REVEGETATION: STANDARDS FOR SUCCESS ON THE NAVAJO MINE, NEW MEXICO[1]

by

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Abstract. An evaluation of the present revegetation success standards at the Navajo Mine, in northwestern New Mexico, found that they were not based on all pertinent data nor on sound ecological concepts. The approved standards significantly exceed the cover and production values found on adjacent undisturbed range sites. The current standards are not weighted based on the percentages of the mine lease occupied by the pre-mine range sites and they also include poisonous and noxious plants. Plant diversity is evaluated in terms of species instead of the more appropriate concept of plant life forms and the approach of using a similarity index is not employed. Recommendations are made on how to improve the ecological validity of the revegetation success standards by changing all of these procedures.

Additional Key Words: revegetation, standards, cover, production, density, diversity.

Introduction

In 1989 the Navajo Mine, in northwestern New Mexico, obtained a Permit to Mine from the Office of Surface Mining, U. S. Department of the Interior. The permit contained revegetation success standards that applied to all areas disturbed from 1989 forward (see Table 1). Federal regulations dealing with revegetation standards for success include:

"Success of revegetation shall be judged on the effectiveness of the vegetation for the approved postmining land use, and the extent of cover compared to the cover occurring in natural vegetation of the area" (30 CFR 816.116 [a]).

"Standards for success shall include criteria representative of unmined lands in the area being reclaimed to evaluate the appropriate vegetation parameters of ground cover, production, or stocking. Ground cover, production, or stocking shall be considered equal to the approved success standard when they are not less than 90% of the success standard" (30 CFR 816.116 [a][2]).

"For areas developed for use as grazing land or pasture land, the ground cover and production of living plants on the revegetated area shall be at least equal to that of a reference area or such other success standards approved by the regulatory authority" (30 CFR 816.116 [b][1]).

The Navajo Mine is located within the Colorado Plateau physiographyic province which has within its borders a wide diversity of topography, geologic materials, soils and vegetation. The general terrain of

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Table 1. Revegetation success standards as found in the 1989 mining permit for Navajo Mine.

Parameter	1989-Future Revegetation Areas
Cover[1]	5%
Production[1]	250 lb/acre
Woody Species	190/acre
Diversity[1]	2 grasses[2] 1 forb[3] and 2 woody species[4]

[1]Cover, production, and diversity will be only perennial plant species.

[2]Two grass species with relative herbaceous cover values equal to or greater than 5%, with no one species comprising more than 70% relative herbaceous cover.

[3]One forb species with relative herbaceous cover values equal to or greater than 5%, with no one species comprising more than 70% relative herbaceous cover.

[4]Two woody species with density values equal to or greater than 10% of total woody species density, with no one species making up more than 85% of the total species density.

the Navajo mine is characterized by rough and broken topography, badlands, plateaus and mesas, intermingled with escarpments and valleys or washes. Many of the soils are formed from alluvium and or washes. Many of the soils are formed from alluvium and eloian sediments derived from shale and sandstone. Some soils have formed from residium. Most of the soils in the survey area have been forming only since the late-Pleistocene and during the Holocene. It is very common to find buried soils that date back to the Pleistocene.

Annual precipitation averages 6.1 in with large annual differences. Snowfall may occur from November to April and snow depth averaged 9.0 in each year. The temperature is typical of continental areas, rarely exceeding 100°F with few days of temperature below 0°F. The average daily range of temperature is 38°F.

The approved post-mining land use for the Navajo Mine is livestock grazing. Because of the mining plans and the landowner situation around the mine, reference areas could not be utilized. Instead, Navajo Mine has been collecting historic data on undisturbed range sites within the lease for the last 8 years. There are 8 separate range sites on the mine lease and they vary from extensive, unproductive badlands to small, productive sand dunes. During the permitting process, Navajo Mine was allowed only to use vegetation data from the 4 most productive range sites in developing the revegetation success standards.

The purpose of this study was to examine and evaluate the current methods and procedures used to develop revegetation success standards at the Navajo Mine. The paper will present:

1. The current method used to develop each standard.
2. A discussion on the validity of that method and the standard.
3. Recommendations on changes to the method or the standard.

Cover

Methods

Cover refers to the area covered by the vertical projection of the live crown on the ground (Brown 1954). It is a primary attribute of vegetation in ecological and range studies (Cook and Stubbendieck 1986). Cover can be used as a basis for comparison among plants of differing life forms and is a non-destructive measurement. Permanent sampling units can be established and repeated measurements taken. The cover-data sampling technique approved and used on the Navajo Mine is the line-intercept method first described by Canfield (1941). It consists of stretching a 30 m long tape between 2 points that are randomly located 40 times within a range site or reclaim area. Interception is recorded in millimeters by species (Martin-Erickson 1990). Canfield (1941) recommended a 30 m line for cover below 5%. The line-intercept method is often considered one of the most reliable methods for determining cover and is often used for comparing other methods (Hormay 1949, Kinsinger et al 1960, Brun and Box 1963, and Hanley 1978). As an example comparison, point sampling is a popular alternative method for faster evaluation; it often results in a positive bias (Goodall

Table 2. Mean perennial cover for various pre-mine range sites at the Navajo Mine and a nearby Bureau of Land Management (BLM) Study Area.

Range site[1]	Perennial cover	Mean cover	Percentage of mine lease		Weighted mean
Dunes	4.90%	4.40%	x 6.5	=	0.29
Saline sands	4.18	3.98	x 11.8	=	0.47
Arroyo shrub	3.93	2.89	x 1.0	=	0.03
Sands	3.91	2.91	x 13.7	=	0.40
Calcareous sands	3.31	3.13	x 3.7	=	0.11
Thinbreaks	3.23	3.05	x 9.0	=	0.27
Alkali wash	1.36	1.29	x 27.3	=	0.35
Badland	0.88	0.85	x 27.1	=	0.23
			Total		2.15%
BLM Study Area[1]	2.62	2.26			2.26%

[1]Years covered for 1983, 1984, 1985, 1986, 1987, 1988, and 1989.

1952, Whitman and Siggeirsson 1954, Johnston 1957, Warren Wilson 1963). The method is considered to have a comparatively small sampling error (Schultz et al 1961). The main drawback to the line-intercept method is the time required to conduct the sampling (Heady et al 1959).

Results

The present revegetation success standard for cover is 5% at the Navajo Mine. This standard is based on data from only the 4 most productive pre-mine range sites. An analysis of cover data collected since 1982 shows this value is significantly higher than cover values found on all undisturbed range sites within the lease area (see Table 2). Two of these range sites, Badland (27.1% of the lease) and Alkali Wash 27.3% of the lease), collectively occupy 54.4% of the pre-mine lease and have 0.85 and 1.29% mean cover, respectively. Incidentally, neither of these areas contain suitable sources of topdressing material for the land reclamation program, yet suitable topdressing material will be distributed over these areas when they are reclaimed. That material will come from approximately 45% of the lease area. In general, less than half of the lease provides the topdressing for the entire reclamation program. In addition, more than half the lease (54.4%) has a mean cover of 1.07%. To accurately determine the mean cover value of the pre-mine lease condition, the area of each range site must be used to arrive at a weighted mean (see Table 2). A simple arithmetic mean would not accurately account for the extensive area of low cover. The proportions of each range site (see Figure 1) were used to calculate a weighted mean for cover (see Table 2). The value represents the mean pre-mine condition, which is being approximated in the post-mining reclamation program by reclaiming all lands uniformly.

Also used for comparison is a nearby Bureau of Land Management (BLM) Study Area that has been excluded from livestock grazing for 20 years. Many of the species and all the plant life forms found in the BLM Study Area are found on the range sites of the Navajo Mine lease.

Many range sites contain large amounts of poisonous and noxious plants. These are mostly broom snakeweed (*Gutierrezia sarothrae*), greasewood (*Sarcobatus vermiculatus*), and cacti (*Opuntia* spp. and *Yucca* spp.). Reasons for not including poisonous and noxious plants in the standard are readily apparent in an example. A range site may contain 3% total perennial cover of which 2.5% is poisonous and noxious and only 0.5% is favorable. If the area is mined and reclaimed with a resultant favorable cover of 2% perennial cover and very little poisonous and noxious plant cover, then the reclaim success is below the pre-mine standard but 400% above the level usable for the post-mining land use. Eliminating the poisonous and noxious cover from the standard eliminates the need to plant poisonous and noxious plants in the reclaimed areas to meet a standard.

Table 2 shows the pre-mine range sites found on the Navajo Mine lease, the total mean perennial cover, and the adjusted mean perennial cover resulting from removal of poisonous and noxious plants. Also shown are the percentage of mine lease associated with each range site and the weighted adjusted mean cover resulting from multiplying the adjusted mean cover by the percentage of mine lease. As an example, dunes have 4.90% total perennial cover. After poisonous and noxious plant cover is removed, the adjusted mean is 4.40%. Only 6.5% of the mine lease area is dunes. The adjusted mean cover (4.40%) multiplied by the percentage area of the lease (0.065) gives a weighted value of 0.29. The weighted values are summed to give an accurate mean cover value for the Navajo Mine

for all range sites without poisonous and noxious plants. The weighted mean is 2.15%. The BLM Study Area has a similar value (2.26%) which is not significantly different ($p = 0.01$) from the Navajo Mine pre-mine range sites. Both of these values (2.15 and 2.26%) are substantially lower than the 5% cover standard.

Production

Methods

Production refers to plant weight and is found by clipping the current years growth. Clipping is the most common method for determining plant weight (Milner and Hughes 1968). Although the method is time consuming, it yields a direct and objective measure of herbage weight (Cook and Stubbendieck 1986). Adjacent to each 30 m long cover transect, a 1 m^2 plot (10 cm X 10 m) is clipped, separated by species, and dried at 60°C and weighed.

Results

The present revegetation success standard for production is 250 lb/acre of perennial plants at the Navajo Mine. Like cover, this standard is also based on only the 4 best pre-mine range sites. An analysis of production data collected since 1982 shows this value is too high for the Navajo Mine. Over half (58%) of the range sites' acreage (calcareous sands, alkali wash, and badland) produced less than 250 lb/acre. In addition, the BLM Study Area had less than 250 lb/acre of perennial plants. Like cover, production should be weighted based on the percentage of all pre-mine range sites within the mine lease.

As pointed out in the section on cover, many of the sites contain large amounts of poisonous and noxious plants. Their production values should not be used to set the standard for perennial plant production for the same reasons they should not be used in the standard for cover.

Table 3 shows the pre-mine range sites found on the Navajo Mine lease, the total mean perennial production, and the adjusted mean perennial production resulting from removal of poisonous and noxious plants. Also shown are the percentage of mine lease associated with each range site and the weighted adjusted mean production resulting from multiplying the adjusted mean production by the percentage of mine lease. The weighted adjusted mean for all range sites was 198.4 lb/acre which is considerably below the 250 lb/acre standard. The BLM Study Area has a similar value (208.0 lb/acre), which is not significantly different ($p = 0.01$) from the Navajo Mine pre-mine range sites. Both of these values (198.4 and 208.0 lb/acre) are substantially lower than the 250 lb/acre standard.

Density

Methods

Density is defined as the number of individuals per unit area (Cooper 1959). Density determinations are useful when, in addition to cover and production, the number of individuals are of interest, such as in evaluations of shrubs. At the Navajo Mine, density is conducted along the 30 m tape used for measuring cover by counting each shrub whose base falls within 1 m width on both sides of the tape.

Results

The present standard is 190 woody plants/acre. This standard was included in the permit with the sole intention of adequately addressing the needs of livestock grazing requirements. This is an adequate and appropriate number for reclaimed areas of the Navajo Mine for the following reasons:

1. Livestock grazing has been identified in the permit as the primary land use for reclaimed areas. Some shrubs are desirable in the vegetation community because they provide protein during winter. While cured grasses and forbs mainly provide energy, protein is also necessary during gestation for proper fetus development before spring lambing and calving. Actively growing plant parts, like leaves and twigs on evergreen shrubs such as fourwing saltbush, have much higher protein levels than do plants that are dormant, such as grasses and forbs. Unlike energy and most minerals, protein cannot be stored by the animal's body, so a continuous supply is required (Holechek et al 1989). Low to moderate amounts of plants high in protein (10 to 50% of the diet) in New Mexico can be nutritionally advantageous, while amounts exceeding 50% of the diet are sometimes toxic (Rafique et al 1988). In an effort to develop meaningful shrub density information for reclaimed areas on mining properties in New Mexico, the State of New Mexico Mining and Minerals Division staff found through a review of the literature that shrub species account for approximately 10% of cattle diets. By comparing this percentage to grazing lands of the Lee Ranch (Santa Fe Coal) and La Plata (BHP-Utah International Inc.) Mines, it was determined that a shrub density of 190 plants/acre was necessary to provide shrub production equal to 10% of cattle diets (personal

communication between Mariah Assoc. Inc. and Bob Edgar of New Mexico Mining and Minerals Division, Oct. 19, 1984). Woody plants provide adequate levels of protein especially when the dominant species is fourwing saltbush.

2. A density of 190 shrubs/acre represents 15 ft between shrub centers. Many mature shrubs such as fourwing saltbush have a 2 to 3 ft radius. A density of 190 shrubs/acre with 2 to 3 ft radii results in 9 to 11 ft between shrubs. Studies in runoff and erosion on shrub dominated grasslands show the understory diminishes and runoff and erosion increase to unacceptable levels as shrub dominance increases (Barney and Friscchknect 1974; Rogers 1982; Carrara and Carroll 1979; Wood and Blackburn 1984; and Wood and Wood 1988). Distances of 15 feet between shrub centers will results in minimal competition between shrubs and the understory. A healthy understory will help reduce runoff and erosion (Balliette et al 1986).

Plant Diversity

Methods

Plant species diversity is often referred to as alpha diversity, which is the within-habitat or intracommunity diversity. It includes both species number (richness) and the manner in which importance is proportioned among species (evenness) (Whittaker 1972).

Plant diversity is frequently assessed simply as species richness without evenness being considered. Evenness is important because 2 communities that have the same numbers of species (richness) can exhibit very different relationships of species importance. The standard used to assess the alpha diversity (richness and evenness) of reclaimed mine land is usually the pre-mining community or a reference area so that measures selected for an evaluation should be suitable for direct comparisons between 2 communities (Chambers 1983).

Comparing the diversity of 1 area to the diversity of another area may be done with similarity indices that take into account both richness and evenness (Mueller-Dombois and Ellenberg 1974). They seem particularly promising for the evaluation of mined land diversity (Chambers 1983). Chambers and Brown (1982) recommended techniques by Motyka et al (1957), Bray and Curtis (1957), and/or Spatz (1970) for evaluating alpha diversity on reclaimed mined lands.

Results

The present standard for diversity on the Navajo Mine is shown in Table 1. It should be pointed out that the reclaimed area must include a grass component and a forb component and a shrub component. None of the pre-mine range sites meet this diversity standard.

For similarity indices on pre-mined and reclaimed areas, Chambers (1983 and 1991) has recommended life-forms and standing crop (production) values be used instead of species lists. The wisdom of using life-forms can be seen in the following example:

> One area has a large amount of a warm-season grass (sand dropseed) and a small amount of another warm-season grass (Indian ricegrass) while area 2 has just the opposite. When considered as life forms, the evenness (the proportion of species in each area) of these two areas is identical. When considered as species, the evenness of the 2 areas is quite different.

This example shows that while the species and their proportions are different, the life form will function in a similar manner in the ecosystem.

Similarity indices using life forms are presently being used by other companies at other mines in the Western United States (DePuit 1991 and Smith 1991). Of these indices, the Motyka method is most widely accepted.

Conclusions and Recommendations

The present revegetation success standards for the Navajo Mine are not based on all pertinent data nor on sound ecological concepts. To improve the validity of the standards, the following conclusions and recommendations are made:

1. The present revegetation success standard for cover (5%) is not based on pre-mine range site data which are substantially lower than 5%. The revegetation success standard should not include poisonous and noxious plant cover. The revegetation success standard for cover should reflect the adjusted weighted mean value (2.15%) for all range sites and the adjusted mean value for the BLM Study Area (2.26%).

Table 3. Mean perennial production for various pre-mine range sites at the Navajo Mine and a nearby Bureau of Land Management (BLM) Study Area.

Range site[1]	Total mean perennial production	Adjusted mean production		Percentage of mine lease		Weighted mean
Dunes	426.8 lbs/acre	379.9 lbs/acre	x	6.5%	=	24.7
Arroyo shrub	387.3	291.2	x	1.0	=	2.9
Sands	352.8	258.6	x	13.7	=	35.4
Saline sands	340.5	314.4	x	11.8	=	37.1
Thinbreaks	319.6	303.4	x	9.0	=	27.2
Calcareous sands	226.4	208.2	x	3.7	=	7.6
Alkali wash	119.3	116.3	x	27.3	=	31.8
Badland	117.3	117.1	x	27.1	=	31.7
				Total		198.4 lb/acre
BLM Study Area[1]	243.0	208.0				208.0 lb/acre

[1]Years covered for 1983, 1984, 1985, 1986, 1987, 1988, and 1989.

2. The present revegetation success standard for production (250 lb/acre) is not based on pre-mine range site data which are substantially lower than 250 lb/acre. The revegetation success standard should not include poisonous and noxious plant production. The revegetation success standard for production should reflect the adjusted weighted mean value (198.4 lb/acre) for all range sites and the adjusted mean value for the BLM Study Area (208.0 lb/acre).

3. The present revegetation success standard for shrub density coincides with the nutritional needs of livestock and the erosional stability of the plant community. This revegetation success standard should remain unchanged.

4. The present revegetation success standard for plant diversity is not based on pre-mine range site data, which are substantially different than the present standard. The revegetation success standard for plant diversity should be changed to the Motyka Similarity Index, using life-forms and production values, to compare reclaim areas with pre-mine range sites.

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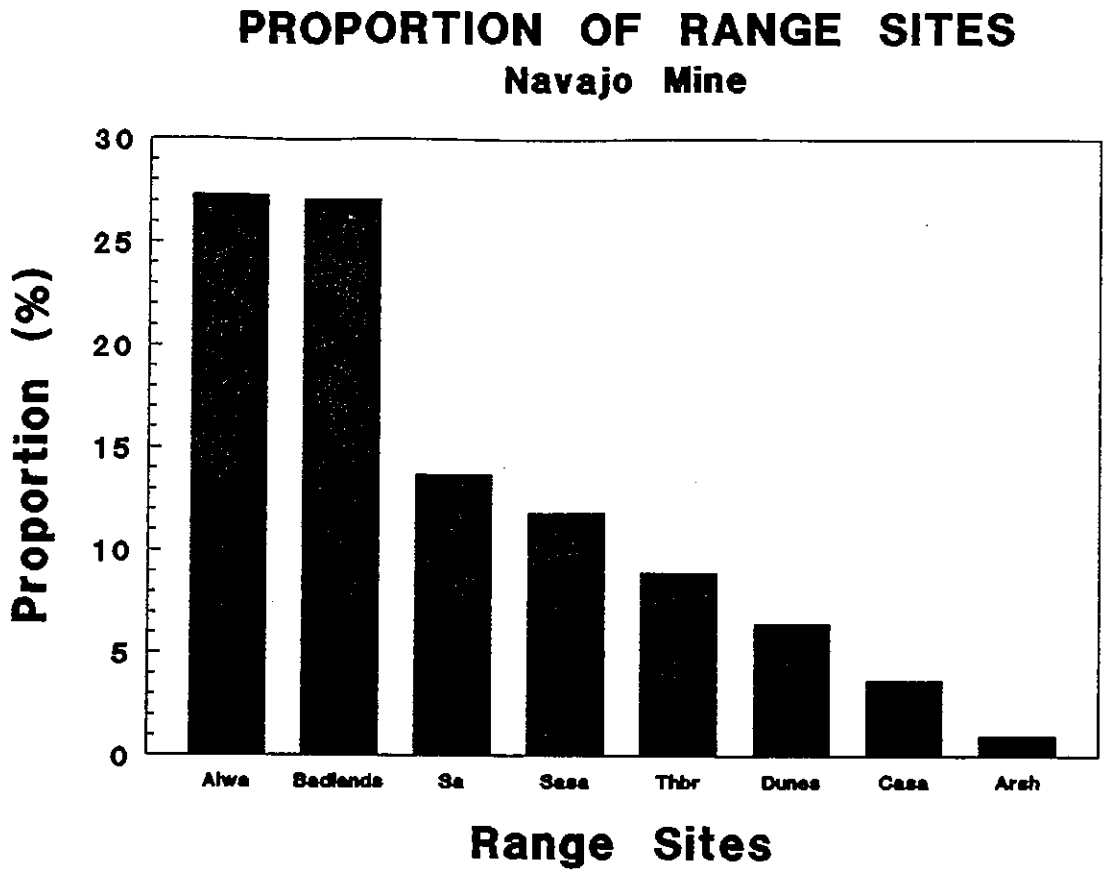

Figure 1. The percentage or proportions of area occupied by each pre-mine range site on the Navajo Mine lease. Alwa = Alkali wash, Sa = Sands, Sasa = Saline sands, Thbr = Thinbreaks, Casa = Calcareous sands, and Arsh = Arroyo shrub.