USING REFERENCE AREAS VS. TECHNICAL STANDARDS IN ASSESSING REVEGETATION SUCCESS: A QUANTITATIVE CASE STUDY[1]

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Abstract. Two options exist under Montana law for use in determining whether revegetation criteria have been successfully met following reclamation of coal mined lands – reference area comparisons and specific technical standards. Reference areas are communities used as models to which reclaimed areas are compared to evaluate revegetation success. Technical standards are usually numeric or descriptive performance standards derived from a variety of sources such as historical data and USDA range management information. Problems exist with both options. Reference areas are often not used as a reference because of the misconception that they set unattainable standards. Many mines prefer technical standards because they can provide a known standard, reduce costs, and avoid management problems associated with reference areas. Setting suitable performance standards in arid to semiarid environments is often problematic due to substantial climactic variation. In this study, the use of reference areas and technical standards are explored using 16 years of cover and production vegetation data collected from the Big Sky Mine in Rosebud County, Montana. These long-term data allow an exploration of the relationship between vegetation data and climatic variability, i.e., precipitation, and the effect of this relationship on revegetation success as measured by reference areas or technical standards. The technical standards used in this analysis were based on NRCS rangeland ecological site descriptions, a proposed technical standard from another Montana mine in the same region, and simple linear regression models based on precipitation and Big Sky reference area plant cover and biomass production averages. Results show that revegetation criteria are less likely to be achieved when technical standards are used than when reference areas are used.

Additional Key Words: Montana, reclamation, Ecological Site Description, climatic variability, precipitation, regression model, cover, production, semiarid environment

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[1] Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, ***Revitalizing the Environment: Proven Solutions and Innovative Approaches*** May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Proceedings America Society of Mining and Reclamation, 2009 pp 1470-1481
DOI: 10.21000/JASMR09011470
http://dx.doi.org/10.21000/JASMR09011470

Introduction

The objective of this paper is to explore the strengths and weaknesses of using reference areas versus technical standards in evaluating revegetation success and the varying capabilities of each to incorporate climatic variability. Regulations pursuant to the Montana Strip and Underground Mine Reclamation Act (MSUMRA) specify that reclamation establish a vegetation community that is: 1) diverse, effective, and permanent; 2) composed of species native to the area or of desirable introduced species that are at least equal in extent of cover to the natural vegetation of the area; and 3) reestablished vegetation, specifically biomass production, must be useful for grazing and be comparable to premining conditions if the postmining land use is pastureland or grazing land. Regulations specify reestablished plant species must have the same seasonal growth characteristics as the original vegetation, be capable of self-regeneration and plant succession, and be compatible with the plant and animal species of the area.

Two options are available to determine whether these revegetation criteria have been met: 1) comparison with a reference area; or 2) comparison with a technical standard. The Montana Department of Environmental Quality (MDEQ) recommends the reference area approach for cover and production comparison (MDEQ, 2000). The technical standards approach is an alternative, but is less widely used. The Administrative Rules of Montana (ARM) (17.24.726(1), ARM, 2008) require MDEQ to supply data collection methodology guidelines for the above-mentioned criteria. This information is provided in the MDEQ "Guidelines for Vegetation Sampling" (MDEQ, 2009a) and "Framework for Technical Vegetation Standards" (MDEQ, 2009b).

Reference areas are communities used as models to which reclaimed areas are compared to evaluate revegetation success. Reference areas must have similar characteristics to the permit area including geology, soil, slope, and vegetation, and are often matched with areas to be mined based on these environmental variables (82-4-203(44), MCA, 2007). Reference areas can also be adjacent or nearby areas of successful revegetation with a climate similar to the area to be mined.

Technical standards are usually numeric or written descriptions of revegetation performance standards derived from a variety of sources such as historical data and NRCS rangeland Ecological Site Descriptions. Technical standards may also be predictive mathematical models or regression equations based on precipitation data. Mines often prefer technical standards because they may reduce sampling costs since only the reclaimed areas need to be sampled for bond release evaluation.

Problems exist with both options. Reference areas are often not used because of the concern that they set unattainable standards and that they require management, for example, the control of livestock grazing. Mines often prefer technical standards since reference area management can be difficult due to changing mine plans, boundaries, and personnel. Practical management reasons can therefore preclude the establishment of reference areas. It is also debatable whether a native vegetation community should be compared with a reclaimed vegetation community – i.e., comparing a mature native vegetation community with an early seral stage reclaimed vegetation community. Establishing suitable technical standards is difficult. Cover and production levels may vary with annual moisture by factors of 2-3x and 10x respectively in arid to semiarid environments (Buckner, 2006). Establishing an historical record-based technical standard can also be problematic for mines as there is often not enough time to gather suitable data for an historical record. Historical record type data also produce technical standards that are based on averages, making them inflexible in regard to factors like climatic variability. The process of negotiating a technical standard with regulatory agencies can also be time consuming since both parties involved, the regulators, who tend to err on the high side, and the operators, who tend err on the low side, must find the technical standard reasonable and achievable.

Methods

The utility of reference areas was compared to technical standards using 16 years of cover and production vegetation data collected from the Peabody Coal Big Sky Mine in Rosebud County, Montana. The Big Sky Mine has used reference areas to evaluate cover and production revegetation success and has monitored the vegetation of reference and reclaimed areas annually beginning in 1978. The most recent 16 years of these data were collected by ESCO Associates and are used in this study. These long-term data allow a comparison of vegetation data in relation to climatic variability. Species diversity and shrub density performance standards were not included in this analysis as these, especially the latter, are typically addressed via technical standards (MDEQ, 2000).

The Big Sky Mine is situated in southeastern Montana in a landscape of scattered ridges and buttes between which lie broad valleys. These buttes and ridges have shoulders of eroded slopes of shale and sandstone as well as scoria. Soils in the area have developed in-situ from underlying sandstones and shales as well as from alluvial, colluvial, and aeolian materials that are more prevalent in the valleys (Southard, 1973). The climate is semiarid with an average temperature of 7.9 degrees C and an average of 380.0 mm precipitation annually (WRCC, 2009). Most precipitation occurs between April and June and the summers are hot and dry. The predominant vegetation types are ponderosa pine (*Pinus ponderosa*) forest and shrub-grasslands. The reference area for this mine is an intact area of ~178 hectares on the north portion of the mine permit area consisting of vegetation types including grassland, sagebrush and ponderosa pine forest. Elevation of the mine permit areas varies from ~975 to ~1,100 meters.

Sixteen years of cover and production vegetation data have been collected from random and permanent sites throughout reclaimed areas and the associated reference area. Reclaimed areas included in this analysis had been seeded with a mix of cool season grasses and perennial forbs and were mature enough at the time of sampling to be eligible for Phase III Bond Release, which cannot legally occur until 10 years after reseeding in the western U. S., including Montana.

Cover values were derived from a point-intercept sampling of 100 points uniformly distributed along a 50 meter transect. Each point intercept was recorded through a Cover-Point Model 5 optical point projection device that projects an optically defined point of 0.07-mm diameter at ground level. Percent cover is based on a tally of interceptions or hits of plants with the projected point. Production data are standing crop measures (paired with the cover transects) from 0.5 square meter plots clipped by lifeform each year and are placed in labeled paper bags, dried at 105°C for 24 hours and weighed to the nearest 0.1 gram.

Precipitation data were obtained from the Big Sky Mine meteorological station until 2006. This meteorological station has a continuous record extending from 1949 through 2006, when the station was closed due to a cessation of mine operations. Precipitation data from 2007-2008 were obtained from a meteorological station managed by the Western Regional Climate Center (WRCC) in Colstrip, Montana located about 9.7 km northeast of the sample site (WRCC, 2009). The long-term precipitation average used in this study is based on WRCC data, which has a continuous record from 1927 to the present. Vegetation sampling occurred in early to mid July each year; therefore climate data were assessed for a 12-month period ending in June each year, i.e., the precipitation of the previous 12 months was the total from July of the previous year through June of the sample year.

Four ways of assessing revegetation success for both plant cover and production were explored: 1) a comparison of reference area and reclaimed area means, 2) a comparison of reclamation mean values to technical standards for cover and production based on NRCS rangeland Ecological Site Descriptions, 3) a comparison of reclamation area mean values to a proposed technical standard from another Montana mine in the same region, and 4) a comparison of reclamation area mean values to technical standards that were established using a simple linear regression model based on precipitation and Big Sky Mine historical reference area data. Monitoring was not designed to satisfy sample size and distribution criteria each year; consequently, the data were not statistically compared. For purposes of each comparison and as per Montana prescribed procedure, performance standards, however derived, were multiplied by 0.9 prior to comparison with reclaimed area means.

Results

Average total vegetation cover for the reclaimed area over the 16-year period varied from 30.5 percent to 59.6 percent, averaging 43.8 percent. Average total vegetation cover for the reference area over the 16-year period varied from 25.7 percent to 54.2 percent, averaging 40.0 percent. Average production for the reclaimed area over the 16-year period varied from 666.5 kg/ha to 2,503.1 kg/ha, averaging 1,585.7 kg/ha. Average production for the reference area over the 16-year period varied from 415.7 kg/ha to 1,362.9 kg/ha, averaging 879.2 kg/ha. For the period of 1993 to 2008, the precipitation of the 12 months preceding sampling (i.e. July of previous year through June of sample year) varied from ~157.2 mm below to ~167.1 mm above the long-term average of 376.9 mm (period of record 1927-present).

Reference Area and Reclaimed Area Comparison

Revegetation success was achieved 16 of 16 times for cover data and 16 of 16 times for production data when the reclaimed area means were compared with 90 percent of the reference area means (i.e. the reclaimed area mean met or exceeded 90 percent of the reference area mean). Reclaimed and reference area cover and production means for the period of 1993-2008 are presented in Table 1.

Table 1. Mean cover and production of reclaimed and reference areas (1993-2008) Big Sky Mine, Rosebud County, MT.

		-------Reclaimed Area-------		-----Reference Area-----		--Reference Area--	
	Precip.	Cover	Production	Cover (%)		Production (kg/ha)	
Year	(mm)[A]	(%)	(kg/ha)	Total	x 0.9	Total	x 0.9
1993	349.8	47.8	2012.6	47.8	43.0	1,109.1	998.2
1994	427.0	50.2	2052.6	42.0	37.8	1,033.2	929.9
1995	455.9	59.6	2503.1	54.2	48.8	1,362.9	1,226.6
1996	317.3	44.4	1,345.4	47.6	42.8	807.4	726.7
1997	407.2	51.7	1,922.1	46.4	41.8	1,043.2	938.9
1998	338.6	42.8	1,647.7	27.2	24.5	735.4	661.9
1999	452.9	46.3	1,858.7	42.2	38.0	910.6	819.5
2000	372.1	39.4	1,389.3	39.8	35.8	587.6	528.8
2001[B]	338.3	33.2 (CI=3.3)	666.5	37.8 (CI=5.0)	34.0	525.6	473.1
2002[B]	279.4	30.8 (CI=3.1)	969.4	34.5 (CI=3.0)	31.1	603.0	542.7
2003	516.9	49.5	1,814.0	44.6	40.1	1,087.2	978.5
2004	219.7	30.5	972.6	25.7	23.1	415.7	374.2
2005	529.8	46.5	1,696.5	36.2	32.6	1,141.2	1,027.1
2006	358.4	32.4	1,157.3	30.6	27.5	716.5	644.8
2007	544.1	50.3	1,796.3	44.6	40.1	1,151.1	1,036.0
2008	416.1	45.1	1,567.0	39.3	35.4	837.4	753.7
Avg.	376.9[C]	43.8	1,585.7	40.0	36.0	879.2	791.3

[A] Precipitation data were assessed for a 12-month period ending in June, i.e., the precipitation of the previous 12 months was total from July of the previous year through June of the sample year.

[B] Confidence Intervals indicated to show that the reclamation and reference area average cover values are statistically similar. Datasets were sufficiently large to detect a 10% reduction in the mean with 90% confidence.

[C] Long term average from Western Regional Climate Center (period of record 1927-present).

NRCS Rangeland Ecological Site Description Technical Standard

The Silty, 10-14 Mean Annual Precipitation (MAP) Ecological Site (Rangeland) (MLRA: 58A – Sedimentary Plains, East) developed by the NRCS was determined to be representative of the Big Sky Mine area. Total production at this ecological site under precipitation conditions matching the long term average for the area (MAP 355.6 mm (14 in)) should be 2,465.9 kg/ha and total hit vegetation cover (basal plus canopy cover for cryptograms, grasses/sedges, forbs and shrubs) should range from 72 to 111 percent. The cover and production values indicated in the NRCS Ecological Site Description are for a range site in the Historical Climax Plant Community, i.e., in excellent condition or under favorable vegetative management treatments.

A technical standard was based on 90 percent of each of these values, i.e., 90 percent of 2,464.0 kg/ha is 2,217.6 kg/ha and 90 percent of 72.0 is 64.8 percent. Revegetation success was indicated 1 out of 16 times for cover data and 1 out of 16 times for production data.

NRCS production weights are calculated on an air-dry basis. As a rough average, more or less stable air dry weights are 10 to 11 percent higher than oven dry weights (D. Buckner, personal communication, S. Viert personal communication). To account for this oven dry vs. air dry difference, a second technical standard was created by first subtracting 10 percent from 2,464.0 kg/ha which is 2,217.6 kg/ha and then calculating the technical standard as 90 percent of this, which is 1,995.8 kg/ha. Using this revised technical standard, revegetation success was indicated 3 out of 16 times for production data.

Proposed Technical Standard from Another Mine

For purposes of demonstration only, a technical standard proposed for use at another Montana mine in the same region was also examined here. This technical standard requires 50 % vegetation cover (45 % must be from perennials) and 1,120 kg/ha production (1,008 kg/ha from perennials). These values were based on baseline vegetation sampling data from one year with assumed representative spring precipitation.

Revegetation success was indicated 9 out of 16 times when comparing total vegetation cover, and 4 out of 16 times when comparing perennial vegetation cover. Revegetation success was indicated 13 out of 16 times when comparing total plant production and 14 out of 16 times when comparing perennial plant production.

Regression Model Based on Precipitation

Annual variation in precipitation, and perhaps other climatic parameters, has a large effect on the magnitude of total vegetation cover and production. A linear regression model was developed to evaluate the effect of precipitation on cover and production. A defined precipitation cycle is necessary to facilitate comparisons between vegetation and precipitation. New Mexico is one of the few western states to specify a minimum number of years (i.e., 5 years) of data collection to underlie and document a technical standard (19.8 ATTACHMENT 1, (per the New Mexico Administrative Code (NMAC, 1999))). This 5-year period should account for any variations in vegetation responses to environmental conditions. A similar standard does not exist in Montana; consequently, the New Mexico 5-year standard was used to define a climactic cycle relative to revegetation standards.

Thirteen regression equations were created for cover and production respectively using 16 years of data collected from the Big Sky Mine reference area and precipitation for the previous 12 months ending in June of each year. One regression equation was based on the entire 16-year data set (1993-2008). The other 12 regression equations were based on data from 5-year periods beginning with 1993-1997 and ending with 2004-2008.

These regression equations were then used to predict the cover and production values in the reference area, which could then be used as technical standards against which to evaluate revegetation success. When comparing 90 percent of the predicted reference area value to the actual reclaimed area value, the regression equation based on the entire 16 year data set correctly predicted thirteen outcomes of revegetation success for cover and fifteen outcomes for production (cover r^2 = 0.24, production r^2 = 0.62). The ‘best fit” five-year regression equations had both a high number of correct predictions and a high r^2 value. The “best-fit” five-year regression equation for cover data occurred from the 2003-2007 data set (r^2 = 0.82). This regression correctly predicted all outcomes for cover. The “best-fit” five-year regression equation for production data also occurred from the 2003-2007 data set (r^2 = 1.00 or 0.999). This regression correctly predicted all 16 outcomes for production. A summary of all regressions and correctly predicted outcomes is outlined in Table 2.

Discussion

Data collected between 1993 and 2008 indicate that vegetation cover and production are responsive to changes in precipitation. Concern regarding sensitivity to annual fluctuations in precipitation and other climatic variables underlay the development of reference areas in the assessment of revegetation success as codified in the Surface Mine Control Reclamation Act of 1977 (SMCRA).

Table 2. Summary of correctly predicted revegetation outcomes for 16 years of data using regressions based on five-year precipitation values and mean cover and production values in the reference area, Big Sky Mine, Rosebud County, MT.

Precipitation Regression Period	Number of Correctly Predicted Outcomes* Cover (r^2)	Production (r^2)
1993-2008	13 (0.24)	15 (0.62)
1993-1997	11 (0.04)	15 (0.60)
1994-1998	12 (0.27)	15 (0.85)
1995-1999	12 (0.22)	15 (0.56)
1996-2000	12 (0.05)	11 (0.25)
1997-2001	14 (0.48)	16 (0.53)
1998-2002	15 (0.37)	16 (0.54)
1999-2003	13 (0.98)	16 (0.84)
2000-2004	15 (0.87)	16 (0.85)
2001-2005	16 (0.59)	16 (0.94)
2002-2006	16 (0.64)	16 (0.99)
2003-2007	16 (0.82)	16 (1.0 or 0.999)
2004-2008	16 (0.77)	16 (1.0 or 0.997)

* Correctly predicted outcome means agreement between regression-based determination of reclamation success and the reference area-based determination for the years indicated.

Revegetation success was achieved relative to reference areas in all 16 (100 %) of the cases in this study when the reclaimed area means were compared with 90 % of the reference area means for both cover and production, as would be the procedure when using reference areas. In contrast, revegetation success was achieved in only 1 out of 16 (~6 %) of the cases for both cover and production relative to technical standards based on NRCS Ecological Site Descriptions, which are developed from range sites in "excellent" range condition. Reference areas are usually in "good" range condition and this difference could contribute to results that indicate that revegetation success has not been achieved. Both of the cover and production successes relative to NRCS–based standards occurred for the year 1995. In that year, areas sampled were predominantly of the improved pasture type which is often characterized by an abundance of very vigorous introduced perennial cool season grasses.

A proposed technical standard from another mine was included in this study to demonstrate that technical standards based on a limited number of years of data can decrease the possibility of achieving revegetation success, especially for vegetation cover. In this case, the technical standard used was based on baseline vegetation sampling data from one year with assumed representative spring precipitation. Revegetation success was achieved in 9 out of 16 (~56 %) of the cases for total cover and in 4 out of 16 (25 %) of the cases for perennial cover. Revegetation success was achieved in 13 out of 16 (~81%) of the cases for total production and in 14 out of 16 (~87 %) of the cases for perennial production.

Of the technical standards explored in this study, one based on a regression relationship between precipitation and reference area vegetation cover or production proved the most accurate predictor of revegetation success or failure because of its flexibility and attention to climatic variability. On average, the five-year regression models predicted revegetation success for 88 percent (~14 out of 16) of the cases for cover and 96 %t (~15 out of 16) of the cases for production. The series of five years that produced the strongest-predicting regression model for cover and production was 2003-2007, predicting revegetation success for 100 % of the cases for cover and production. Rather than these years having a steady run of average precipitation, these years were more volatile in terms of precipitation having both extremely above average and extremely below average levels of precipitation (for the previous 12 months). It is reasoned here that a larger range of precipitation variability is likely to have allowed the effect of increased or decreased moisture availability to express itself in higher or lower cover or production numbers. This then strengthened the predictive capability of the model. However, given that this conclusion was based on one case study, it should be regarded as tentative. More complex multiple regression models that incorporate additional variables such as soil type, temperature and timing of precipitation events would likely be the strongest predictors of revegetation success when using technical standards.

Summary

Assessment of revegetation success for vegetation cover and production is facilitated for both operators and regulators when reference areas are used because these on-site native plant communities naturally integrate the effects of fluctuating environmental conditions of the mine area. Because they lack the direct link to conditions of the year at the mine site, technical standards based on fixed numbers are frequently off target. This study, based on data collected annually over a 16-year period from the Big Sky Mine, showed that use of simple, predictive linear regression models based on precipitation data could nearly equal the effectiveness of reference area-based performance standards. This effectiveness was maximized when the regression was based on a period of at least five years that included wide variation (up and down) in annual precipitation. However, even when many years of data are collected for what seems to be a strong predictive model, non-linear response may be encountered for climatic conditions outside the range of the original model. Furthermore, the likelihood of a string of years in a mine's five year historic record that perfectly reflect vegetation response to environment (in this case precipitation) is low. It is clear from this study that use of technical standards, though attractively simplified, can cause difficulty in demonstration of revegetation success for the criteria of plant cover and biomass production. Revegetation success is more likely to be demonstrated when reference areas are used than when technical standards are used, based on this case study.

Acknowledgements

The author wishes to thank Big Sky Mine and Reg Hoff for access to revegetation monitoring data. The author also wishes to thank David Bucker of ESCO Associates, Shannon Downey of the Montana Department of Environmental Quality, and Steve Viert of Cedar Creek Associates for their comments and suggestions.

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