DROUGHT EFFECTS ON PLANT DIVERSITY OF RECLAIMED GRASSLANDS IN WESTERN NORTH DAKOTA[1]

by

L. Frarck, K. Krabbenhoft, D. Kirby and D. Nilson[2]

Abstract. The objective of the study was to determine the effects of drought on plant diversity of reclaimed grasslands following surface coal mine operations on the Glenharold Mine in the Missouri Coteau region of western North Dakota. The dynamics of species diversity were examined on a silty range site for predought years, 1983-1987, and drought years, 1988-1990. Species diversity was obtained using ten-point frames. Two hundred ten-point frames (2000 total points) were recorded across both the reclaimed and reference landscapes for years 1983-1987. In 1988, 4 and 2 permanent transects were located within the reclaimed and reference landscapes, respectively, and positioned such that maximum topographic variation was obtained. Each of the transects contained ten equidistant sampling points. Ten ten-point frames were recorded at each sampling point for years 1988-1990, 1000 total points per transect. Drought had no significant effects on species diversity. However, drought tended to repress localized diversification of established plant communities on reclaimed grasslands.

Additional Key Words: Plant Diversity, Alpha Diversity, Beta Diversity, and Mosaic Diversity.

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[2]Lisa Frarck, Kelly Krabbenhoft, and Don Kirby are Research Assistant, Research Specialist, and Associate Professor, respectively, Animal and Range Sciences Department, North Dakota State University, Fargo, ND 58105. Dave Nilson is Reclamation Specialist, Basin Cooperative Services, Glenharold Mine, Stanton, ND 58571.

Introduction

The northern Great Plains contain 59% of the strippable coal deposits in the United States (Young 1984). Accessing this resource drastically disturbs rangeland soil profiles and plant communities. Regulations outlined in the 1977 United States Surface Mine Control and Reclamation Act (SMCRA) require that reclaimed grasslands meet or exceed the diversity, production, canopy cover, and permanence of similar undisturbed sites. In North Dakota, the primary limiting factor affecting the ability of reclaimed grasslands to meet or exceed such requirements is the availability of water, assuming that a necessary depth of soil has been replaced to the landscape.

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The original rangelands in the Great Plains are thought to have developed under periodic droughts (Albertson et al. 1957). As such, native grasslands are quite resilient to drought. Reclaimed grasslands, however, are probably more susceptible to drought than undisturbed rangelands due to highly compacted soils that have decreased water infiltration capabilities resulting from soil replacement procedures (Young 1984, Potter et al. 1988, Nilson 1989). Drought can severely deplete available soil water such that even with one year of normal precipitation, drought recovery may be delayed at least one growing season due to a precipitation deficiency carryover effect (Albertson et al. 1957). Such physical and environmental water limitations would presumably depress the vigor and perhaps halt or repress the development of plant community structure leading to the diversity and permanence required by the SMCRA for reclaimed grasslands.

Vegetation diversity can be observed and quantified on three different planes: alpha, beta and mosaic. Alpha (intra-community) diversity is that diversity observed at any random point in a landscape. Alpha diversity is dependent on the ratio of numbers of individuals of the various species present and is primarily influenced by the effects of topography, climate and degree of disturbance at a highly localized scale.

Beta diversity, expressed as mean dissimilarity (1-beta similarity), is that diversity observed along an environmental gradient such as topography. Topography is the primary factor in the overall distribution of occurrent precipitation (Wollenhaupt and Richardson 1982). Beta (inter-community) diversity quantifies compositional changes of vegetative communities in relation to environmental gradients.

Mosaic (landscape) diversity is a measure of the "compositional relatedness" of the interlocking communities of a landscape. Mosaic diversity accounts for the distribution patterns, random to contagious, of vegetation and communities within a whole landscape.

The objective of this study was to determine the effects of drought on plant diversity of reclaimed grasslands following surface coal mine operations by comparing alpha, beta and mosaic diversity levels between a reclaimed site and a native rangeland reference site.

Study Area

Research was conducted on the Glenharold surface coal mine, located in Oliver and Mercer counties of west-central North Dakota (fig. 1). The mine is located within the Missouri Plateau Physiographic Region of North Dakota where soils formed from glacial deposits and residuum weathered from bedrock (Wilhelm 1978).

The climate is semi-arid continental with temperatures ranging from -13.6 C in January to 20.7 C in July. The growing season averages 115 days with first and last frosts occurring in late May and early September. Annual precipitation is 41 cm, 70% of which falls from May to September (Wilhelm 1978). Cockrell (1990) noted that the effects of climatic variables varied greatly from site to site, due largely to topographical variation.

Growing season (May-September) precipitation from 1979-1990 inclusive at the Glenharold Mine averaged 25.0 cm (fig. 2). The years 1988 (13.7 cm) and 1989 (15.5 cm) were the driest and third driest years of the past twelve years.

Field and Statistical Methods

Dynamics of species diversity were examined for "silty" reclaimed and reference range sites, as classified by the Soil Conservation Service (Wilhelm 1978), for predrought years (1983-1987) and drought years (1988-1990). Vegetation was reestablished in 1979 on the

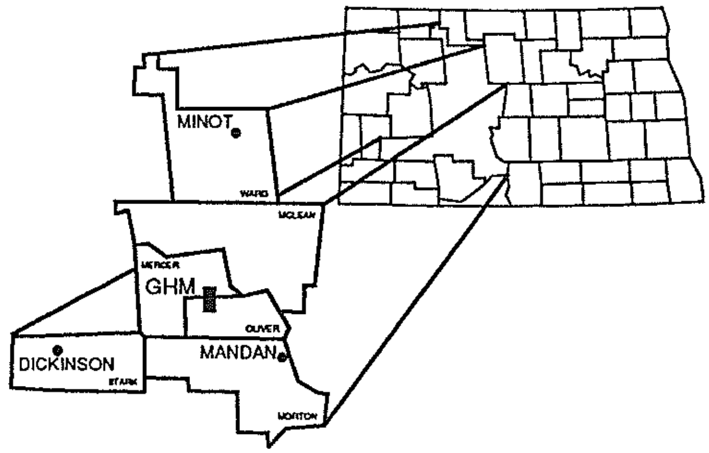

Figure 1. Study area in west-central North Dakota.

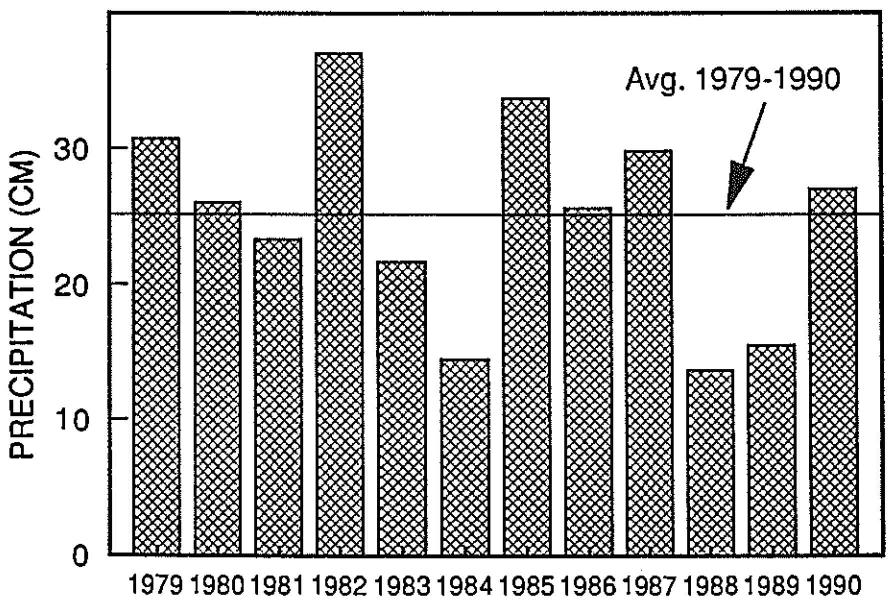

Figure 2. Growing season precipitation (May-Sept.) for 1979-1990 at the Glenharold Mine, Stanton, North Dakota.

reclaimed site. Data for years 1983-1987 were obtained through sampling live basal cover of vegetation at randomly located points across the reclaimed and reference landscapes, respectively. In 1988, four permanent transects were located within the reclaimed and two permanent transects within the reference landscapes. Each transect contained ten equidistant sampling points. Transects were positioned such that maximum topographic variation was obtained (Krabbenhoft 1991). These transects were used to collect data for years 1988-1990.

Species diversity was obtained using ten-point frames (Arny and Schmid 1942). Two hundred random frame readings were taken each year for 1983-1987. Ten frame readings were taken randomly at each sampling point along transects for years 1988-1990, totalling 100 frame readings per transect.

Alpha diversities (H') were calculated using the Shannon-Weiner index (Shannon and Weaver 1973). Unpaired t-test comparisons were made between predrought years reclaimed vs. reference, drought years reclaimed vs. reference, reclaimed predrought vs. drought years, and reference predought vs. drought years (SAS 1990).

Affinity analysis (Scheiner and Istock 1987) and presence/absence data were used to estimate beta (Whittaker 1965) and mosaic diversities. Beta diversity is expressed as mean dissimilarity, while mosaic diversity is expressed as variation in composition around the mean. Mosaic diversity was standardized and analyzed with the bootstrap technique according to Scheiner and Istock (1987).

Multiresponse permutation procedure (MRPP) (Biondini et al. 1988) was used to (1) determine if reclaimed and reference beta and mosaic diversities differed from predrought to drought, and (2) determine significance of reclaimed and reference intersite differences in beta and mosaic diversity levels. Sample size in all cases was adequate ($n \geq 6$).

Results

The dominant species on the silty reclaimed site included several wheatgrasses (*Agropyron intermedium, A. smithii* and *A. trachycaulum*), *Stipa viridula* and the warm-season grasses *Bouteloua curtipendula* and *B. gracilis* (Table 1). Dominant species on the silty reference site included cool season grasses *Agropyron smithii, Koeleria pyramidata,* and *Stipa comata, Carex* spp., and the warm season grass *Bouteloua gracilis.* Forbs and shrubs were more frequent on the silty reference site (Table 2).

Intrasite alpha diversity levels of reclaimed and reference sites for years 1983-1990 were not different ($P>0.05$). Intersite alpha diversity levels of reclaimed and reference sites for predrought and drought periods were different ($P<0.05$) (fig. 3).

Intrasite beta diversity levels of reclaimed and reference sites, and intersite beta diversity for predrought were not different ($P>0.05$). Beta diversity on the reclaimed site in drought years was higher than on the reference site ($P<0.05$) (fig. 4).

Mosaic diversity levels exceeded the upper limit of the random model indicative of contagious plant distribution in 1984-1986 and 1988-1990 on the reclaimed site, but only in years 1986, 1989, and 1990 on the reference site. Predrought intra- and intersite mosaic diversities were not different ($P>0.05$). Mosaic diversity on the reclaimed site during drought was higher than on the reference site ($P<0.05$) (fig. 5).

Discussion

Drought is a frequent event in the climatic regime of the northern Great Plains under which the original rangelands are thought to have developed (Albertson et al. 1957). Deleterious effects of

Table 1. Frequency (%) of species sampled on the silty reclaimed site.

Plant class and species[1]	Predrought 1983	1984	1985	1986	1987	Drought 1988	1989	1990
Agropyron smithii	35	65	85	80	85	90	83	65
Agropyron spp.[2]	50	25	25		30	38	5	5
Stipa viridula	10	5	5	5	40	8	15	23
Poa spp.[3]			5					
Bouteloua curtipendula	95	75	90	80	100	78	75	75
B. gracilis	50	10	10	10	30	18	5	3
Calamovilfa longifolia		10						
Schizachyrium scoparium		5	20	5	10	10		
Other				10	10	25	18	15
Forb						5	3	8

[1]Scientific names follow the Great Plains Flora Association (1986).
[2]includes *Agropyron cristatum, A. intermedium* and *A. trachycaulum.*
[3]includes *Poa pratensis, P. sandbergii* and *P. compressa.*

Table 2. Frequency (%) of species sampled on the silty reference site.

Plant class and species[1]	Predrought 1983	1984	1985	1986	1987	Drought 1988	1989	1990
Agropyron smithii	40	10	20	10	15	40	15	10
Koeleria pyramidata	90	95	60	60	60	5		15
Poa spp.[2]		10	40	10			10	5
Stipa comata	75	75	50	75	60	95	95	100
S. viridula				5		20	10	
S. spartea		5		5				
Carex spp.	90	70	55	60	70	70	85	70
Bouteloua curtipendula							5	
B. gracilis	100	100	70	85	95	100	75	80
Schizachyrium scoparium							5	
Other					5			
Forb	50	15	5	5	15	35	35	20
Shrub		5	15		15	20	5	

[1]Scientific names follow the Great Plains Flora Association (1986).
[2]includes *Poa pratensis, P. sandbergii* and *P. compressa.*

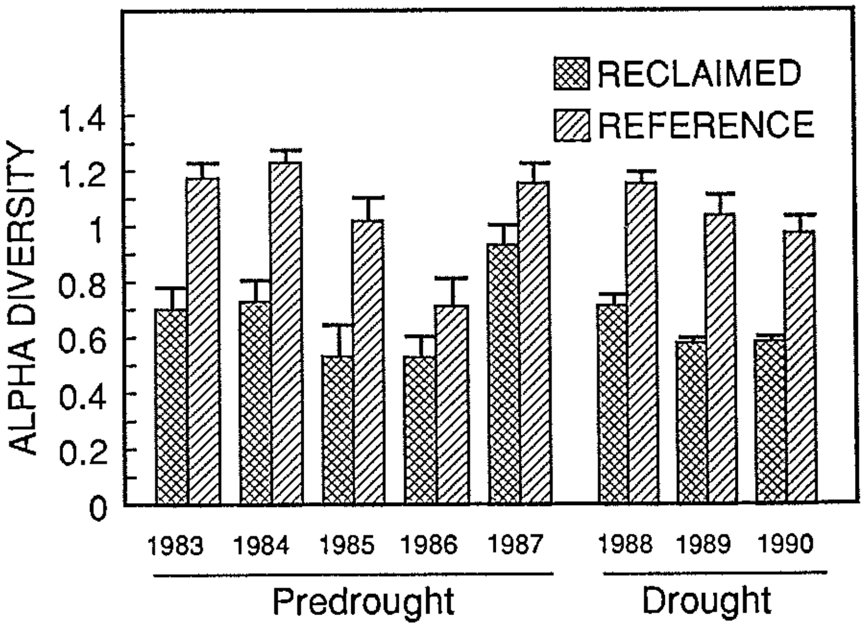

Figure 3. Alpha diversity levels on silty reclaimed and reference sites. Standard error bars are given.

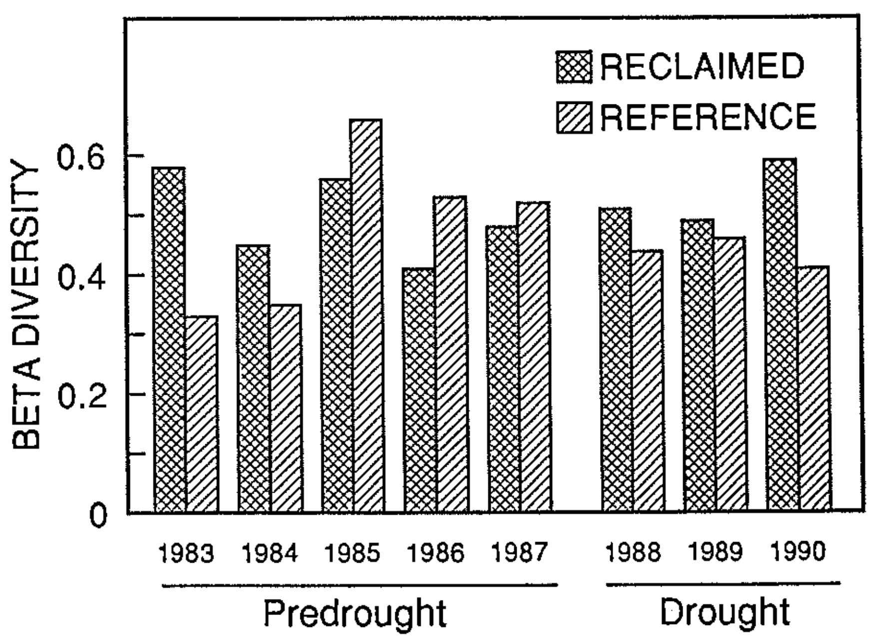

Figure 4. Beta diversity levels on silty reclaimed and reference sites.

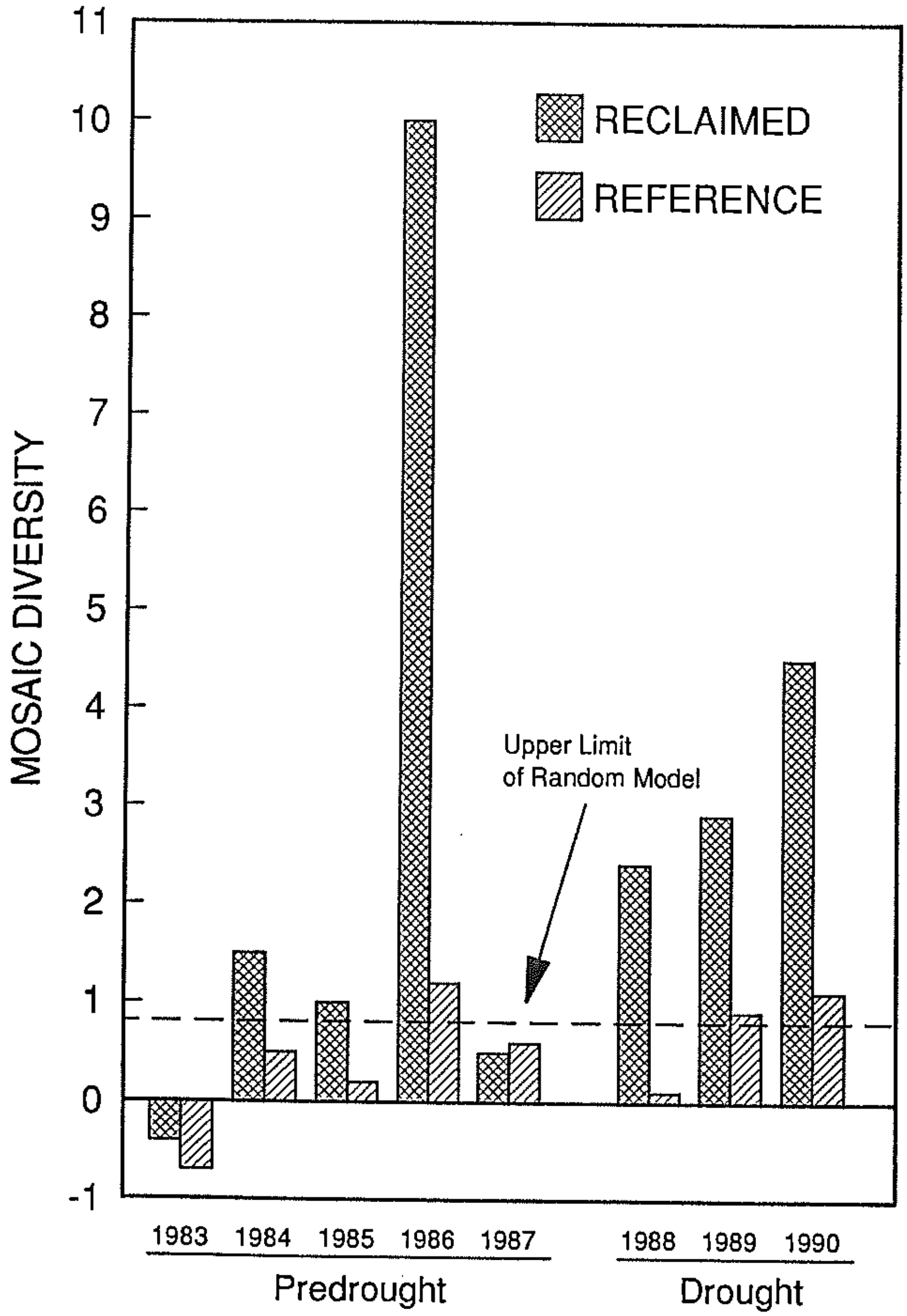

Figure 5. Mosaic diversity levels on silty reclaimed and reference sites.

drought on the Great Plains have been widely documented. Historically, the southern and central Great Plains seem to have been effected more drastically and recovered more slowly than North Dakota rangelands (Robertson 1939, Savage 1937, Albertson and Weaver 1942, Whitman et al. 1943). The severity of the 1980s drought was not enough to significantly effect the silty rangeland reference area but did result in significant effects on the silty type reclaimed grassland. It is important to note that drought effects on range and grasslands are a function of three primary factors: intensity and duration of drought and predrought vegetation vigor (Bedell and Ganskoop 1980).

Alpha diversity tended to decrease slightly from predrought to drought periods on both reference and reclaimed sites. Several southern and central Great Plains drought studies report significant changes in plant species diversity and dominance (Robertson 1939, Weaver et al. 1940, Albertson and Weaver 1946). In North Dakota, drought has tended to thin plant communities without affecting plant species dominance (Whitman et al. 1943). Our results support this observance.

Alpha diversity on the reference site was higher than on the reclaimed site for both predrought and drought periods. Reference site alpha diversity has been maintained by low level, infrequent disturbances such as grazing, fire, drought and small mammals. No disturbance or extreme disturbance may decrease alpha diversity (Huston 1979, Tilman 1982). Lower alpha diversity on the reclaimed site is due to the large amount of disturbance during soil handling procedures and is limited by the diversity of the seed mixture and methods used to reclaim the area, and the length of time of development following reclamation.

Intrasite beta diversity levels for both predrought and drought periods were not significantly different due to variability of beta diversity levels. During drought, beta diversity levels were less variable and were significantly higher on the reclaimed than on the reference landscape. Environmental gradients favorable to beta diversity can be constructed during land surface reconstruction (Young 1984, Redente and DePuit 1988).

Yearly mosaic diversity levels on the reclaimed site for 1984-1986 and 1988-1990 were significantly different from random expectations. Mosaic diversity levels on the reference site were significantly different from random expectations only in 1986, 1989 and 1990. Mosaic diversity levels on the reclaimed area do not appear to have been effected by drought. However, it appears that drought may increase the patchiness of a natural (reference) landscape.

Concerning intra- and intersite mosaic diversity level comparisons for predrought and drought periods, only the intersite drought period was significantly different. The reclaimed landscape exhibited higher mosaic diversity levels during the drought than did the reference landscape. The reclaimed intrasite mosaic diversity tended to increase successionally from 1983 to 1990. The reference intrasite mosaic diversity was much more variable.

A direct relationship between differences in mosaic diversity and site size (area) has been reported (Hatton et al. 1985). Although the sizes of our sites differed, no consistent relationship between site size and mosaic diversity was observed. A similar observation was made by Krabbenhoft (1991).

Reclaimed grassland communities are significantly less diverse than original rangelands in terms of species present, due to drastic soil disturbance, drill seeding and the limited number of graminoid species available for seeding. However, shaping and contouring of reclaimed landscapes and creation of planned topographical gradients allow greater distribution of occurrent precipitation (Wollenhaupt and Richardson 1982). Such gradients then allow reclaimed grasslands to exhibit equal or greater beta diversity than original rangeland. The reclamation process and interactions of the reclaimed grassland communities also result in greater mosaic diversity; a contagious versus random occurrence of plant species.

Greater beta and mosaic diversities do not depend on the ratio of numbers of individuals of species present as does alpha diversity. Rather, beta and mosaic diversities are expressions of diversity along a specific environmental grad and across the whole landscape, respectively. A greater degree of contagiousness of vegetation within environmental gradients and the overall landscape results in greater beta and mosaic diversities. At these diversity levels, the rangelands studied exhibited a greater degree of homogeneity due to less topographic variation than the reclaimed grassland. The exact opposite was true at the alpha level.

Although the ability of reclaimed grasslands to exhibit permanence similar to that of an original rangeland is perhaps initially inhibited by the graminoid varieties and reclamation methods available to reclamation specialists, drought plays a significant role in developing a permanent grassland. The results of this study show that drought tended to repress localized diversification of established plant communities on reclaimed grasslands.

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