ENHANCING SHRUB ESTABLISHMENT BY UTILIZING DIRECT HAUL TOPSOIL ON MINE SPOILS IN WESTERN COLORADO

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ABSTRACT

Achieving a required high shrub density level in the postmining reclamation plant communities can be relatively expensive, time consuming, and also requires a high level of replanting maintenance due to high levels of mortality. This study was initiated to investigate differences in shrub establishment among three types of reclamation sites: Graded spoils/no topsoil, graded spoils/direct haul topsoil, and graded spoils/topsoil from stockpiles. Through a random sampling method, 87 transect sites were sampled at the Seneca II Mine, 16 kilometers southeast of Hayden, Colorado. Big sagebrush, (Artemisia tridentata) and rubber rabbitbrush (Chrysothammus nauseosus) had the highest numbers in graded spoil. Big sagebrush and mountain snowberry (Symphoricarpos oreophilus) contributed the highest numbers to total shrub composition in topsoiled areas. Shrub establishment increased substantially from the older graded spoils with no topsoil to the newer direct haul topsoiled areas. Natural shrub establishment is maximized when the topsoil resources are either direct hauled or stockpiled for less than one year, replaced by lifts, and handled during moist soil conditions. Management practices such as minimized seedbed preparation and vegetation shredding prior to topsoil removal also promote higher shrub densities.

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INTRODUCTION

Increased surface coal mining activity in the western United States has created a variety of challenges and requirements for the mining industry. Reclamation efforts have increased substantially in recent years, and in particular since the passage of the Surface Mine Control and Reclamation Act[1].

In Colorado, rules and regulations applicable to surface coal mining operations and reclamation have been promulgated by the Colorado Mined Land Reclamation Board [2]. Revegetation requirements for reclaimed lands include the establishment of plant communities that meet various cover, production, species composition, diversity, and woody plant density standards.

Reclamation of mined lands has developed into a process that involves a variety of disciplines and requires the coordination of planning and operations staffs. How these reclamation plans and methods are implemented in the field will dictate to a large extent the level of reclamation success.

In areas of surface coal mining where premining vegetation consists of the mixed brush or sagebrush vegetation communities, achieving postmining shrub densities (which are related back to premine densities and dictated by regulatory requirements) has became a point of considerable debate. Crofts and Parkin demonstrated that achieving high shrub density levels can be relatively expensive, and also requires a high level of replanting maintenance due to high levels of mortality.[3]

A means of achieving this elusive goal is to maximize natural processes of reinvasion, regeneration, and succession in reclaimed areas. With the increased use of direct haul topsoil or short duration stored topsoil, in reclamation efforts, natural regeneration of native woody vegetation can be increased markedly. [4,5] This can often be further enhanced by maximizing the placement of the uppermost native topsoil layers on the surface of the retopsoiled areas and by controlling the time of topsoil replacement.[5]

The following study was initiated to document the amount and composition of woody plant regeneration occurring on reclaimed lands at Peabody Coal Company's Seneca II Mine near Hayden, Colorado.

STUDY AREA DESCRIPTION

The Seneca II Mine is located approximately 200 kilometers northwest of Denver, Colorado, and more specifically, 16 kilometers southeast of Hayden, Colorado. Elevations range from 2040 meters on the west edge of the mine property to 2440 meters on the east side. The average annual precipitation is intermediate between 40 and 50 centimeters. Precipitation occurs predominantly as snowfall and early spring rains while summers are hot and dry.

Two vegetation types and one subtype have been identified at the Seneca II Mine: the sagebrush grassland type, the mixed brush type, and a minor aspen subtype. The mixed brush type is the most extensive on the study area and is dominated by a shrub overstory of Gambel's oak (Quercus gambelii), common chokecherry (Prunus virginiana), and saskatoon serviceberry (Amelanchier alnifolia). The understory is a mix of herbaceous species, big sagebrush (Artemisia tridentata), and mountain snowberry (Symphoricarpos oreophilus). Shrub densities in the premine mixed brush type are about 8,000 stems/ha. The sagebrush grassland type accounts for nearly all of the remaining vegetation on the study area. While big sagebrush, mountain snowberry, and Douglas rabbitbrush (Chrysothamnus viscidiflorus) are common, the herbaceous component accounts for a large percentage of the vegetative cover. Shrub densities in the sagebrush-grassland type average about 4,000 stems/ha.

Soils on the study area have developed from parent material consisting of interbedded shale and fine sandstone. Soils are generally loamy in nature with high organic matter contents. The dominant soils are classified as Cryoborolls which have thick A horizons which often directly overlay the fractured light yellowish brown sandstone. Soil depths range from less than 15 centimeters to more than 125 centimeters. The moderately deep loamy soils which have developed on north to northeast facing slopes and high ridges are favorable to the mixed brush vegetation type. Small amounts of aspen occur on moderately deep to deep silt loam and silty clay loam soils on high north facing slopes, in drainages, or on concave sideslopes. A combination of the mixed brush and sagebrush grassland communities occur on shallow to moderately deep loamy soils of lower ridges and other higher south and southwest facing slopes.

STUDY METHODS

Reclamation activities at the Seneca II Mine have been ongoing since the late 60's. This has resulted in a variety of methods used in reclamation which can be associated with changes in regulatory requirements, methodologies, and technology. Three general types of reclamation were sampled at the Seneca II Mine. These include graded spoils, no topsoil; graded spoils, topsoil from stockpiles; and graded spoils, direct hauled topsoil.

Prior to selection of the sample sites, the area for each of the three reclamation types to be studied was delineated on a 1" = 400' topographic base map. All sample sites were selected by a random process in which a 200 x 200 foot grid system was overlain on the 1" = 400' topographic base map and a random numbers table used to assign spatial (x, y) coordinates. Sample size was based on previous vegetation studies conducted by Western Resource Development Corporation of Boulder, Colorado [6] and the Vegetation Guideline No. 2 of the Wyoming Department of Enviromental Quality [7]. Sample sizes were:

30 Graded spoil sites with no replaced topsoil
50 Graded spoil sites which had direct haul topsoil, and
6 Graded spoil sites with topsoil replaced from stockpiles

Sample sites were located during the field survey in August and September, 1982 using a 1" = 400' topographic map with a 10 foot contour interval. At each sample site a 50 meter transect line was randomly orientated from the sample point. A 1 meter wide strip along the line transect was sampled yielding a 50 square meter sample area at each site.

Shrubs at each site which were rooted within the 1 meter x 50 meter rectangular quadrat were counted by species and the low and high shrub heights recorded in centimeters. Additionally, the compass orientation of the transect, the average percent slope, and the slope aspect were recorded.

RESULTS

Establishment of shrubs has occurred in all of the areas studied, but was variable within each of the three types. Shrub establishment increased substantially from the older graded spoils with no topsoil to the newer direct haul topsoiled areas. While many transects in the topsoiled areas did not have shrubs rooted within, shrubs were present in the immediate vicinity of the transects.

Big sagebrush and mountain snowberry contributed the highest numbers to total shrub composition in topsoiled areas. Big sagebrush and rubber rabbitbrush had the highest numbers in graded spoils. In topsoiled areas, all major shrub species present in the mixed brush and sagebrush grassland types were reestablishing.

Graded Spoils/No Topsoil

This study area included those areas of graded and seeded spoils reclaimed from the period of 1972 to 1976. Topsoiling was not carried out on any of the 53 hectares included in the sample area.

Total estimated shrub density on this sample unit was .72 stems/50m^2 (Table 1) or 144 stems per hectare. Species contributing the highest densities were rubber rabbitbrush (Chrysothamnus nauseosus) at 54 percent and big sagebrush at 25 percent of all shrubs sampled. Other shrubs present include skunkbrush sumac (Rhus trilobata), Gambel's oak and mountain snowberry. Shrub heights ranged from a mean low of 10.0 cm for skunkbush sumac to a mean high of 63.6 cm for rubber rabbitbrush.

Graded Spoils/Direct Haul Topsoil

Approximately 123 hectares were sampled in this unit, the largest of the three units sampled. This included areas that hove had direct haul topsoil replaced on graded spoils from 1977 to the present. Many areas of this unit received upper lifts of topsoil that contained seed, roots, and plant residues. These areas are generally in the most recently reclaimed portion of the sample unit.

Table 1 Summary of Shrub Establishment Data
Seneca II Mine - 1982

Sampled Area	Height (cm) Mean Low	Mean High	% Shrub Composition	Mean Density No/50m²	No./Ha	No./Ac
GRADED SPOILS/NO TOPSOIL (n = 28)						
Rubber Rabbitbrush	26.5	63.6	54.1	0.39	78	32
Big Sagebrush	17.5	25.5	25.0	0.18	36	15
Skunkbush Sumac	10.0	20.0	9.7	0.07	14	6
Gambel's Oak	30.0		5.6	0.04	8	3
Mountain Snowberry	18.0		5.6	0.04	8	3
ALL SHRUBS			100.0	0.72	144	59
				(s = 1.30)		
GRADED SPOILS/DIRECT HAUL TOPSOIL (n = 50)						
Big Sagebrush	13.8	40.5	55.2	4.80	960	389
Mountain Snowberry	9.9	28.3	35.6	3.10	620	251
Common Chokecherry	14.5	23.4	4.8	0.42	84	34
Woods Rose	15.0	31.7	2.1	0.18	36	15
Saskatoon Serviceberry	8.7	41.0	1.4	0.12	24	10
Douglas Rabbitbrush	30.0	40.0	0.7	0.06	12	5
Gambel's Oak	12.0		0.2	0.02	4	2
ALL SHRUBS			100.00	8.70	1740	706
				(s = 9.56)		
GRADED SPOILS/TOPSOIL FROM STOCKPILES (n = 6)						
Mountain Snowberry	10.0	41.0	54.6	5.83	1166	472
Big Sagebrush	21.0	55.0	31.2	3.33	666	270
Common Chokecherry	5.0	10.0	6.3	0.67	134	54
Saskatoon Serviceberry	10.0	22.0	4.7	0.50	100	40
Gambel's Oak	10.0		1.6	0.17	34	14
Woods Rose	30.0		1.6	0.17	34	14
ALL SHRUBS			100.0	10.67	2134	864
				(s = 12.99)		

The shrub density within this sample unit was 8.70 stems/50 m^2 or 1,740 stems/hectare. Highest densities were contributed by big sagebrush at 55 percent and mountain snowberry at 35 percent of all shrubs sampled. Other shrubs present were common chokecherry, Woods rose (Rosa woodsii), saskatoon serviceberry, Douglas rabbitbrush, and Gambel's oak. Shrub heights ranged from a mean low of 9.9 cm for mountain snowberry to a mean high of 41.0 cm for saskatoon serviceberrry.

Graded Spoils/Topsoil From Stockpiles

This unit of the study area included those areas of graded spoils that were reclaimed during the period of 1972 to 1981. Topsoil placed on these graded spoil areas came from topsoil stockpiles. Verification as to the actual length of time topsoil remained in these stockpiles is not available but should generally have been less than 18 months. Approximately 10 hectares were included in this sample unit.

The estimated shrub density for this sample unit was 10.7 stems/50 m^2 or 2,134 stems/hectare. Species with the highest densities were mountain snowberry and big sagebrush, contributing 54 percent and 31 percent respectively. Other shrubs occurring on the site were common chokecherry, saskatoon serviceberry, Gambel's oak, and Woods rose. Shrub heights ranged from a mean low of 10.0 cm for mountain snowberry and serviceberry to a mean high of 55.0 cm for big sagebrush.

DISCUSSION

The primary objective of this study was to evaluate the extent and composition of shrub regeneration on a variety of reclaimed lands at the Seneca II Mine in northwestern Colorado. Results of this study will aid in estimating the amount of shrub establishment that is feasible in areas that have been topsoiled with soils from the native sagebrush grassland and mixed brush vegetation types. Additionally, general reclamation methods were evaluated as to their affects on the amount and extent of shrub establishment in reclaimed areas.

In developing the study, it was assumed that three factors would contribute importantly to shrub regeneratian on reclaimed lands; the first is natural invasion and regeneration from seed sources in native stands outside the reclamation, second, a variety of native seed and rooting materials would be present in topsoil, and third, direct hauling and particularly top-lifting, of topsoil or short duration stored topsoil would maximize the transfer of viable seed and rooting materials.

Invasion of shrubby species from native stands outside the reclaimed areas may be a result of wind and water borne seed as well as seed transported into the area by animals. In areas of graded spoils with no topsoil, these are the primary means of natural shrub regeneration.

Large amounts of seed and regenerative root materials are present in the upper layers of topsoil, particularly in productive plant communities and fertile soils such as those found at the Seneca II Mine. Big sagebrush, a common species at the Seneca II Mine, propagates by seed only, but this is partially offset by the large quantities of seed produced and the relative ease with which seedlings may become established.[8, 9] Mueggler found that large quantities of big sagebrush seed are residual in soils after disturbance.[10] On the other hand, the remaining dominant shrubs such as Gambel's oak, mountain snowberry, saskatoon serviceberry, and common chokecherry reproduce both by seed and root sprouting with root sprouting usually being more important.[9,11,12]

The method af topsoil replacement is important in natural regeneration of native shrubby species. The time of season that topsoil is stripped and replaced will determine to some extent how much regeneration occurs. Because of the short field season at the Seneca II Mine, topsoil stripping and replacement must be maximized during late spring, summer,

and early fall. During those early periods in the season when soil moisture levels are high and warming temperatures occur, root development and seed germination are stimulated. During the drier summer and early fall months, soil moisture levels may not be adequate and equipment handling of topsoil may actually contribute to desicating conditions. Several transects in fall topsoiled areas showed lower densities and may have been partially affected by dry soil conditions. However, recent observations during summer 1984 have shown high sagebrush densities in topsoil direct hauled during September, 1983. Seed production may have peaked at the time the soil was handled. In addition to time of topsoil replacement, maximizing direct haul, and upper lift replacement of topsoil that contains the highest number of reproductive materials and soil microbial populations will aid in regeneration. Those areas that showed evidence of being upper lift topsoil also had generally higher densities of shrubs. Because of seed viability and root sprouting abilities of the various shrubs [9] topsoil in stockpiles less than one year may retain quantities of viable reproductive materials.

Shrub regeneration in the reclaimed spoil areas that were not topsoiled is quite limited and restricted to those areas closest to undisturbed stands of native vegetation. Wind blown seed from stands of rubber rabbitbrush and big sagebrush is the most likely method of establishment for these two species in the graded spoils area. Even though grading and seeding of this area occurred eight to ten years ago, very limited regeneration has occurred. A very heavy stand of alfalfa and grass has become established which has effectively slowed the establishment of invading species. Bartolome and Heady found that sagebrush reinvasion was slowed or halted in areas that were cleared of sagebrush, seeded, and had a good establishment of herbaceous cover [13] The few mountain snowberry plants established in the spoil/no topsoil area were probably a result of seed transported by animals.

The small areas of graded spoil which were topsoiled from topsoil stockpiles were highly variable in shrub establishment. There were localized heavy stands of mature big sagebrush adjacent to those transects with high densities of big sagebrush which most probably contributed to establishment. In addition it may be possible that seed in the soil which was stockpiled less than one year maintained an adequate level of viability. Big sagebrush seed can remain dormant in the soil for periods of up to four months and subspecies vaseyana requires a period of stratification (two to three months) for proper germination.[9]

The areas of graded spoil where topsoil was replaced by direct haul methods had good establishment of shrubs in terms of total numbers and number of species. It has already been shown that high levels of residual sagebrush seed in the soil can be expected, and thus good establishment of sagebrush is possible. Big sagebrush was the most common shrub established in direct hauled areas and exhibited the best vigor and highest densities where the herbaceous vegetation was not established or had low cover. Many of the big sagebrush plants in areas that were reclaimed three years ago or longer were producing seed.

The remaining dominant shrub species which reproduce by both seed and root sprouting, established at lower levels in direct hauled topsoil areas. The exception to this was mountain snowberry. This species is an extensive colonizer, reproducing by seed and extensively by rhizomes.[11] Tisdale and Hironaka in a review of the literature on the sageburch-grass region found that little has been published on the ecology of mountain snowberry.[9] Additionally, the literature pertaining to mixed brush species and their ability to regenerate after severe mechanical disturbance of a site is somewhat sparse. Valentine summarized that recovery of mixed brush species when sprayed with herbicides or treated mechanically was good.[14] The relatively low numbers of common chokecherry, saskatoon serviceberry, and Gambel's oak becoming estalished in the early periods of reclamation may be due in part to the loss or damage of the root crowns where sprouting usually occurs. Brushy vegetation at the Seneca II Mine is removed with a bulldozer and consequently plant materials near and just below the soil surface may be removed as well. It should be noted that in most cases it appeared that the above species and mountain snowberry were sprouting from vegetative materials. Observations during summer 1984 showed extensive root sprouting of Gambel's oak ond mountain snowberry in a recent (1984) direct hauled topsoil reclamation area.

Seedbed preparation and seeding cause surface soil disturbance and tend to reduce the number of seedlings established depending on the type and extent of operations. Croft and Parkin found that tillage associated with revegetation significantly reduced natural seedling establishment.[4] Similarly, transects which were located in topsoiled areas that were disked showed lower or no shrub densities. While more limited in its affect, drill seeding operations may also reduce seedling establishment.

In those areas where topsoil is carefully replaced and direct haul topsoil is maximized, reestablishment of the native communities is greatly improved. Succession in the re-

claimed plant communities is enhanced and begins as secondary versus primary succession. Secondary succession is characterized by community development on sites previously occupied by well-developed communities or sites where nutrients and conditions of existence are already favorable.[15] Primary succession would be successional processes that occur on those areas of unreclaimed spoil piles.

CONCLUSION

Establishment of woody vegetation in reclaimed landscapes by natural regeneration is feasible and can be further enhanced by proper reclamation procedures. Maximizing direct haul topsoil or short duration stored topsoil replacement methods and insuring that upper lifts are replaced near the surface of the reclaimed areas as often as is feasible are minimum requirements. Minimizing seedbed preparation whenever possible will also insure a higher level of seedling survival. Shredding vegetation prior to topsoil stripping and minimizing the use of dozers with standard blades during brush removal will insure that a maximum amount of seed, rooting materials, and organic matter are replaced in the reclaimed areas. An additional benefit, often overlooked, is the enhanced possibility for rapid restoration of the rhizosphere where interaction between plants (roots) and soil microorganisms result in critical nutrient cycling, energy flow, and stimulation of plant growth and increased microbial populations.[16,17] Establishment of both producer and decomposer systems seems to offer the most promising potentials in achieving long-term success in semi-arid land reclamation [18]. This particular area is in need of increased study, particularly in relation to improving plant establishment ond succession in reclaimed communities.

Environmental conditions such as premine plant communities, soils, and climate will determine the potential for natural shrub regeneration. However, natural shrub regeneration from direct haul or short duration stored topsoil can play a major role in reestablishing overall woody plant densities in the reclaimed landscapes. In the case of woody plant establishment, this would then allow planting efforts and resources to be directed to those areas that contribute to critical habitat and improve wildlife edge and diversity.

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