Title: Effects of Land Form and Soil Characteristics On Plant Community Development and Productivity On 28-Year Old Reclaimed Mine Land.

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Research in the 1970's showed that topsoil and subsoil salvage and spreading would adequately reclaim sodic minespoils in the northern Great Plains, but long term assessments were needed. A 1.4 ha North Dakota coal stripmine site was reclaimed in 1975 with 0.2 m of topsoil over 0 to 1.2 m of subsoils, forming a double wedge with 5% north and 1.5% south slope. Subsoils A, B, and C had 43%, 23%, and 14% clay. Seeding treatments were crested wheatgrass (CWG, *Agropyron cristatum*), Russian wildrye (RWR, *Psathyrostachys juncea*), alfalfa (ALF, *Medicago sativa*), and smooth brome (BRN, *Bromus inermus*). In 2003, plant productivity, biomass diversity and soil properties were determined. Species persistence of treatments was: CWG, 50%; BRN, 49%; RWR, 19%; ALF, 5%. Areas seeded to ALF had highest diversity index value. The order of production of CWG & RWR treatments by subsoil in 1978-81 was C > B > A with 25% avg. C-A difference, which changed little in 2003: C ~ B > A with 28% C-A difference. Productivity of CWG & RWR treatments in 1978-81 was greatest on lower-midslope areas, and relationships between productivity and slope position were strong ($P < 0.0001$). In 2003, positions with greatest production in CWG & RWR treatments had moved upslope, to upper-midslope and shoulder, but not as much upslope for ALF & BRN. Productivity vs. position relationships in 2003 were weaker ($P = 0.03$ to 0.05). Strong relationships of productivity to position in 1978-81 obscured response to soil depth, but 2003 results showed productivity responding to 0.8 to 1.0 m soil depth. Increased diversity by 2003 implies more species were using water later in the season than during 1978-81, thereby increasing response to soil depth. Soil EC (0 – 0.6 m) in 2003 was lower than in 1978, indicating soil development, which should have improved response to soil depth.

INTRODUCTION AND METHODS SECTION

Coal is the number 1 source of energy in the United States

Coal surface mine in North Dakota: lower left, stripping and salvage of soil; upper left, removal of strata above coal seam by dragline; upper right, loading of fractured coal for tranport to nearby power station or rail loading facility. Following coal removal, spoil is leveled, salvaged topsoil and subsoil materials are respread, and the tract is revegetated. Source: BNI Coal Co.

Original Zap Wedge Experiment

In 1974, the late Dr. J. F. Power and colleagues at USDA-ARS, Mandan, ND initiated two large-scale experiments at coal surface-mines designed to answer the following questions about reclamation of sodic-type minespoils:

(a) Is separate salvage and respreading of topsoil (mostly A horizon of Ustolls) and subsoil (mostly B and C horizon) necessary?
(b) What depth of soil materials is necessary to restore vegetative productivity?
(c) What are productivity responses to subsoil quality?

A wedge of subsoil was covered by several uniform depths of topsoil, mixed topsoil and subsoil, or no topsoil, in the Stanton Wedge experiment (Power et al., 1981). The Zap Wedge experiment featured a uniform 0.2 m depth of topsoil over a double wedge of 3 kinds of subsoil (Fig. 1; Table 1), with total soil depth ranging from 0.2 to 1.3 m.

New Zap Wedge Research

Employing a geographic-ecological approach, Dr. A. W. Wick and colleagues carried out new research in 2003 designed to answer these questions:

(a) What changes in plant community productivity and species diversity and coverage have occurred?
(b) What changes in plant community response to soil depth and landform position have occurred?
(c) Have there been changes in soil ephemeral properties?

METHODS

Location: near Zap, Mercer Co., North Dakota, USA

Climate: Continental; 430 mm annual precipitation mean

Soils: predominantly Ustolls

Original Experiment: 1975 – 1983

Approach: agronomic

Vegetation: Subplots up/down wedge were seeded 1975 to crested wheatgrass (*Agropyron cristatum*), Russian wildrye (*Psathyrostachys juncea*), alfalfa (*Medicago sativa*), and spring wheat, which was seeded to smooth brome (*Bromus inermus*) at experiment's end. Vegetative productivity was measured by mowing 8-m^2 areas elongated up-down wedge.

Soils: Samples were taken at 4 fixed positions up/down both aspects. Chemical properties were by saturation-extract procedure.

New Research: 2003

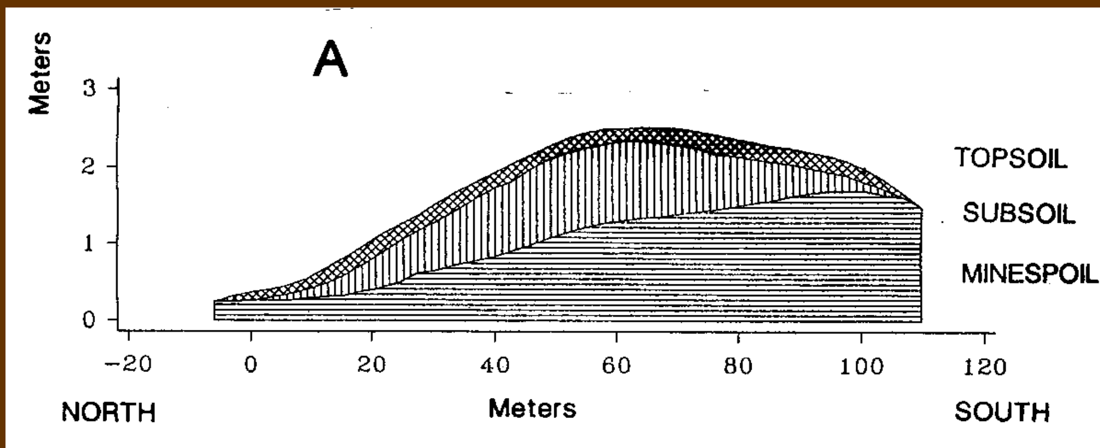
Approach: geographic/ecological

Vegetation: sampling locations were randomly distributed for equal areal coverage. Production and composition were measured by handclipping 0.25 m^2-plots. Composition and type of coverage was measured by point frame.

Soils: Samples were taken at selected vegetative plot positions. EC and pH were by 1:1 extracts and texture was by hydrometer.

New and Old: Both analyzed by uniform ANOVA with nearly equal degrees of freedom.

Structure and Plan of Zap Wedge Experiment



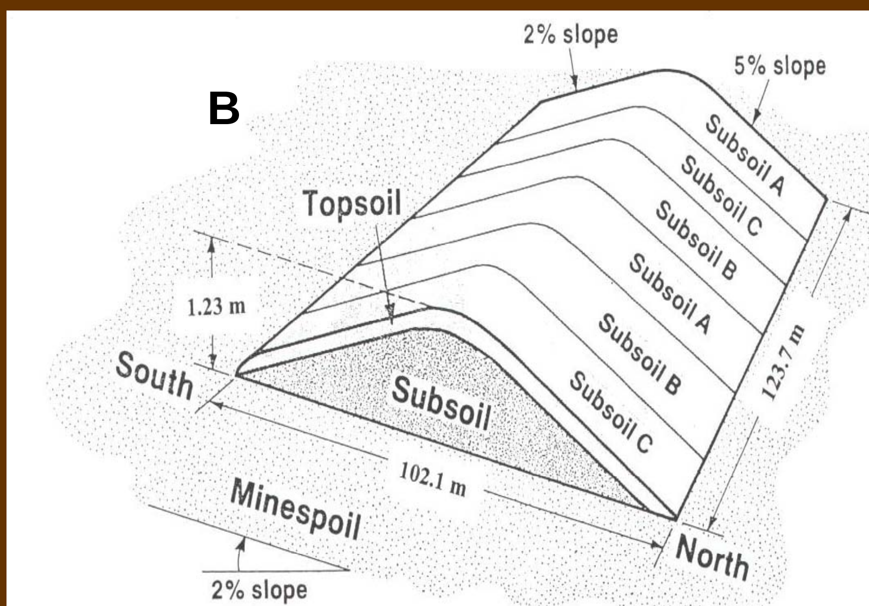


Figure 1. A. Structure of double wedge reclamation site near Zap, ND. B. Plan of replicated subsoil quality areas on wedge.

Properties of Soil and Spoil Materials

Property	Top-soil	Subsoil			Mine-spoil
		A	B	C	
Clay percent	22.8	43.0	23.3	13.6	37.0
Water holding capacity – g kg^{-1}	93	124	146	64	180
EC 1:1 dS cm^{-1}	0.25	2.44	1.06	0.33	3.21
SAR$ (mol $m^{-3})^{1/2}$	2.6	6.5	4.6	3.1	14.6

Table 1. Properties of respread soil and minespoil materials.
$. Sodium adsorption ratio, by saturation extract analyses

RESULTS SECTION

Vegetative Composition

	Species seeded in 1975			
	Alfalfa	**Crested whtgrs.**	**Smooth brome**	**Russian wildrye**
Species or category - 2003	- - - - - - - - percentage - - - - - - - -			
Alfalfa[1]	**5.2**	2.4	3.3	3.7
Crested wheatgrass[2]	29.6	**49.8**	15.5	14.1
Smooth brome[3]	10.0	1.4	**49.3**	14.4
Russian wildrye[4]	12.4	0.1	12.2	**18.9**
Yellow sweetclover[5]	10.3	18.6	12.2	17.5
Other broadleaf	23.3	24.9	15.4	22.3
Other grassy	9.3	2.8	3.1	8.0

Table 2. Composition of vegetative production measured in 2003.
1. *Medicago sativa*. 2. *Agropyron cristatum*. 3. *Bromus inermis*.
4. *Psathyrostachys juncea*. 5. *Melilotus officinalis*.

Productivity Response to Subsoil

	Subsoil type			% diff-erence A vs. C
	A	B	C	
Year	- - - - - kg / ha - - - - -			
2003	1523[b]	1899[a]	1899[a]	27.5
1981	944[c]	1060[b]	1454[a]	42.5
1979	1144[c]	1241[b]	1485[a]	25.9
1978	2542[b]	2725[a]	2729[a]	7.1

Table 3. Plant productivity in response to subsoil quality.
Values in a row with the same letter are not significantly different at the P = 0.05 level according to Tukey's Studentized range test .

Diversity

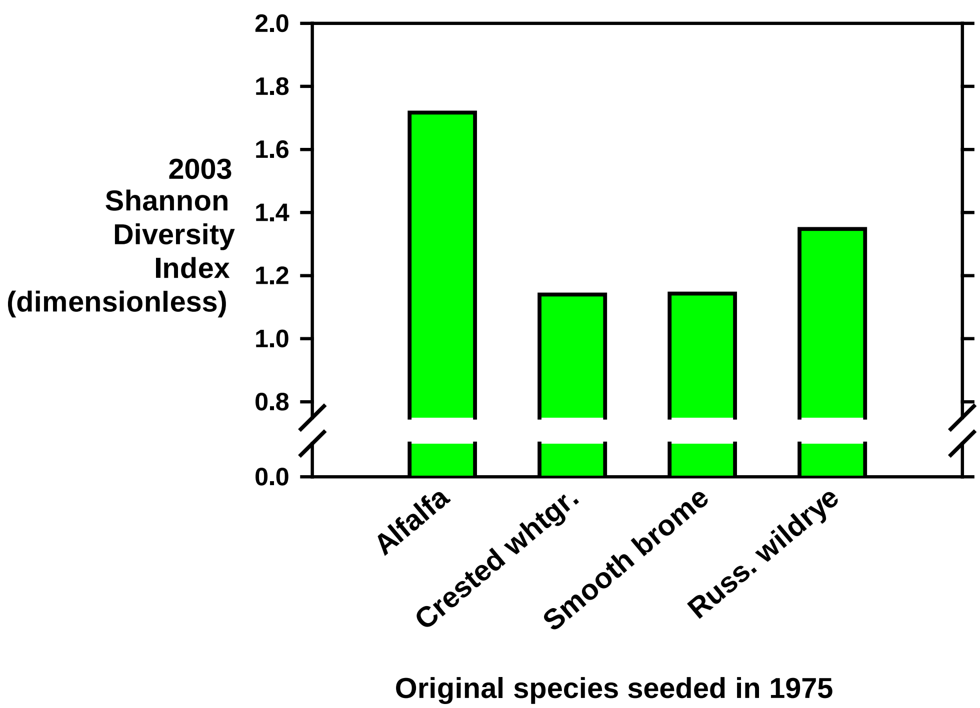


Figure 2. Shannon diversity index calculated from basal coverage data.

Vegetative Produvtivity vs. Soil Depth and Slope Position

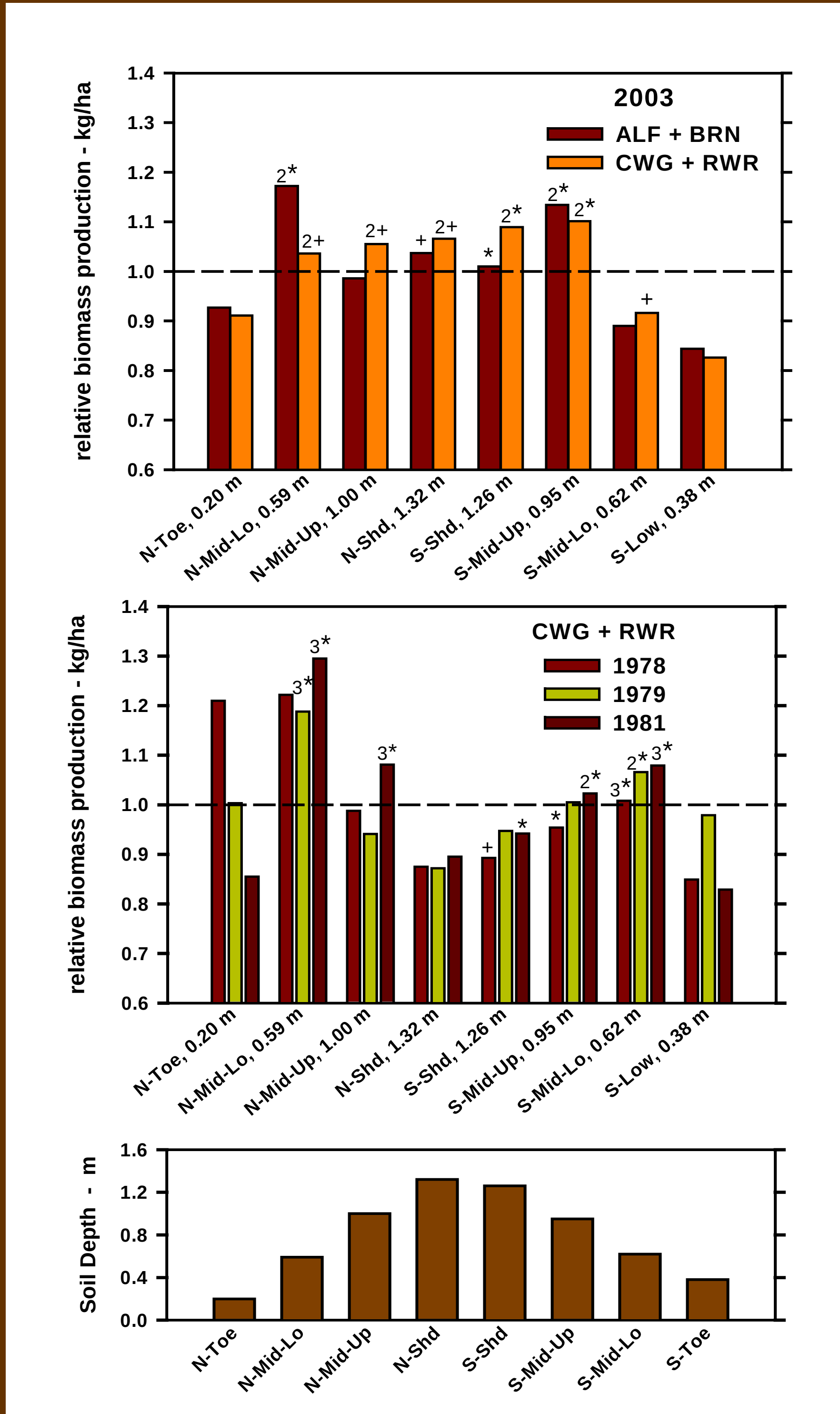


Figure 3. Vegetative produvtivity vs. soil depth and slope position. Original species seeded: ALF, alfalfa; BRN, smooth brome; CWG, crested wheatgrass; RWR, Russian wildrye. Probability levels of single-tailed t-tests of positive differences with N Toe or S Low (near toe) values are: +, P < 0.20; 2+, P < 0.10; *, P < 0.05; 2*, P < 0.01; 3*, P < 0.001.

Electrical Conductivity 1978 and 2003

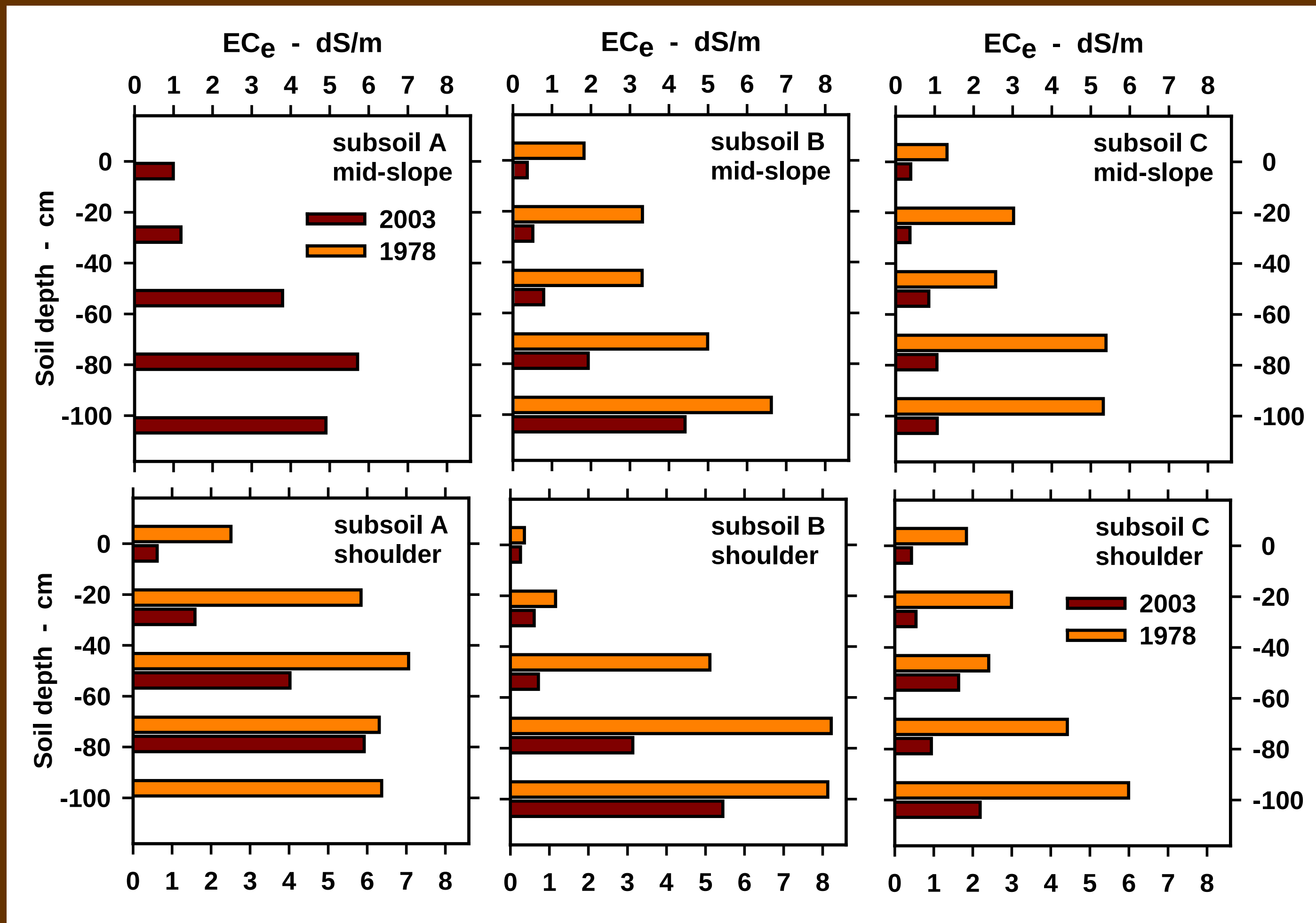


Figure 4. Saturation extract equivalent electrical conductivity (EC_e) vs. depth for subsoils A, B and C in 1978 and 2003.

DISCUSSION SECTION

RESULTS

1. Persistence of seeded species ranged from 50% for crested wheatgrass to 5% for alfalfa, and ranking for diversity index was closely inverse to that of persistence (Table 2, Figure 2).

2. Strong relationships of vegetative productivity to slope position in original study obscured response to soil depth (Figure 3).

3. By 2003, productivity was less dependent on slope position and showed response to 0.8 to 1.0 m soil depth (Figure 3).

4. Productivity response to subsoil quality in 2003 approximated the average of 1978, 1979, and 1981 (Table 3).

5. Soil EC in 2003 was lower than in 1978, indicating soil change (Figure 4).

CONCLUSIONS

1. Increased diversity by 2003 implies more species were using water later in the season than during 1978-81, thereby decreasing effect of the formerly more dominant cool-season grasses' response to spring runoff-runon water and aspect, and increasing production at higher slope positions having greater respread soil depth.
2. Revegetation with diverse native species should reduce sensitivity of production to respread soil depth and landform topographic position, and should promote community development compared with seeding aggressive, non-native grasses.
3. Linking soil-plant study of smaller plot areas having multiple soil depths and qualities to ecological-edaphic study of landforms that are uniformly reclaimed by soil respreading should yield more durable and applicable reclamation research results than wedge or inverse wedge (trench) designs of the past.

Zap Wedge Lessons Learned

1. Best understanding of agro-ecological systems comes from integrating soil-plant interactions at lower scale with land processes at immediately higher scales.

2. More durable and applicable research results come from linking ecological, geographic, and edaphic-agronomic approaches.

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