PLANT DIVERSITY PATTERNS ON NORTH DAKOTA MINED LANDS[1]

by

Kelly Krabbenhoft, Don Kirby, Mario Biondini and Dave Nilson[2]

Abstract. Reclamation on mined lands must presently meet intracommunity (alpha) diversity standards. Intercommunity (beta) and landscape (mosaic) diversity are not addressed by state and federal regulations. This study was conducted on three strip coal mines in western North Dakota to determine diversity patterns on reference and reclaimed areas. Transects, containing ten equidistant points, were established within sandy, silty and thin claypan range sites so as to gain maximum variation between points. Basal cover was measured using the ten-point frame method. Alpha diversity was determined using the Shannon-Wiener index. Presence/absence data was used in determining beta and mosaic diversity through affinity analysis. Alpha diversity on reference and reclaimed areas were different ($p<.10$) on silty and sandy range sites but not on thin claypan sites. Alpha diversity was higher, though not always significant, on reference areas when compared to reclaimed areas of the same range type. Beta diversity on reference and reclaimed areas were different ($p<.10$) on silty and sandy range sites but not on thin claypan sites. For all range types, reclaimed areas had a greater dissimilarity than their respective reference areas. On all reference areas, mosaic diversity was not different from that of a random distribution of species across the landscape. The sandy reclaimed site followed the same random pattern exhibited by the reference areas. Silty and thin claypan reclaimed sites had mosaic diversities consistently greater than expected from a random distribution model. Scale is an important factor in determining diversity success of reclaimed mined lands, therefore diversity regulations should be concerned with the entire reconstructed landscape instead of a single point.

Additional key words: Alpha Diversity, Beta Diversity, Mosaic Diversity

Introduction

Creating diverse plant communities on land disturbed by surface coal mining is desirable for revegetation success. Reclamation on mined land must meet intracommunity (alpha) diversity standards. State and federal regulations do not consider intercommunity (beta) and landscape (mosaic) diversity.

Patterns of plant diversity can be examined at differing scales, using several indices. The objectives of this study were 1) to compare alpha, beta and mosaic diversity indices between mined and unmined sites and across three strip coal mines in western North Dakota, and 2) to recommend changes in revegetation standards for analysis of species diversity.

Study Area and Methods

The research was conducted on the Glenharold, Baukol Noonan and Indian Head strip coal mines in Mercer and Oliver Counties of central North Dakota. The mines are located within the Missouri Plateau Physiographic Region of North Dakota, which is on the western edge of an area where soils are formed from glacial deposits and residuum weathered from bedrock. The semiarid-continental climate is characterized by cold winters and hot summers. Temperatures range from -12°C in January to 22°C in July, with a mean of 6°C. Average annual precipitation is 44 cm, of which 80% falls between April and September. The average length of the growing season is 120 days, with the last and first frosts occurring May 20 and September 18, respectively (Weiser 1975; Wilhelm 1978).

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Transects were located randomly within reference and reclaimed areas of silty, sandy and thin claypan range sites as classified by the Soil Conservation Service (Weiser 1975), and were placed in such a manner that maximum topographic variation would occur among sampling points. Ten sampling points were located equidistantly along each transect, except as otherwise noted.

Vegetative cover, by species, was used to measure plant diversity. Cover was estimated each year using the ten-point frame method (Arny and Schmid 1942). Ten frame (100 points) readings were taken randomly at each sampling point to determine live basal cover. Frequency of each species was measured using cover data.

Glenharold Mine

Research began on the Glenharold Mine, Stanton, ND, in 1988. Four silty range sites, two reference and two reclaimed, were studied. The undisturbed sites, each containing two transects, were an association of Temvik and Williams silt loam soils (Wilhelm 1978). Before mining, the disturbed sites, one with four transects and the other with five, contained Temvik and Williams silt loam and Cabba loam soils (Wilhelm 1978).

Three sandy sites, two undisturbed and one disturbed, were studied. The undisturbed sites, each with two transects, contained Telfer soils (Wilhelm 1978). Before mining, the disturbed site, with two ten-point and one 20-point transect, contained Parshall series soils (Wilhelm 1978).

Two thin claypan sites, one undisturbed and one disturbed, were studied. The undisturbed site, with two transects, contained a Daglum-Rhoades complex (Wilhelm 1978). The disturbed site, with four transects, contained a Daglum-Rhoades complex before mining (Weiser 1975).

Baukol Noonan Mine

In 1989, research was expanded to the Baukol Noonan Mine, Center, ND. Three transects within one silty reclaimed area were established. Ten randomly placed wire cages were used on each of the two undisturbed sites to exclude cattle. The undisturbed sites contained Temvik and Williams silt loams (Weiser 1975). The disturbed site contained a Williams silt loam before mining (Weiser 1975).

Indian Head Mine

In 1989, transects were established on the Indian Head Mine, Beulah, ND, within two thin claypan reference areas and one thin claypan reclaimed area. The undisturbed sites, each with two transects, contained a Daglum-Rhoades complex (Wilhelm 1978). The disturbed site, with four transects, contained a Rhoades clay loam before mining (Wilhelm 1978).

Statistical Methods

Alpha diversity was calculated using the Shannon-Wiener index (Shannon and Weaver 1973). Beta (Whittaker 1965) and mosaic diversity were estimated from presence/absence data, using affinity analysis (Scheiner and Istock 1987). Beta diversity was calculated among sampling points within a site as mean dissimilarity. Mosaic diversity was calculated as the variation and degree of structuring around the mean similarity, and diversity values standardized and analyzed with the use of the bootstrap technique (Istock and Scheiner 1987; Scheiner and Istock 1987).

Multiresponse permutation procedure (MRPP), as described by Biondini et al. (1988), was used to determine if reference and reclaimed areas of the same range type differed at the alpha diversity level. For alpha diversity, sufficient data points ($n>6$) were present to analyze the average diversity across the two study years. Multiresponse block procedure (MRBP) (Biondini et al. 1988) was used to determine if reference and reclaimed areas of the same range type differed at the beta diversity level. For beta diversity, when an average was made across years, a sample size of $n<6$ resulted. MRBP was used to block out the effects of years and mines. For each range type, average and standard errors were calculated for the standardized mosaic diversity to test whether reference and reclaimed areas differed from the random expectation.

Results

During both study years, precipitation was below the 20-year average (NOAA) for growing season and monthly totals (Figure 1). In 1988, 13 cm of precipitation were recorded for the growing season with 8 cm falling in June and July. In 1989, nearly 17 cm of precipitation fell more uniformly throughout the growing season.

Frequency of cool-season grasses was greater on reference and reclaimed areas, within each range type, compared to warm-season grasses (Table 1). A greater number of cool-season grass species compared to warm-season grasses was observed on all reference and reclaimed range types, except on sandy reference sites.

Of the three forage classes, graminoids were observed most frequently (Table 1). Cool-season graminoids frequently observed on sandy and silty reference areas were western wheatgrass (Agropyron smithii), needle-and-thread (Stipa comata) and sedges (Carex spp.). Frequently encountered warm-season grasses on sandy and silty reference areas included blue grama (Bouteloua gracilis), sideoats grama (B.

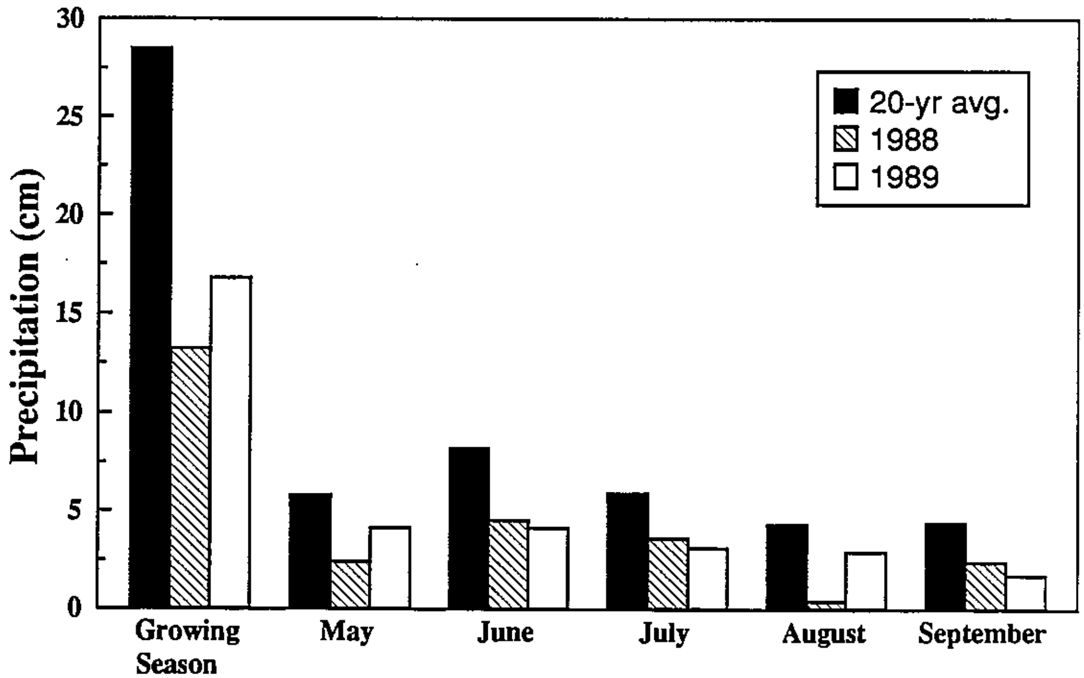

Figure 1. Growing season precipitation in 1988 and 1989 and the 20-year average (NOAA) for the study sites.

curtipendula) and prairie sandreed (Calamovilfa longifolia).

Important graminoids on thin claypan reference areas included western wheatgrass, bluegrasses (Poa spp.), prairie junegrass (Koeleria pyramidata), sedges, and two warm-season grasses, blue grama and sideoats grama. Important cool-season grasses on sandy, silty and thin claypan reclaimed areas were wheatgrasses (Agropyron spp.) and green needlegrass (Stipa viridula). The warm-season grasses, sideoats grama and little bluestem (Schizachyrium scoparium), were encountered frequently on sandy and thin claypan reclaimed sites. Warm-season grasses on silty reclaimed sites included blue grama and sideoats grama.

Intramine alpha diversity on similar sites was greater ($p<.10$) on reference compared to reclaimed areas with one exception (Figure 2). Alpha diversity of thin claypan reference and reclaimed sites on the Glenharold Mine did not differ ($p>.10$). Intermine comparisons, where possible, indicated no difference ($p>.10$) among similar sites, except for thin claypan reclaimed sites.

Reclaimed sites were more dissimilar within gradients (greater beta diversity) than their respective reference sites (Figure 3). Silty and sandy reclaimed sites exhibited significantly greater ($p<.10$) beta diversity compared to similar reference sites. Beta diversity did not differ ($p>.10$) between thin claypan sites.

Mosaic diversity on reference sites did not differ from that of a random distribution of species across the landscape (Figure 4). Reclaimed areas exhibited two types of mosaic diversity. The sandy site followed a random pattern similar to the reference areas. Silty and thin claypan reclaimed sites had a mosaic diversity consistently higher than expected from a random distribution model.

Discussion

Current regulations (NDAC 1987) measure reclamation success of coal-mined lands from production (yield), cover, diversity and permanence standards. Of these standards, plant diversity requirements are the most difficult to meet (Hirsch and Nilson 1990).

Alpha diversity was generally greater on the unmined reference sites. The reclaimed sites had a lower alpha diversity due to soil handling and the homogeneity impact of cultural practices. In contrast to the extreme disturbance of mined sites, reference areas have been subject to intermediate levels of disturbance due to fire, drought, or herbivory in an evolutionary scale, allowing for plant diversification.

Gradients in plant communities are enhanced by changes in topography across a landscape which plays a large role in redistributing soil moisture (Wollenhaupt and Richardson 1982). The reclaimed grasslands in our

Table 1. Frequency (%) of species observed at transect points on reference (Rf) and reclaimed (Rc) sandy, silty and thin claypan sites on three surface coal mines in western North Dakota.

Plant class and species[1]	Sandy Rf	Sandy Rc	Silty Rf	Silty Rc	Thin claypan Rf	Thin claypan Rc
GRASS and GRASS-LIKE						
Agropyron smithii	11	61	38	79	80	54
Agropyron spp.[2]	0	25	5	28	0	52
Koeleria pyramidata	10	0	3	1	20	0
Poa spp.[3]	8	25	9	1	45	2
Stipa comata	59	0	68	2	14	0
Stipa viridula	0	30	17	30	13	45
Other cool-season[4]	1	15	3	14	6	11
Carex spp.	86	4	78	0	53	0
Bouteloua curtipendula	0	33	13	50	24	48
Bouteloua gracilis	51	0	78	40	45	22
Calamovilfa longifolia	23	15	3	0	4	1
Panicum virgatum	0	16	0	3	0	3
Schizachyrium scoparium	9	33	3	2	0	8
Other warm-season[5]	19	9	0	1	8	1
FORB	25	6	17	1	19	5
SHRUB	24	0	10	0	13	0

[1]Scientific names follow the Great Plains Flora Association (1986) or more recent taxonomic considerations.
[2]Includes A. cristatum, A. intermedium var. intermedium and var. trichophorum and A. trachycaulum.
[3]Includes P. pratensis, P. sandbergii and P. compressa.
[4]Includes Bromus inermis and Stipa spartea.
[5]Includes Andropogon gerardii, A. hallii, Distichlis spicata, Panicum wilcoxianum, Phalaris arundinacea and Sporobolus cryptandrus.

study exhibited diverse topographic positions (concave, convex, summit, backslope, or footslope). The diverse topographic gradients yielded greater beta diversity on each reclaimed site compared to the corresponding reference area. The reclamation process can be used to create gradients suitable to establish and maintain diverse plant communities at the intercommunity level, despite being less diverse at the intracommunity (alpha) level.

Mosaic (landscape) diversity of the reference and reclaimed sites differed from that observed at the alpha level, except for the sandy reclaimed sites. All reference and the sandy reclaimed sites had mosaic diversity that did not differ from that expected of a random distribution of plant species across the landscape. The silty and thin claypan reclaimed sites had a patchy distribution of plant assemblages indicative of high species diversity but at a greater spatial scale.

Decreases in niche or resource diversity can cause subsequent declines in plant species diversity (Diamond 1988). Often, reclamation processes tend to create homogeneous areas, thus reducing niche diversity and species diversity. Plant diversity standards in North Dakota do not account for changes in niche resource diversity following the reclamation process. Hirsch and Nilson (1990) found that diversity (alpha) standards in North Dakota appear somewhat stringent when actual field diversity is analyzed.

Reclamation techniques can be used to create niches, stable landforms and variable landscapes. Sampling

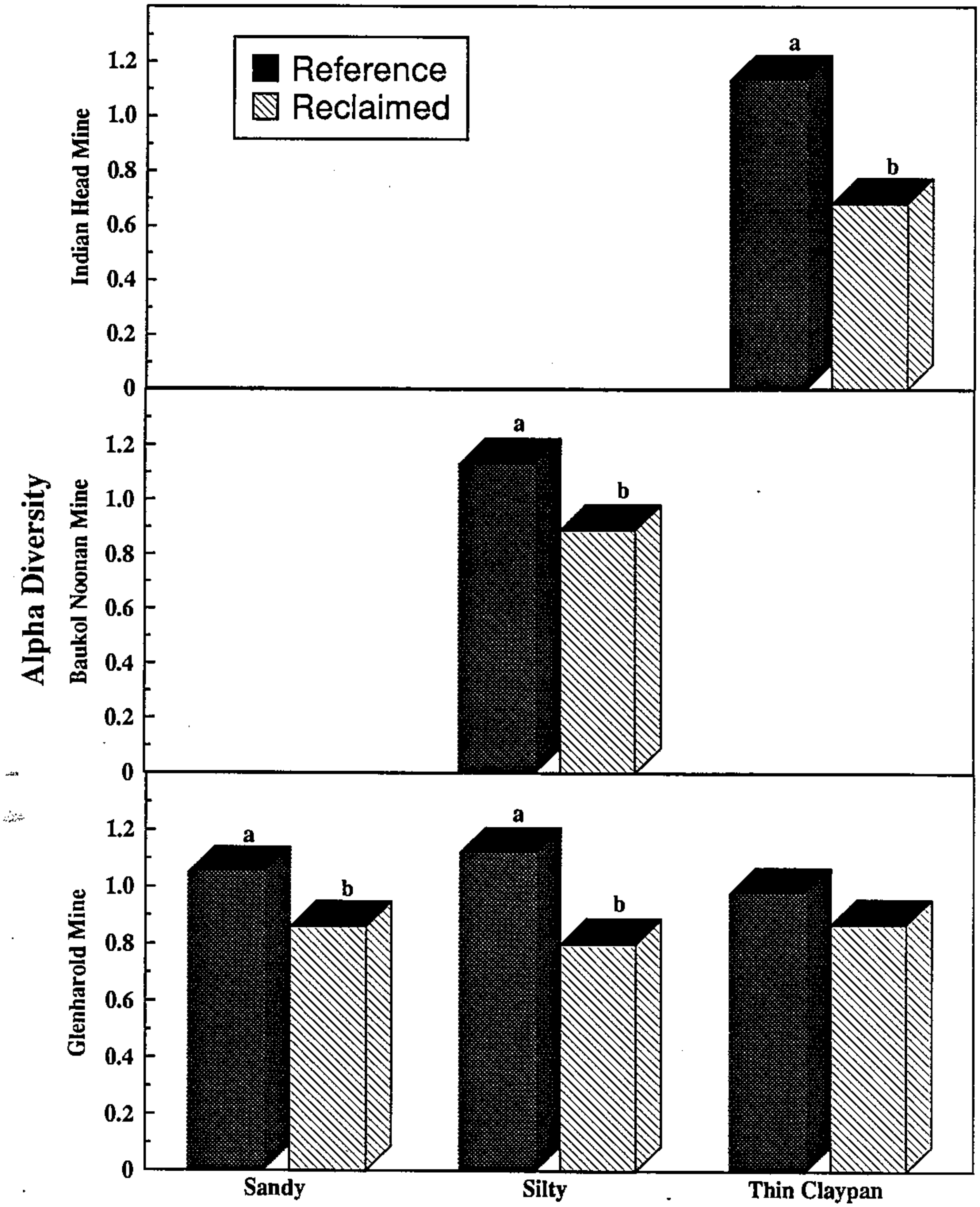

Figure 2. Alpha diversity for reference and reclaimed sites on three surface coal mines in western North Dakota. Bars with different letters differ (P<.05).

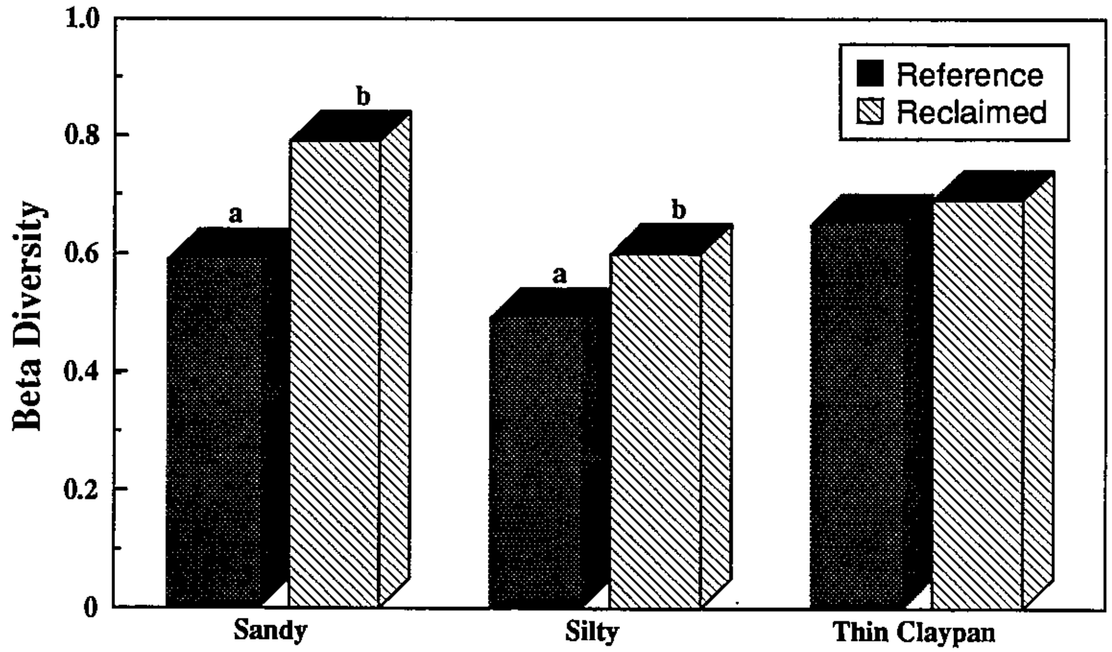

Figure 3. Beta diversity averaged across reference or reclaimed sites for three surface coal mines in western North Dakota. Bars with different letters differ (P<.05).

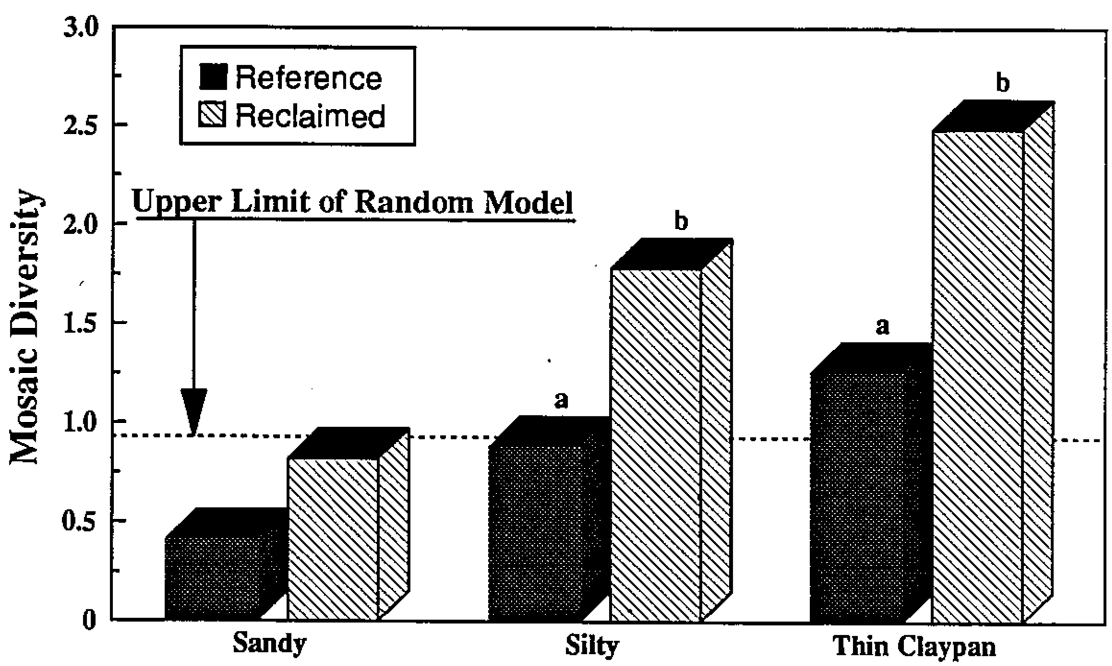

Figure 4. Mosaic diversity averaged across reference or reclaimed sites for three surface coal mines in western North Dakota. Bars with different letters differ (P<.05).

techniques used to evaluate reclamation success should be characteristic of all diversity levels. Post-mining management practices of the reclaimed area should be equivalent to that of the reference areas. Diversity regulations should be concerned with the entire reconstructed ecosystem instead of with a single point. Proper soil handling, landscape reconstruction, seeding procedures, management and sampling techniques should provide a more objective view of reclamation success. By analyzing at all diversity levels, a compromise may be attainable if diversity standards are not met. This is in contrast to present techniques, which do not allow for flexibility.

Diversity standards could be based on our results, which were collected during a severe drought. Conditions should not get worse than we encountered, thus providing minimal values for reclamation success.

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