EFFECTS OF SOIL DEPTH AND DROUGHT ON RECLAIMED WOODLANDS IN WEST CENTRAL NORTH DAKOTA[1]

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Abstract: Changes in survival, mean stem densities, and species diversity on mixed deciduous woodlands reestablished on mined land were monitored over 12 growing seasons from 1983 through 1994. The effects of drought during the late 1980's is contrasted with woodland vegetation responses recorded prior to drought and during cool wet years experienced in the early 1990's. Vegetation response lagged climatic changes as mean stem densities declined significantly ($p<0.01$) by 1990 following severe drought conditions in 1988. Stem densities recovered substantially in 1993 with the advent of cool wet weather in 1992. However, recovery rates differed between two soil replacement depths. Mean stem densities on sites with 25-50 cm of topsoil and subsoil declined from 4,943 to 3,996 stems per hectare and did not recover with the return of favorable weather. Sites respread with 100-150 cm of soil increased significantly ($p<0.001$) from a low of 3,064 to 6,110 plants per hectare. Changes in species diversity followed a similar pattern from pre-drought, to drought and post-drought periods for both soil depths but these changes were not significant ($p>0.10$). Species diversity values (H') ranged from 1.207 to 1.462 over the study period and were similar to premining woodland plant communities.

Additional Key Words: Woodland reclamation, species diversity, hardwood draws.

Introduction

Surface mining and reclamation operations in the west require the removal and replacement of woodland vegetation that is limited in extent but scattered throughout the semiarid Northern Great Plains. While woodlands constitute approximately 1 percent of the vegetation in this region (Bjugstad 1977), they are more prominent in locations where favorable topography leads to increased soil moisture. In southwestern North Dakota where average annual precipitation is 36 cm, woodland plant communities constitute 5-7 percent of the total ground cover (Hopkins 1983). At the Glenharold Mine which is located in the "Missouri Breaks" in west central North Dakota, woodlands constitute over 10 percent of the coal reserve area. Where present, they are a valuable component of rangeland providing an alternate source of forage as well as shelter for livestock during extreme

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weather. From an ecological standpoint, woodlands enhance watershed stability and provide biological diversity including important and sometime unique habitat for both resident and migratory wildlife species.

Replacing native woodlands in semiarid regions following mining and demonstrating reclamation success within the regulatory framework of the Surface Mining Control and Reclamation Act requires some understanding of how replacement woodlands will function in reconstructed environments. In undisturbed woodlands at the Glenharold Mine, Richardson (1979) and Mack (1981) studied the relationship between soil moisture and surface configuration and the presence of woody vegetation. Approximately 90 percent of the woody vegetation occurs on north and east facing slopes on lower slope positions and convergent topography which collect surface runoff. In a premining woodland ecological study conducted at the Glenharold Mine (Williamson et al. 1981), it was noted that woody vegetation occurred in these locations on concave sites and was absent from adjacent, convex surfaces within the same soil series. Mack (1981) found no significant decrease in growth ring size of tree species located in the most favorable topographic locations during the drought of the 1930's. Based on these observations, planting trees and shrubs in the most advantageous topographical positions is of paramount importance to the long term success of reestablished woodland plant communities.

How these reestablished communities develop as succession proceeds over a variety of climatic conditions is important for demonstrating reclamation success and improving reclamation techniques. The objectives of this study were: (1) to examine survival, density and species diversity changes in reestablished deciduous woodlands on mined lands in North Dakota between 1986 and 1994; and (2) determine differences in woody vegetation response between two soil depths (25-50 cm and 100-150 cm) over a period of extreme climatic variation.

Study Area

Data presented in this paper were collected from the Glenharold Mine which is located 90 km northwest of Bismarck. Native woodland vegetation is common on north and east facing slopes and along numerous drainages that flow intermittently toward the Missouri River. Mack (1981) recorded 255 vascular plants; 221 species (87%) occur in native woodland areas. Major shrub species in order of abundance are chokecherry (Prunus virginiana), silver buffaloberry (Shepherdia argentea), serviceberry (Amelanchier alnifolia), hawthorn (Crataegus rotundifolia) and American plum (Prunus americana). Western snowberry (Symphoricarpos albus), silverberry (Elaeagnus argentea) and woods rose (Rosa woodsii) may occur alone or in an ecotone between woodland and native grassland communities. These species are first to colonize an area then decrease as later seral species become established due to improved site conditions. Green ash (Fraxinus pennsylvanica) is the most abundant tree species and has less affinity to specific site characteristics than American elm (Ulmus americana) and boxelder (Acer negundo). Cottonwood (Populus deltoides) and willow (Salix spp.) are often associated with spring seeps and ponding water along the bottom of drainages. Clumps of aspen (Populus tremuloides) are infrequent and generally occur in the vicinity of water bearing strata.

Soils supporting woody vegetation are similar to unmined prairie soils that have developed from glacial deposits and residuum weathered from bedrock (Wilhelm 1978). Richardson (1979) described uplands as Typic and Pachic Haploborolls where Temvik, Amor, Parshall and Sen soil series are common and most productive. The soils of shoulder and upper backslopes of wooded, valley drainages are Ustorthents and typically consist of the Cabba soil series. On lower slope locations, soils are classified as Lithic and Entic Haploborolls where the Werner soil series is common.

North Dakota surface mining and reclamation regulations require removal and segregation of all topsoil and subsoil material to a depth of 150 cm as specified by a professional soils classifier. Soils with inherent chemical problems such as high salinity and sodicity are not salvaged. Suitable plant growth material (SPGM) is stockpiled and redistributed evenly across the reconstructed landscape. Since surface mining began in the late 1960's, respread depths have varied due to changes in North Dakota reclamation laws and the quantity of SPGM available prior to disturbance.

The regional climate is semiarid and continental with low rainfall and relative humidity. Average annual precipitation is 41 cm. Approximately 70 percent occurs during the growing season from May through September and 50 percent falls during the months of May, June and July (Fig. 1).

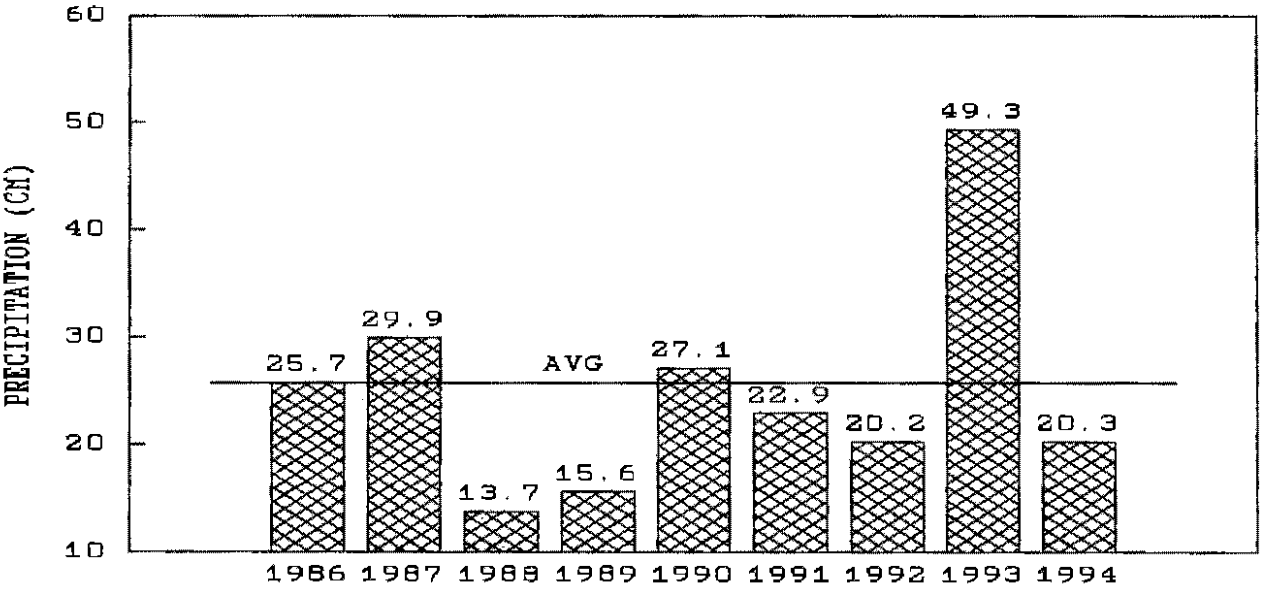

Figure 1. Growing season precipitation (May-September) at the Glenharold Mine, Stanton, ND.

While adequate precipitation is important for the establishment of woody vegetation, below average temperature is also conducive to survival and growth when precipitation is limited. Since woodland reclamation began in the early 1980's, severe drought conditions occurred in 1988 and dry conditions continued through 1989. May-July precipitation during 1988 and 1989 was 47 and 40 percent below average respectively. Drought conditions were amplified by above average temperatures during those years (Fig. 2). Conversely, above average precipitation and below average temperatures were experienced in the early 1990's, particularly 1993.

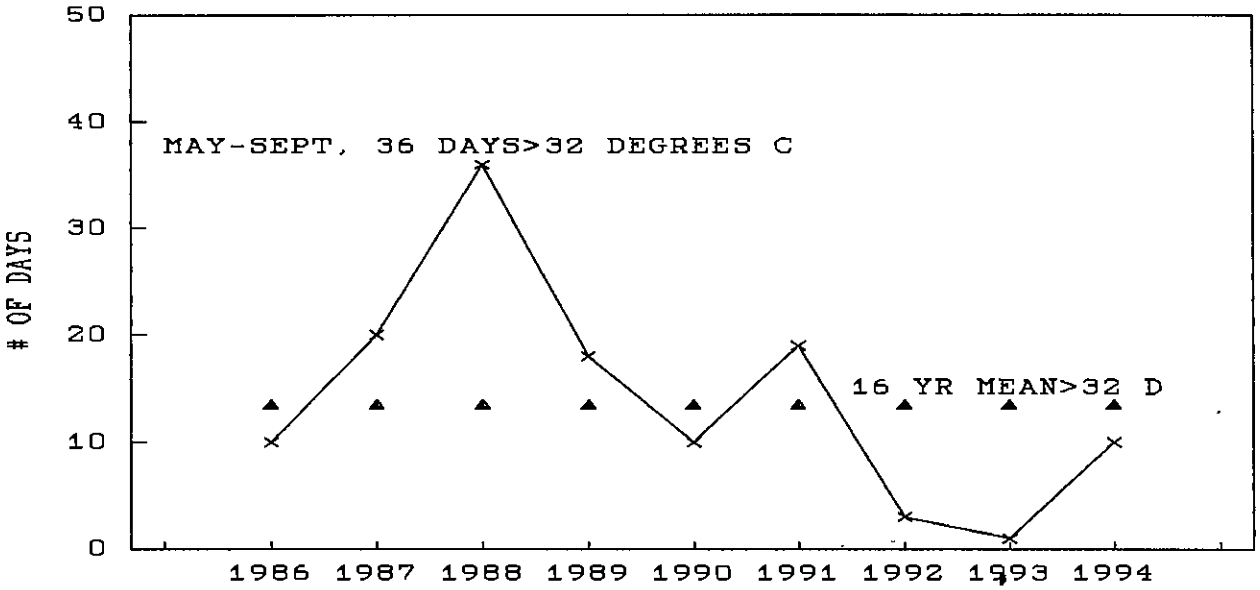

Figure 2. Temperature patterns during the study period expressed as the number of days > 32 degrees Celsius relative to the Glenharold Mine 16 year mean.

Methods

Reclamation woodland sites established on the Glenharold Mine in the early 1980's were selected for this study. Woodland establishment and management techniques are described by Nilson (1989). All trees and shrubs were 1 to 2 year old bare root nursery stock grown from seed collected at the mine. Planting mixtures and percent composition of woodland study sites evaluated in this paper are presented in table 1.

Data were collected annually during mid summer to determine survival of individual species and changes in mean stem densities and species diversity over several years of extreme climatic variability experienced from 1986 through 1994. Pre-drought, drought and post-drought vegetation response periods were distinguished from pre-drought, drought and post-drought years by noticeable changes in mean stem densities. These differences were consistent across all woodland study sites. Generally, changes in stem densities lagged climatic events by 1 to 2 years.

Table 1. Typical woodland reclamation planting mixtures used to replace mixed deciduous and tall shrub plant communities on the Glenharold Mine, Stanton, ND.

SPECIES	Deciduous Woodlands Plants/ha	Deciduous Woodlands % Comp.	Tall Shrub Plants/ha	Tall Shrub % Comp.
Tree Layer (TL)				
Willow	62	5		
Boxelder	198	15		
Green Ash	802	60		
Cottonwood	198	15		
Bur Oak	37	3		
Hackberry	37	3		
TOTAL TL	1,334	100		
Tall Shrub Layer (TS)				
Native Plum	1,062	25	1,087	20
Silver buffaloberry	556	13	1,087	20
Serviceberry	803	19	543	10
Chokecherry	1,062	25	1,198	22
Round-leaved hawthorn	531	12	1,087	20
Red-osier dogwood	247	6	272	5
Bristly gooseberry	0	0	161	3
TOTAL TS	4,261	100	5,435	100
Low Shrub Layer (LS)				
Silverberry	531	50	371	30
Woods rose	272	25	494	40
Western snowberry	272	25	371	30
TOTAL LS	1,075	100	1,236	100

Data were collected from permanent 10m X 10m quadrats which were randomly located in each woodland site. The pre-drought vegetation response period included data collected from 90 quadrats sampled during 1987, 1988 and 1989. The vegetation response period resulting from drought conditions included 124 quadrats sampled from 1990 through 1992. The post-drought vegetation response period included data collected from 78 quadrats during 1993 and 1994.

Two data sets were extracted from each vegetation response period within two SPGM respread depths to compare vegetation changes from pre-drought to post-drought periods. This comparison included woodland sites established on 25-50 cm of SPGM and sites where 100-150 cm was respread. Community similarity based on stem densities was compared for the 2 soil depth classes using the Curtis and Bray index of similarity (Bray and Curtis 1957). The Students t-test was used to determine significant differences in mean stem densities and species diversity between vegetation response periods for each soil depth class. Species diversity (H') was calculated for each woodland reclamation site using the Shannon-Wiener index (Shannon and Weaver 1963).

Results

Vegetation response lagged climatic events by 1-2 years. While increases in mean stems per hectare were observed on some woodland sites in 1989 following severe drought conditions in 1988, decreases were not evident until 1990. Similarly, as more favorable weather conditions returned in 1992, increases in stem densities were not noticeable until 1993.

Drought followed by favorable weather conditions for woodland development resulted in different community responses between sites with 25-50 cm of SPGM (depth 1) and sites with 100-150 cm (depth 2) (Fig. 3). On depth 1 sites, mean shrub density declined significantly ($p<.05$) from 4,889 to 3,950 stems per hectare. Most of this decrease (97%) was attributed to a reduction in woods rose (-63%), red-osier dogwood (-91%) and silver buffaloberry (-39%) (tables 2 and 3). Additionally, species requiring more mesic conditions including native cottonwoods and willows were eliminated as a result of drought conditions in 1988 and 1989. While decreased densities of these species were recorded, American plum and chokecherry increased 11 and 22 percent respectively from pre-drought to drought periods and 21 and 22 percent from pre-drought to the post-drought period.

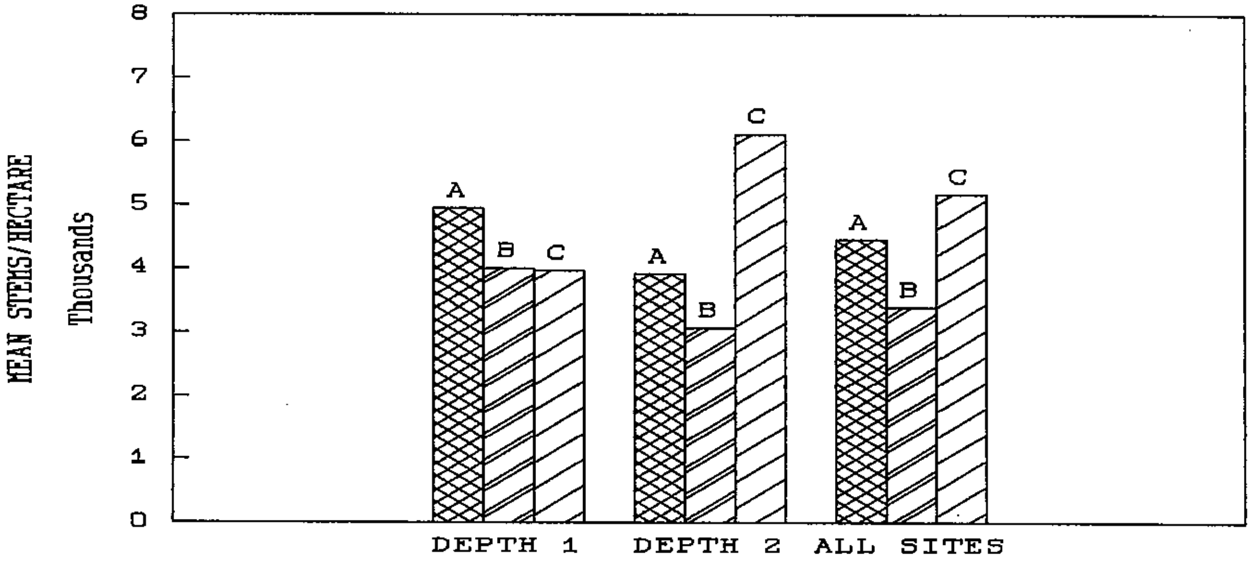

Figure 3. Changes in mean stem densities on two soil depths (Depth 1 = 25-50 cm, Depth 2 = 100-150 cm) between pre-drought (A), drought (B) and post-drought (C) vegetation response periods on the Glenharold Mine, Stanton, ND.

Similarly, mean shrub densities on depth 2 sites decreased significantly (p<.001) from 3847 to 3013 stems per hectare. As with depth 1 sites, 60 percent of this loss was attributed to reductions in woods rose (-45%) and buffaloberry (-55%). However, other more aggressive species also declined including silverberry (-55%), chokecherry (-9%) and American plum (-7%).

With the return of cool, wet weather in 1992 and 1993, recovery rates differed between the two soil depths. From drought to post-drought periods, depth 1 mean shrub density did not change while depth 2 shrub density doubled (p<.001) from 3,013 to 6,028 stems per hectare. On depth 2 sites, species affected most by drought including buffaloberry, woods rose and red-osier dogwood recovered dramatically with growth rates of 44, 136 and 167 percent respectively. Species contributing most to the total stem density increase during the post-drought period were American plum (35%), chokecherry (32%), serviceberry (20%), and woods rose (10%). Also, overall shrub density increased 57 percent from pre-drought to the post-drought period while mean shrub density declined 20 percent on depth 1 sites. Stem densities on depth 2 sites during the post-drought period are within 86 percent of the mean density in undisturbed tall shrub communities. Premining stem densities averaged 7,143 stems per hectare and ranged from 4,170 to 9,920 across the mine (Keammerer and Keammerer 1979).

Community similarity between depth 1 and depth 2 woodlands was 79 percent for the pre-drought period and did not change appreciably during drought (78%) and post-drought periods (79%). Also species diversity (H'), which was not significantly different (p=.11) in the pre-drought period, did not change significantly for either soil depth between vegetation response periods. On depth 1 sites, species diversity declined from 1.305 to 1.229 (p>.10) and did not recover during the post-drought period. On soil depth 2 study sites, species diversity declined from 1.462 to 1.282 (p>.10) from pre-drought to drought periods but recovered to 1.393 in 1993 and 1994. Compared to depth 1 sites, species diversity values were significantly higher (p<.05) on the depth 2 study area during the post-drought period. Diversity values recorded on both soil depth study sites were similar to those observed in undisturbed tall shrub communities across the mine where H' values averaged 1.34 and ranged from .683 to 1.892.

Table 2. Differences in mean stem density (stems/hectare) and species diversity between soil depth study sites during pre-drought (A), drought (B) and post-drought (C) vegetation response periods.

	DEPTH 1, 25-50 cm			DEPTH 2, 100-150 cm		
SPECIES	A	B	C	A	B	C
Serviceberry	170	157	44	243	303	706
Red-osier dogwood	249	21	16	103	47	126
Hawthorn	3	n/d*	n/d	20	3	8
Silverberry	n/d	n/d	n/d	246	111	197
American plum	1185	1314	1434	851	793	1687
Chokecherry	1376	1684	1681	1206	1098	1964
Woods rose	1587	595	534	803	444	1049
Buffaloberry	293	179	211	370	166	239
Western snowberry	23	n/d	2	2	10	30
Misc shrubs	3	n/d	n/d	3	38	22
SHRUB DENSITY	4889	3950	3922	3847	3013	6028
TREE DENSITY	54	46	41	67	51	82
TOTAL DENSITY	4943	3996	3963	3914	3064	6110
MEAN H'	1.305	1.229	1.207	1.462	1.282	1.393

* n/d = not detected

Table 3. Percent change in mean stem density and species diversity between soil depth study sites from pre-drought (A), drought (B) and post-drought (C) vegetation response periods.

	DEPTH 1, 25-50 CM			DEPTH 2, 100-150 CM		
SPECIES	A-B	B-C	A-C	A-B	B-C	A-C
Serviceberry	-8	-72	-74	25	133	191
Red-osier dogwood	-91	-25	-93	-54	167	22
Hawthorn	-100	n/d*	-100	-84	150	-59
Silverberry	n/d	n/d	n/d	-55	77	-20
American plum	11	9	21	-7	113	98
Chokecherry	22	0	22	-9	79	63
Woods rose	-63	-10	-66	-45	136	31
Buffaloberry	-39	18	-28	-55	44	-35
Western snowberry	-100	n/d	-91	400	200	1400
Misc shrubs	-100	n/d	n/d	1166	-42	633
SHRUB DENSITY	-19	-1	-20	-22	100	57
TREE DENSITY	-15	-11	-24	-24	61	22
TOTAL DENSITY	-19	-1	-20	-22	99	56
H'	-5.8	-1.8	-7.5	-12.3	8.6	-4.7

* n/d = not detected

Conclusions

Successful establishment of woodland plant communities in semiarid environments is dependent upon the use of reclamation techniques that prolong plant available water through periods of stress. Abiotic factors, including topography and aspect, are important toward meeting this goal (Richardson 1979, Mack 1981). This has been obvious in reclamation efforts at the Glenharold Mine. Also, constructing a suitable rooting zone with favorable soil physical and chemical characteristics is critical to woody vegetation survival and growth.

Periods of stress, especially during the early years of development, will affect the least adapted species and favor the most resilient. In this study, red-osier dogwood, woods rose and silver buffaloberry were affected most by drought conditions experienced in the late 1980's. On the deeper soil respread depths, these species were less affected by drought and were an important contribution to plant community structure in the post-drought period. The most aggressive species on both soil depths were American plum and chokecherry.

Natural mortality, competition, disease, drought and other coevolutionary interactions will affect reestablished woodland plant communities. However, species losses and declining stem densities, without subsequent recovery, can result in sites unable to compete with perennial grasses. Without reproduction, via either vegetative means or by seed, long term stability is questionable and reclamation success is in doubt.

The thickness of the rooting zone determines soil water storage capacity (Patterson and Richardson 1982). Patterson and Richardson (1982) described species response on natural landscapes to be the result of interaction between landscape, microclimate and soil. In this study, the impact of drought adversely affected survival and growth on woodland reclamation sites with 25-50 cm of total topsoil and subsoil. Woodland sites with 100-150 cm were also adversely affected, but had greater capability to recover to stem densities significantly higher than those recorded during the pre-drought period. This study emphasizes the importance of soil replacement and developing adequate root zone characteristics for woodland reclamation. Reclamation practices that improve soil moisture conditions will enhance survival and reproductive capabilities following periods of climatic stress.

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