SOIL DEPTH, QUALITY AND HERBACEOUS YIELD RELATIONSHIPS ON RECLAIMED GRASSLANDS[1]

by

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Abstract. Soil removal and replacement is a major reclamation cost in surface coal mining operations. The purpose of this research was to further define the relationships between soil depth, spoil quality and reclaimed grassland productivity. The study was conducted between 1988 and 1991 on two strip coal mines in western North Dakota. Twenty-one transects, containing ten equidistant points, were established on silty reclaimed and reference (unmined) soil types. Soil depth, soil physical and chemical characteristics, spoil quality, topography, aspect and slope position were determined for each point. Herbaceous yield was estimated by clipping 0.25 m^2 quadrats. Topoedaphic unit (TEU) analysis determined two site types were present, arid (I) and mesic (II). Regression analyses determined no significant relationship between soil depth, quality and herbaceous yield on either TEU I or TEU II. Mean herbaceous yield of silty reference TEUs were determined. Reclaimed grassland yields equaling or exceeding 90% of these calculated means served as the standard for success. Reclaimed sample points were then separated into successful or non-successful groups for each TEU and soil depths and quality associated with these groupings tested with multi-response permutation procedures. Topsoil and total suitable plant growth material (SPGM) depths, within both reclaimed TEUs, were significantly greater ($P<.01$) for sample points passing herbaceous yield standards. Average topsoil and SPGM depths of successful reclaimed sites for TEUs I and II were 16.9 and 48.9 cm, and 13.4 and 37.2 cm, respectively. No consistent trends between topsoil, SPGM and spoil quality (electrical conductivity, saturation percentage and sodium adsorption ratio) and reclamation success were evident.

Additional key words: North Dakota, Surface Coal Mining

Introduction

Soil replacement is a critical step in reclamation of western surface strip mined lands, where virtually all lands must be reclaimed to cropland or rangeland. The amount of soil needed to reclaim mined land to productive use depends on a variety of factors including soil quality, regraded spoil quality, intended land use, topography and others. Mining and reclamation costs will increase if excess soil is replaced without a concurrent improvement in the permanence and productivity of the reclaimed land. However, permanence and productivity of the reclaimed land will be adversely affected if too little soil is replaced.

Diverse and permanent stands of native and tame grasses have been established on numerous reclaimed lands in North Dakota where less soil was respread than is required by current regulations. Often, the plant cover and productivity of these reclaimed areas are greater than before mining occurred. Current North Dakota regulations [NDAC 69-05. 2-15-04(3)(a)] require an "approximate uniform thickness" of soil replacement during reclamation processes. These regulations, and most of the research in the past two decades, have emphasized soil reclamation standards for croplands. Maximization of yields and soil uniformity are stressed in reclamation of croplands in North Dakota. These standards may be excellent measures

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of reclaimed cropland success, but do not address important regulatory requirements related to rangeland.

The purpose of the research was to further define the relationships among soil depth, quality and reclaimed grassland productivity on silty range sites. The results will be used to determine what reconstructed soil and landscape characteristics, and replacement depths are necessary for rangeland reclamation.

Study Area and Methods

The research was conducted on the Glenharold and Baukol Noonan strip coal mines in west-central North Dakota. The mines are located within the Missouri Plateau Physiographic Region, which is on the western edge of an area where soils were formed from glacial deposits and residuum weathered from bedrock. The semi-arid, continental climate is characterized by cold winters and hot summers. Average monthly temperatures range from -12°C in January to 22°C in July. Average annual precipitation is 44 cm, of which 80% falls between April and September. The average growing season length is 120 days (Weiser 1975, Wilhelm 1978).

The research began on the Glenharold Mine, Stanton, ND, in 1988. Two reference and two reclaimed silty range sites were initially selected. In 1991, three additional reclaimed sites were added to the study. The reference sites, each containing two transects, were located on associations of Temvik and Williams silt loam soils (Wilhelm 1978). The three mined sites, containing four, five and three transects, were composed of Temvik and Williams silt loam and Cabba loam soils prior to mining (Wilhelm 1978).

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

Silty sites generally consist of well-drained, medium-textured soils, and often occur in the Cabba-Williams-Temvik map unit within the study site. These soils are moderately deep, high in organic matter, have good water holding capacity and make good agricultural soils when tilled (Weiser 1975, Wilhelm 1978)

The principal vegetative community on silty range sites of the study area is mixed grass prairie. The mixed grass prairie is dominated by numerous cool-season graminoids (wheatgrasses, needlegrasses, bluegrasses, sedges, prairie junegrass) and warm-season grasses (gramas, bluestems, muhlys) (Barker and Whitman 1988).

The mined sites were reclaimed between 1979 and 1984. One silty reclaimed site was respread with a topsoil-subsoil mixture. The remaining sites were reclaimed by stockpiling and then respreading top- and subsoil separately. All reclaimed sites were drill seeded using a mixture of cool-season (wheatgrasses, needlegrasses) and warm-season (bluestems, gramas, indiangrass, switchgrass, dropseeds) grasses, and alfalfa or sweet clover.

All transects located in 1988 and 1989 were placed randomly and in such a manner to produce maximum topographic variation among sampling points. The transects located in 1991 were established nonrandomly to increase sampling of shallow suitable plant growth material (SPGM = top- and subsoil combined) respread depths. Ten sampling points were located at 10 m intervals along each transect, except those established in 1991.

Herbaceous biomass was estimated at each point at peak standing crop by clipping 0.25 m^2 quadrats. Soil depths were sampled in 30 cm increments to 150 cm. Texture, bulk density, saturation percentage (SP), sodium adsorption ratio (SAR) electrical conductivity (EC) and pH were determined at each point. Aspect and slope position were also determined for each point.

Statistical Methods

Topoedaphic unit analysis (TEU) was performed using techniques outlined by Krabbenhoft (1991). Two TEUs were identified. TEU I was found in convex slope (arid) locations on landscapes while TEU II was identified as mesic, downslope positions. Sample points were separated into TEUs and subsequent analyses were conducted for each TEU.

Regression analysis (SAS 1990) was conducted to examine the relationship of topsoil and SPGM to herbaceous yield for each reclaimed TEU. Where no strong relationship occurred, reclaimed herbaceous yields were separated into successful or non-successful groups. Separation was based on reclaimed sample points exceeding (success) or not exceeding (non-success) 90% of the mean annual reference site herbaceous production. Soil depths and spoil quality (SP, SAR, EC) associated with these groups were tested for differences with multi-response permutation procedures analysis (Biondini et al. 1988).

Results

Growing season precipitation (May through September) averaged 19.8 cm (7.8 in) between 1988 and 1991. This is approximately 70% of the 20-year average of 28 cm (11.2 in).

Herbaceous yield was similar (P>.05) between similar TEUs on reference and reclaimed sites (Table 1). Four-year herbaceous yields averaged approximately 1600 kg/ha on both TEUs of reference and reclaimed sites.

No strong relationship between herbaceous yield and topsoil or SPGM was found for either TEU (Table 2). Correlation coefficients across years ranged between .13 and .21 for topsoil and SPGM. Therefore, sample points were separated by herbaceous yield into successful (exceeding 90% of mean reference herbaceous yield) or non-successful (<90%) groups. The topsoil and SPGM depths associated with these groups were tested with multi-response permutation procedures and found different for each TEU (Table 3). Spoil quality characteristics, SP, SAR, and EC, showed no consistent trend between successful or non-successful topsoil or SPGM depth groups.

Topsoil and SPGM depths, associated with herbaceous yields exceeding 90% of mean reference area yields, averaged 30% greater than depths associated with non-successful yields (Table 4). Successful topsoil depths of both TEUs averaged over 30% of total SPGM depth.

Discussion

Current North Dakota regulations for SPGM redistribution thickness vary depending upon the texture, SAR and SP of the underlying spoil (NDAC 1987). When SAR is low (< 12) and spoil texture course, 90 cm of SPGM is required. If SAR is moderate (12-20) and SP is low (< 95) or high (> 95), then 90 or 105 cm of SPGM are required, respectively. If spoil quality is very poor (SAR > 20), SPGM redistribution thickness must be at least 120 cm.

Spoil quality underlying sampling transects in this study ranged from 3 to 24 SAR and 69 to 108 SP. Average transect SAR and SP were 12.5 and 88, respectively. Over 90% of the transects had an average SAR for spoil material less than 20, while 67% of the transects had spoil SPs of less than 95. Therefore, average spoil quality indicated a SPGM redistribution

Table 1. Annual summary of herbaceous yield ($\bar{x}$ and S.E.) on silty reference and reclaimed sites, 1988-1991.

Year	Reference		Reclaimed	
	TEU I	TEU II	TEU I	TEU II
	g/0.25 m^2			
1988	31.0 (n=24) 1.7	36.9 (n=16) 3.4	25.9 (n=57) 1.6	24.0 (n=33) 2.3
1989	33.1 (n=38) 1.8	31.8 (n=42) 1.3	31.0 (n=61) 1.2	38.1 (n=59) 1.3
1990	40.5 (n=38) 2.8	34.4 (n=42) 2.2	50.2 (n=61) 2.1	43.0 (n=59) 2.3
1991	60.1 (n=38) 3.0	48.2 (n=42) 2.2	55.4 (n=67) 2.8	52.2 (n=53) 4.1
1988-1991*	43.3 (n=138) 1.7	38.1 (n=142) 1.4	40.2 (n=246) 1.3	37.4 (n=204) 1.6

* Weighted average

Table 2. Correlation coefficients (r^2) for herbaceous yield and soil depths on a reclaimed silty site.

Year	Topsoil		SPGM	
	TEU I	TEU II	TEU I	TEU II
1988	< .01	.03	.03	.05
1989	< .01	< .01	< .01	< .01
1990	.12	.36	.10	.25
1991	.31	.39	.21	.11
1988-1991	.19	.21	.18	.13

Table 3. P-values from multi-response permutation procedures analysis of successful and non-successful sample points based on herbaceous yield.

Year	Topsoil		SPGM	
	TEU I	TEU II	TEU I	TEU II
1988	.47	< .01	.77	.10
1989	< .01	.68	.26	< .01
1990	< .01	< .01	< .01	< .01
1991	< .01	< .01	< .01	.01
1988-1991	< .01	< .01	< .01	.01

Table 4. Soil depths (cm) associated with successful or non-successful herbaceous yields on a silty reclaimed site.

Soil Class	Topoedaphic Unit	Successful	Non-successful
Topsoil	I	16.9 (6.7")	11.5 (4.5")
	II	13.4 (5.3")	9.9 (3.9")
Suitable Plant Growth Material	I	48.9 (19.3")	34.0 (13.4")
	II	37.2 (14.6")	28.3 (11.1")

thickness of 90 cm would be required in reclaiming the sites.

Average SPGM depths associated with successful herbaceous yield on both TEUs were approximately 50% of regulated depths. TEU I, at higher landscape positions, averaged 48.9 cm SPGM for successful reclamation based on herbaceous yields. TEU II, found at lower landscape positions, required less SPGM (37.2 cm) to successfully meet yield requirements. Successful reclamation of our silty sites, based on herbaceous yield, was attained at significantly less SPGM depths than current regulations suggest.

Soil depth regulations for reclaimed mined lands in North Dakota are based largely on maximization of cropland yields. These soil replacement depths may be excessive for establishing permanent grasslands. Our study of silty reclaimed sites suggest this to be true. However, soil replacement depths necessary to maintain permanent, diverse and productive grassland will be dependent upon numerous soil, spoil and topographic characteristics inclusive to each reclamation effort. The results of this study are pertinent only to other silty sites having similar topoedaphic characteristics.

Literature Cited

Barker, W.T., and W.C. Whitman. 1988. Vegetation of the Northern Great Plains. Rangelands 10:266-272.

Biondini, M.E., P.W. Mielke, and K.J. Berry. 1988. Data-dependent permutation techniques for the analysis of ecological data. Vegetatio 75:161-168.

Krabbenhoft, K.D. 1991. Plant diversity levels and topoedaphic unit analysis on a reclaimed stripmine in North Dakota. M.S. Thesis, North Dakota State Univ., Fargo.

NDAC, Article 69-05.2. 1987. Public Service Commission, State of North Dakota rules governing the reclamation of surface-mined land. North Dakota Public Service Commission, Bismarck.

SAS. 1990. SAS/STAT User's Guide, Version 6, Fourth Edition, Vol. 2, Cary, N.C. SAS Institute Inc.

Weiser, P.K. 1975. Soil survey of Oliver County, North Dakota. USDA SCS. U.S. Government Printing Off., Washington, D.C.

Wilhelm, F.J. 1978. Soil survey of Mercer County, North Dakota. USDA SCS. U.S. Government Printing Off., Washington, D.C.