyron spicatum (bluebunch wheatgrass) and Koleria cristata (junegrass), was not significantly limited by Japanese brome competition. However, Sitanion hystrix (Squirreltail) emergence was significantly better in control plots without brome. Root, crown, foliage, and total biomass were reduced for all three species when grown with Japanese brome.

Since Bromus japonicus germinates in the autumn or early spring, it may have a competitive advantage over perennials seeded during these seasons. Romo and Eddleman (1987) suggested that perennial seedling mortality could be high in future years where Japanese brome is prevalent. On mined land at Colstrip, Montana, second year mortality of bluebunch averaged 46%, squirreltail 52%, and Junegrass 100% (Eddleman, unpublished data in Romo and Eddleman, 1987). But Parish and Bazazz (1982) stated that because of their broadly overlapping niches, the competition of annual species was more intense when grown together than when grown with the more specialized prairie species.

Pioneer species are replaced by perennial forbs whose dominance in the community increases annually (Costello, 1944). The perennial forb stage is followed by an increased abundance of perennial grasses with the number of species increasing as climax is approached.

One goal of reclamation is to speed up the processes of secondary succession using cultural and management practices to bypass the initial weedy stages of community development. Clements (1916) stated, "It is a universal law that all bare places give rise to new communities..." and open communities are readily invaded whereas closed communities are rarely invaded. Initial stages of succession provide managers with the opportunity to implement strategies that leave the community open for invasion. Once established, the community closes and there is little chance of invasion unless another disturbance occurs which would create new openings.

Effects of Age on Succession

Plant community succession is governed by complex, interrelated environmental and biotic factors as they interact over time (Golley 1965). This interaction makes it difficult to ascribe an observed effect to any particular factor. No single factor was of overall importance in the revegetation of unreclaimed Oklahoma coal strip mines ranging in age from 10 to 70 years (Gibson et al. 1985). Site age was relatively unimportant as an environmental variable in determining species composition whereas site latitude and substrate factors were closely related to the mine-site communities.

Sindelar (1981) found the rate of succession on mined soils in eastern Montana to be "less than that required to assure stability of composition within a 10-year bonding period." His conclusions were based on plantings established between 1969-1977 that included aggressive introduced species. He suggested that newer seedings, post SMCRA, should prove more successful when introduced aggressive species were excluded from the seed mixes.

Productivity, Cover and Age

Productivity on mined land is not generally a concern since yields can double those of native range (1000 kg/ha on unmined rangeland), (Munshower and Neuman 1983). This enhanced productivity was attributed to introduced grasses and legumes selected for forage production. However, a decline in productivity was noted after age four probably as a result of litter buildup. Schafer et al. (1980) showed litter accumulation to be common on minesoils under pioneer vegetation resulting in wide C:N ratios, reduced available N, successional stagnation, and eventual reduced plant community production. An early peak in cover on mined lands was attributed to the growth of annual and biennial species. Cover of perennial species on mined lands was substantial but Sindelar (1981) reported that it did not reach levels equal to native range within ten years.

Microsites, Diversity and Age

Clements (1916) stated that community diversity may be positively influenced by simple variations in spatial heterogeneity such as a rock outcrop, a change in exposure, an ant-heap, a plow furrow or wheel tracks. Similarly, Billings and Bliss (1959) concluded that the micro-zonation of species and communities on the alpine tundra is largely a function of the depth and melt-rate of snowbanks. The slow summer melting of accumulated snow results in steep environmental gradients over a relatively small area. These gradients produce similarly steep vegetational gradients, with respect to floristics and productivity.

Wagner et al. (1978) found species diversity to be much greater on unmined sites than on all unreclaimed spoil banks of different ages in an abandoned coal mine in New Mexico. Of the species present, a relative Importance Value of 64 percent was calculated for annual species on spoils and only five percent for unmined sites. These mined sites were from one to thirteen years old but were still in a very early seral stage as shown by the low species diversity and short-lived taxa. No significant difference in species diversity was found between mined sites of different ages. However, there was a trend from many annuals and few perennials on newly mined sites toward fewer annuals and more perennials on older sites.

Sindelar (1981) reported that after ten years, diversity on revegetated sites was lower than that of native range sites in SE Montana. The number of perennial grass species on mined land was similar to the number on unmined areas. Annual and biennial forb composition on mined land was comparable to native range at Colstrip, MT, whereas shrub and halfshrub composition was somewhat less than that of native range. The greatest difference between native range and revegetated areas was in the number of perennial forb species present. Compared with native range, the number of perennial forbs was very low on mined areas. This lower number of perennial forbs was attributed to the limited number of habitats available and homogenization of soils following mining and recontouring of the terrain.

Post mining soil has been depleted of micro-habitats necessary to encourage community diversity and lacks structure (Schafer et al. 1980). Post mining landscapes and soils are homogenized into a single 'habitat'. Habitat and population act and react upon each other alternating as cause and effect. "The factors of the habitat are the causes of the responses... of the community, and these are the causes of growth and development, and hence of (plant community) structure." (Clements 1916). A limited number of factors in the habitat restricts the number of community responses thereby limiting growth and development of the plant community.

Season of Planting

Reclamation laws require vegetation to be of the same seasonal variety (e.g. cool season or warm season) as that found on the area before mining. For successful seedling establishment, seeding should be initiated under the most favorable moisture conditions. DePuit et al. (1978) reported the superiority of spring versus fall seeding but this was due to higher rates of establishment of introduced species. Fall germination was poor for those same introduced species thus enabling native plants to establish a more diverse plant community.

Rennick and Munshower (1985) studied the effects of seeding date on the structure of plant community reestablishment. Perennial warm season grasses did the poorest of all life forms for all seeding dates. Warm season grasses were found only on the spring seeded plots where their composition was less than one percent. By comparison, the composition of this lifeform on native range is from 2.5 to 5.1 percent. An important point raised was the difficulty of attributing an impact on community structure to any one factor, such as time of seeding, when so many other variables may be influencing species composition as well (soil handling practices, precipitation, edaphic conditions, etc.).

Amount of Field Edge

Landscapes, as ecological units with structure and function, are composed of patches which differ in origin and dynamics. Size, shape, and spatial configuration of patches are important (Forman and Godron 1981). In 1964 Simpson formulated the hypothesis that penninsular species diversity decreases with distance from the mainland as a consequence of colonization-extinction equilibrium and the shape of the land mass. Milne and Forman (1986) concurred that the shape of a patch may exert an effect on species diversity patterns within it. They found the greatest rate of decline in species richness on penninsulas was within the first 2000 m from the mainland. This led to the conclusion that landscape configuration and patch geometry are factors which have major ecological consequences.

Patch area alone has been found to be an important determinant of species diversity, and species groups such as trees, seed-eating birds and insectivorous birds respond differently to patch area (Elfstrom 1976, Forman et al. 1976). Landscape patches affect productivity, nutrient and water flux, and species dynamics (Forman and Godron 1981).

Mining related disturbances are introduced patches under Forman's classification system (1979b). These patches are dominated by individuals (species) introduced into a matrix, or series of landscapes, by human manipulation. Even though the species used today in seeding mixtures are primarily, if not entirely, native species, the patch and resulting community have been introduced into the surrounding matrix. Succession will proceed until the matrix converges with the patch in species similarity with the patch disappearing with time (Forman 1979b). On mined lands, however, such widespread disturbance leaves little natural matrix with which the introduced patches can converge.

These remnant patches of mined land are terrestrial islands in a matrix of native and reclaimed rangeland. Much work on island biogeography (MacArthur and Wilson 1967, Carlquist 1974, Pickett and Thompson 1978) has shown the number of species on an island is related directly to three factors, in order: the island area, its isolation, and its age. The greatest diversity is found on smaller islands which have a greater edge to interior ratio. The micro-environment in the center of an island, or a field, will be different than the microenvironment at the edge largely due to the effects of wind and the surrounding matrix (Forman and Godron 1981). Several factors affect the width of the patch edge with the angle of the sun playing a major role. Edges facing toward the equator are typically wider than those facing toward the pole, and patches in temperate areas are generally wider than in tropical areas (Wales 1972).

The degree of species difference between the patch and matrix is also significant. The patch edge varies in width from a few meters to a few tens of meters in patches at the landscape level (Forman and Godron 1981).

Patch shape is important as a target for dispersal. A large square patch is mostly interior with bands of edge at the outer portions of the patch. A rectangle patch of the same size has proportionally less patch interior and more patch edge. A narrow strip patch of the same size may be all edge. Since community and population characteristics differ between the interior and the edge, comparing these characteristics with the interior-to-edge ratio of patches may be useful in evaluating the importance of patch shape in a landscape. Furthermore, the spatial configuration among the patches present may be just as important as the number of patches (Forman and Godron 1981).

Distance From Undisturbed, Windward Sites

Some seeds are not adapted for migration and travel only a short distance from the parent plant before coming to rest, others are adapted for long distance dispersal. All species benefit occasionally from accidental means of dispersal (Gleason 1926). Gibson et al. (1985) reported large numbers of wind and bird dispersed species on unreclaimed strip mines suggesting that dissemination efficiency is an important factor in determining initial colonization. Gibson (1982) also observed colonization in Oklahoma coal mine spoil by plants that were adapted for long-distance, or efficient, seed dispersal. Leisman (1957) and Harrington (1982) have emphasized the importance of the surrounding vegetation and the dissemination efficiency of propagules on spoil banks. Availability of seed from undisturbed sites is a function of wind direction, seed source quality, quantities of available seed, duration of seed dispersal, and dispersal distance (Zasada 1971).

Van Zalingen (1987) found that as the distance from the nearest windward undisturbed area increased, the percent cover of native species significantly decreased. As previously cited, the windward side provides the greatest amount of edge and microhabitats thereby potentially increasing diversity (Forman and Godron 1981).

Topsoil

Topsoil is salvaged and returned to the recontoured spoil as required under the guidelines of SMCRA. Nevertheless, surface mining affects soil chemistry, soil properties, and disrupts microbial activity. Due to human influence, minesoils differ from natural soils in their lack of structure, lower organic carbon content, and unconsolidated rock fragments (Schafer et al. 1980). Although minesoils may have been altered considerably, studies have shown that adding even a few centimeters of surface soil improves infiltration and vegetative production of minesoils (Power et al. 1974). Varying the depth of topsoil across the landscape, instead of in a uniform layer, would enhance environmental heterogeneity and thus diversity.

Soil depth requirements for reestablishing perennial cool-season grass production have been studied extensively by Barth (1984). The depth required to maximize forage production averaged 50 cm over generic spoil. McGinnies and Nicholas (1980) also found the thickness of topsoil material directly influenced plant growth up to a depth of 46 cm. However, these findings may be inconclusive compared with sites having all native species. Both studies used <u>Agropyron desertorum</u> (crested wheatgrass) in the seed mix. This species is an introduced, aggressive grass which can dominate a site when seeded even in small proportions (DePuit et al. 1978).

Topsoil that has not been stockpiled is an effective supplier of nonseeded species (King 1980). King found an increase in the total number of species, nonseeded species, and nonseeded native species on a direct haul site versus stockpiled sites. His data indicated that properly handled topsoil can increase the number of total species and the frequency of nonseeded native species on revegetated mined land. However, canopy cover of nonseeded native species were not significantly increased by topsoiling.

<u>Cultural Practices and Diversity</u>

The requirement to reestablish diversity within the ten year bonding period is the most challenging aspect of revegetation on western mined lands today. Reclamation managers must make decisions which can positively influence the outcome of revegetation efforts and which are cost effective. Some cultural aspects of reclamation such as seeding mixtures, seeding rates, methods, and mulching practices can influence revegetation costs and success.

A study conducted from 1977 to 1979 evaluated the establishment of diverse native plant communities as influenced by seeding methods, mixtures, and rates (Depuit et al. 1980). They reported diversity had attained a level within the range of native plant communities of the Colstrip, Montana area within two years. However, by the third growing season diversity declined substantially with the loss of pioneer species. This is evidence that initial diversity levels are not necessarily indicative of diversity levels in later stages of plant community development.

Broadcast seeding at twice the drill seed rate initially promoted higher diversity, however, this relationship between diversity and seeding method disappeared by the third growing season. This initial increase in diversity with broadcast seeding may have been a result of the greater number of favorable microsites created. A rough seedbed is used when broadcast seeding and provides variable depth seeding necessary with different seed sizes and creates a greater number of favorable microsites for seedlings (Call and Roundy 1991). Seedling recruitment is a result of the number of seeds in favorable microsites in the seedbed rather than the total number of available seeds (Young 1988). These favorable microsites have been termed "safesites" by Harper (1977) and may occur naturally in gravel or as cracks and depressions in the soil.

Depuit et al. (1980) found that heavier seeding rates for broadcast and drill seeding exerted a negative effect on plant community diversity. This was attributed to reduced evenness of cover among seeded species with a few rate-responsive species dominating.

Increasing the number of species seeded is a way of trying to compensate for a lack of understanding of plant-site relationships (Vallentine 1989). An increase in the number of species seeded did, however, result in increased plant community diversity during the first three years of their study (Depuit et al. 1980).

When two competing individual plants are of the same species, each may be affected equally by the presence of the other because of the similarity in their genetic identity and capabilities of utilizing a given resource. Species sown in mixtures should be chosen on the basis of ecological evidence that they can coexist (Pyke and Archer 1991). When the number of species seeded is increased, niche overlap should be reduced.

Research by Parish and Bazazz (1982) supported the theory that niche reduction and separation can effectively reduce competition within a community, and that selection to reduce competition was more important in the evolution of late-successional species than for early successional species.

Their competition study showed that prairie species have a higher relative yield in mixed stands versus homogenous stands. These findings were consistent with their prediction that late-successional species should use relatively more of the total resources available in mixed stands. If resources are sufficiently heterogeneous, would be competitors in a more homogeneous environment may coexist via small scale spatial segregation (Tillman 1982)..

Using a nurse crop as a temporary stabilizer is not recommended for areas receiving less than 30 cm of annual precipitation due to competition for moisture between the grass seedlings and the nurse crop (Munshower 1991). Instead, a crimped straw mulch is recommended for these regions.

However, root penetration creates microsites that add diversity to the post-mining soil profile. Schuman et al. (1991) found the use of a stubble mulch (Hordeum vulgare) in south central Wyoming resulted in greater seeded grass production and had significantly greater water infiltration than the crimped straw mulch treatment. The small grain crop may have improved the physical condition of the revegetated soil through root penetration leading to greater water infiltration.

METHODS AND MATERIALS

Data Collection

Twelve revegetated surface mined sites at Western Energy's Rosebud mine in southeast Montana were chosen for this study on the basis of age and available historical data. These data included seed mixes, methods, rates, soil depths, and time of planting. These twelve sites were divided into six pairs of spring and fall seeding dates and were either directly adjacent to one another or within the same mine area (Figure 1). Ages of the fields ranged from two to eleven years. Samples were collected twice in 1991, in late May, to estimate the cover of early forbs and again in late July to measure standing biomass by lifeform as well as percent cover of the dominant species.

Acreages ranged from 1.6 ha (4 a) to 11.3 ha (28 a). To limit bias, each field was visually divided into fourths and a stake was set at a central point for each quarter. Each sample location was placed at a randomly selected distance and direction from the central stake.

Percent canopy cover was measured using Daubenmire (1959) coverage classes. Cover data were collected by placing twenty frames (20 x 50 cm) in each field, five within each quarter, and recording areal cover in each frame by species. The number of sample frames was based on species area curves. To be consistent and to provide 'replication', the number of frames per field was held constant at twenty.

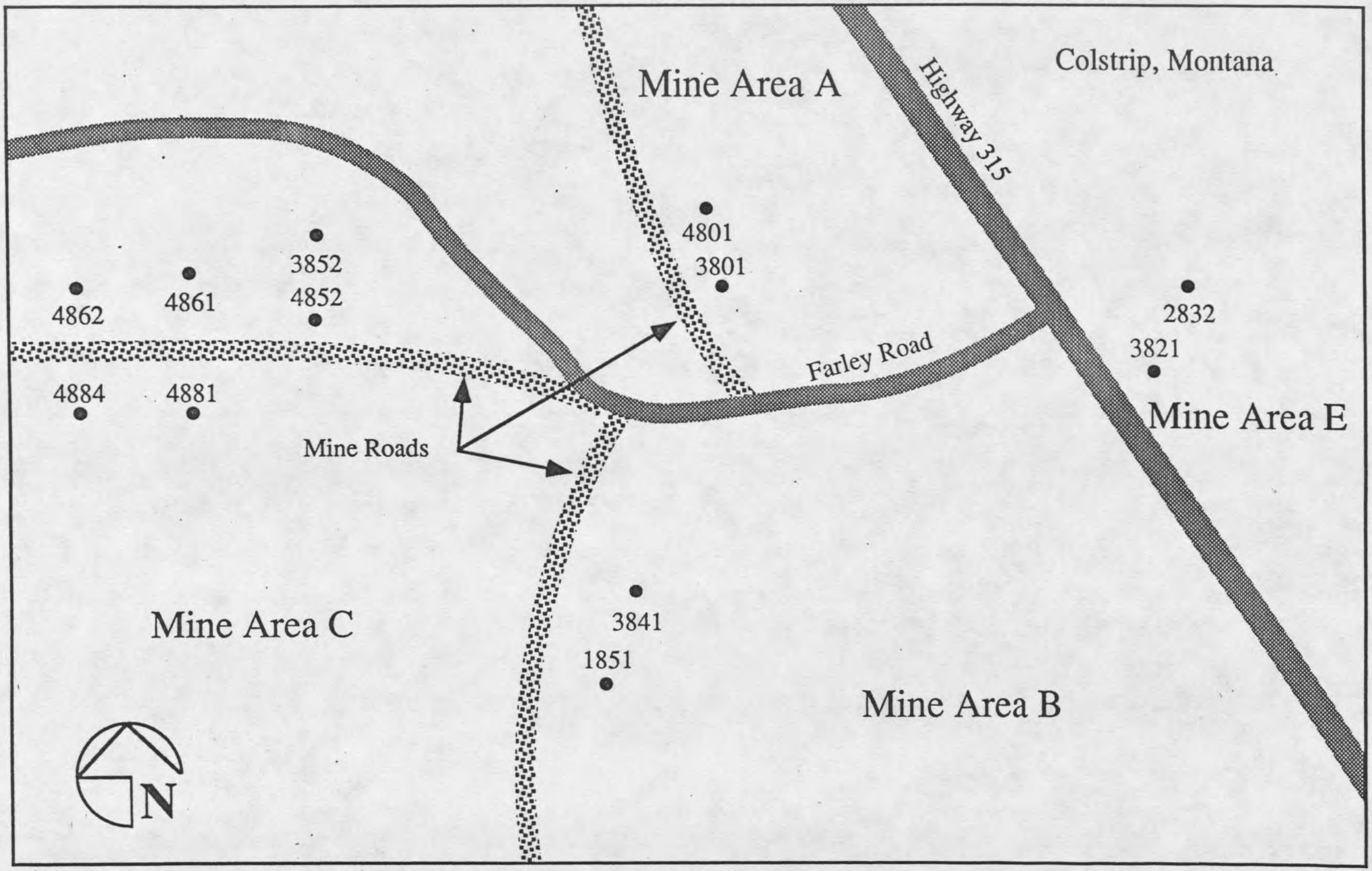

Figure 1. Diagram of the Rosebud Mine areas and study site locations.

In late July canopy cover as well as standing biomass were measured. For species encountered both times, the record with the greatest amount of cover was entered into the data base.

Vegetation was clipped to approximately 1 cm from the ground to estimate standing biomass by lifeform. Vegetative litter was also collected. After estimating cover, a 50 X 50 cm frame was laid on top of the left edge of the cover frame. The plants were clipped by lifeform, put into appropriately marked paper sacks, and oven dried for forty-eight hours at 56°C and then weighed.

Seeding mixtures were known for each field. Each species encountered in a frame was entered into the data base as either seeded or nonseeded to determine invading species.

Distances from undisturbed sites were taken from maps provided by Western Energy Company. Two directions were measured for the prevailing wind. The dominant wind usually rises from the northwest but as summer approaches it becomes more southeasterly (Mitchell and Super 1972).

The ratio of edge to interior of a field was calculated from Western Energy maps. The field's circumference, or edge, was measured and divided by the area within each field giving a ratio of the edge to interior (m/ha).

Topsoil and subsoil samples were collected for each site by Dana Nile of WECO and shipped to Montana State University. Samples were analyzed at the Reclamation Research laboratory for pH, EC, and for textural class using methods described in Methods of Soil Analysis (Gee and Bauder 1986)

Seeding Histories

Each field was assigned a seeding 'code' to simplify analysis of the seeding variables. Western Energy Company's reclamation mixes fall into one of four categories:

1) Upland mix: composed of cool and warm season native grasses.
2) Cover: a nurse crop of either wheat or wintergraze.
3) Supplemental mix: primarily perennial forbs.
4) Warm season mix: warm season grass species.

Table 1 provides a summary of the seeding history for all fields used in this study. Seeding variables are listed in the order referred to above.

Statistical Analysis

Data used in statistical analyses included information provided by Western Energy Company's reclamation records as well as cover and production data collected during 1991. Analyses consisted primarily of covariance analysis using the General Linear Model (GLM) procedure in SAS (Version 6.03, SAS Institute, Cary, NC, 1983). Variables were considered significant when P-values were 0.10 or lower. Analyses were done at the frame level to provide replication. I acknowledge that this is not true replication and therefore the data will be interpreted to establish trends on these sites rather than to infer absolute conclusions of reclaimed sites in general.

Dependent variables were percent areal cover, productivity of standing biomass, and percent invading species. Independent variables were age of fields, season of planting, ratio of edge to interior of fields, soil depths, and distance from undisturbed windward sites from the northwest and southeast.

Seeding methods, mixes, and rates were not included in models for analysis of variance; each field was uniquely defined by a combination of these variables. These variables are discussed in the text.

Table 1. Seeding history of fields.

Field	Seed rate (kg/ha PLS)	Seed mix*	Seed method**	Age of field-season
3801	8-1-0-0***	18-37-0-0	2-2-0-0	10-F****
4801	30-4-0-0	18-37-0-0	2-2-0-0	10-S
1851	44-0-13-0	22-0-24-0	1-0-2-0	6-S
3841	25-2-16-0	22-37-25-0	1-1-2-0	7-F
3852	23-0-10-0	22-0-25-0	1-0-2-0	6-F
4852	12-0-8-0	28-0-27-0	1-0-2-0	5-S
4861	16-0-11-30	28-0-27-26	1-0-2-2	5-F
4862	22-0-6-30	29-0-30-26	1-0-2-2	4-S
4884	13-0-8-0	33-0-30-0	1-0-2-0	2-S
4881	22-0-5-0	33-0-30-0	1-0-2-0	3-F
2832	33-7-21-0	19-36-20-0	1-2-2-0	8-S
3821	67-10-0-0	19-36-0-0	1-1-0-0	9-F

* See table 59, Appendix C; numbers refer to mixes.

** 1=drill
2=broadcast.

*** Refers to the type of mix, i.e. upland, cover, supplemental, and warm season.

****F=fall seeding
S=spring seeding.

SITE DESCRIPTION

The study area is located in southeastern Montana near the town of Colstrip at Western Energy Company's Rosebud Mine. Twelve topsoiled sites ranging in age from two to ten years were chosen on the basis of age and available historical data. Six of these sites were in Area C of the Rosebud Mine, two in Area A, two in Area B, and two in Area E (Figure 1).

Colstrip is located along the east fork of Armell's Creek at approximately 980 m above sea level. This area has a semiarid, continental climate, with annual precipitation averaging 40 cm most of which occurs from April to June. Streams generally flow intermittently and major channels drain northerly into the Yellowstone River. The landscape is dominated by rolling prairie with sandstone bluffs, broad valleys, footslopes, and stream terraces. The vegetation is characterized by mixed prairie and pine savanna typical of southeastern Montana.

Native soils are usually sandy or loamy, and poorly developed with a general absence of a B horizon. They are classified as Ustic Toriorthents, Borollic camborthids, Aridic haploborolls, and Ustic torrifluvents.

Results and Discussion

Results

Each of the twelve fields in this study has a unique set of characteristics that define its history and therefore influence its present state. Such variability among sites makes it difficult to directly imply cause and effect to the observed results. Nevertheless, these data should be used to support further research for improving diversity on mined lands.

Significance tests were run to determine effects on percent areal cover, standing biomass, and percent invading species. Independent variables analyzed were: age, season of planting, ratio of edge to interior of fields, field size, top soil depth, total soil depth and distance from northwest and southeast undisturbed sites.

A descriptive summary of each field is presented in the text, management practices are noted when applied. Statistical results are presented and should be limited to the scope of this study.

Field 3801

This field is one of the two sites in area A of the Rosebud mine (Figure 1). It was fall seeded in October of 1981 with an uplands mix at 8.5 kg/ha (7 lb/a) pure live seed (PLS), and a cover crop of wheat at 1.5 kg/ha (1.3 lb/a). Both mixes were broadcast seeded (Table 1). Four species were in the uplands mix and only Agropyron trachycaulum (slender wheatgrass), was not found on the site. This was not surprising since this species usually disappears by the third or fourth growing season (S.C.S. 1988). Agropyron smithii (western wheatgrass) and A. dasystachyum (thickspike wheatgrass) were not differentiated in the field and were considered collectively as Agropyron smithii for this study. The total number of species within frames for this field was thirty-five; of this total thirty-two were invaders. Table 2 summarizes variables for this field.

Table 2. Summary of field 3801.

Age	10 years
Time of planting	October 1981
Ratio of edge to interior	377 m/ha
Size of field	1.6 ha
Topsoil depth	30 cm
Total soil depth	102 cm
NW distance from undisturbed area	810 m
SE distance from undisturbed area	268 m
Total species seeded	4 + cover
Total species within frames	35
Invading species within frames	32
Floristic richness*	14

*Based on species having >1% cover.

Field 3801 had the greatest number of invading species for all fields in this study. It was one of three fields to be seeded with an uplands mixture containing only four species plus a cover crop. A cover crop is generally an annual grain crop such as Triticum aestivum (wheat) which provides rapid soil stabilization but which dies out within a few growing seasons. The seeding rate for this field was the lowest reported for this study (Table 1).

Table 3 lists the species seeded, their percentage of the mix, and their percent composition, by cover, at the time of this study. Species are noted by four character abbreviations throughout this report and are defined in Table 50. Table 4 summarizes canopy coverage data by species for field 3801. Table 5 lists all species observed throughout the field, their origin (native or introduced), and whether or not they were an invading species.

Table 3. Species seeded in field 3801 with percent composition recorded at the time of study.

Species and variety	Percent of mix	Percent composition*
Mix 18: Uplands mixture		
AGTRA**	5	0
AGSM Rosanna/AGDA	40/25	8
STVI	30	16
Mix 37: Cover crop		
TRAE	100	0

* Species with 0% composition may not have been recorded in a frame but may have been noted on the complete species list (Table 5).
**See Table 50.