SPATIAL VARIABILITY IN THE CHEMICAL AND PHYSICAL PROPERTIES OF REGRADED MINE SPOIL[1]

by

Gary A. Halvorson[2]

Abstract The variability in the chemical and physical properties of regraded mine spoil was measured at four locations in western North Dakota. The ultimate objective of this study is to predict regraded surface properties from core data from the original overburden. The samples were taken from an expanding square pattern so the variability in a small area could be compared to the variability in a large area. The size of the area sampled ranged from 9 sq. m to 55 ha. Spoil properties measured included pH, electrical conductivity, soluble Ca, Mg and Na, sodium adsorption ratio and percent sand, silt and clay. Variability in soil properties as measured by the coefficient of variation in the smallest area was 30-70% of that in the largest area for most parameters at three mines. Difficulties were encountered in matching the premine overburden with the regraded spoil properties because the degree of surface grading following mining was not predictable. Sampling to a depth of 1.2 m in 0.3 m increments did not significantly improve the information available on the variability of spoil properties compared to the surface 0.3 m alone.

Additional Key Words: reclamation, overburden, chemical properties, physical properties, premine.

Introduction

The amount of topsoil and subsoil necessary to reclaim mined land in the northern Great Plains is dependent on the properties of the spoil material. In a subsoil wedge experiment in which the combined topsoil - subsoil thickness was increased from 0 to 2.1 m over highly sodic spoil, highest yields of all crops occurred when about 0.20 m of topsoil was placed over 0.55 to 1.10 m of subsoil (Power et al., 1981). The depth of soil required for maximum production on 15 wedge plots in Wyoming, Montana, and North Dakota was dependent on spoil characteristics (Barth and Martin, 1984). Maximum production was achieved on these plots when replaced soil depths were 0.71 m on sodic spoil, 0 m on soil-like spoil and 0.50 m on spoil lacking distinguishing traits such as sodicity. Spoil materials can be inherently deficient in available nutrients, especially P and N (Bauer et al., 1965, 1966). Merrill et al. (1985) reported that the low hydraulic conductivity of sodic minespoil (sodium adsorption ratio

[1]Paper presented at the Conference 'Reclamation, A Global Perspective,' Calgary, Alberta, Canada, August 27-31, 1989. Publication in this proceedings does not preclude the author from publishing this manuscript, whole or in part, in other publication outlets.

[2]G. A. Halvorson, Associate Soil Scientist, Land Reclamation Research Center, North Dakota State University P. O. Box 459, Mandan, ND 58554.

Proceedings America Society of Mining and Reclamation, 1989 pp 589-596

DOI: 10.21000/JASMR89020589

https://doi.org/10.21000/JASMR89010589

(SAR) = 30) was the dominant factor limiting plant growth. In a study using trenches which simulated reclamation with various types of spoil material at least 0.69 m of silt loam topsoil was necessary to produce maximum yields over sandy loam spoil (Halvorson et al., 1986). On moderately sodic spoil yields of corn silage and wheat grain were significantly higher on 0.15, 0.30 and 0.60 m of topsoil compared to 0.05 m (Halvorson et al., 1987). The clay loam spoil in this study was not as drought prone as the sandy loam topsoil and therefore, as the thickness of topsoil increased, the ability of the profile to continuously supply water to the growing crop decreased.

The results of these and other experiments have been summarized by Doll et al. (1984). They also drew up recommendations for topsoil depth replacement based on spoil properties in the northern Great Plains. These spoil properties are not uniform in a permit area or a tract of reclaimed land. It is therefore, important to understand the variability in spoil properties and how this affects the reclamation of a given tract of mined land. It would also be useful to predict this variability in spoil material from the original overburden bore hole data. The objectives of this research were therefore; (1) to determine the variability of regraded spoil; (2) determine the depth of sampling necessary to characterize this variability, and (3) predict the regraded spoil properties from the original premine bore hole data.

Methods and Materials

Four sites were selected for study, one each at the Indianhead, Glenharold, Falkirk and South Beulah Mines in North Dakota. The sites were located on regraded spoil which was at or near final grade. Sampling was done using an expanding square technique. This sampling scheme has also been called a systematic radial sampling scheme (Wilding, 1985). An area of 3 x 3 m was subdivided into 9 equal squares and the center of each square was sampled to a depth of 1.2 m in 0.3 m increments. An area of 9 x 9 m was subdivided into 9 equal squares using the original 3 x 3 m area as the center square. The center of each of the new expanded squares was sampled to a depth of 1.2 m. The square was expanded similarly a total of five times to give six sampling areas of different sizes. The largest expansion sampled (#6) had a total area of 55 ha.

Clay percentage was determined using the pipette method (Day, 1965). A glass electrode was used to measure pH (Peech, 1965). Soluble salts, (electrical conductivity (EC) and saturation percentage were determined on saturation extracts (Bower and Wilcox, 1965) and soluble Ca, Mg, and Na concentrations were determined quantitatively using atomic absorption spectrophotometry and were used to calculate SAR values.

The standard deviation and coefficient of variation were calculated for each expansion at each site. Analysis of variance was used to determine significant differences between sampling depths for each square expansion.

Results and Discussion

Mean values for all parameters for each expansion at each site generally did not change very much as the size of the sample area increased (Table 1). An exception was the SAR values at the Indianhead Mine which increased from 10 in the smallest area (expansion 1) to 19 and 17 in expansions 5 and 6, respectively. The SAR in the center was lower than most of the surrounding sample area at this site.

Table 1. The mean, standard deviation (STD) and coefficient of variation (CV) of the sodium adsorption ratio (SAR), saturation percentage (SP), electrical conductivity (EC), and % clay content from a site at each of four mines in North Dakota.

Mine	Expansion	Mean	STD	CV	Mean	STD	CV
		SAR			SP		
South Beulah	1	16	4	23	90	8	8
	2	16	2	14	91	7	8
	3	16	3	18.	91	9	10
	4	17	6	34	87	12	14
	5	14	3	20	93	13	14
	6	12	8	65	91	18	20
Glenharold	1	43	5	12	154	19	12
	2	44	3	7	151	13	9
	3	41	6	14	147	19	13
	4	41	5	13	140	17	12
	5	41	5	13	137	16	12
	6	40	5	13	141	15	11
Indianhead	1	10	1	11	67	5	7
	2	10	1	9	69	5	7
	3	11	3	25	76	12	16
	4	17	6	34	100	24	24
	5	19	8	42	97	25	26
	6	17	9	49	96	22	22
Falkirk	1	4.9	1.6	32	80	6	7
	2	5.4	1.5	27	78	5	6
	3	3.5	1.4	41	78	5	7
	4	6.2	2.6	41	78	8	11
	5	3.6	2.3	63	77	10	13
	6	5.4	3.8	70	74	10	13
		EC (dS/m)			% Clay		
South Beulah	1	6.9	1.0	14	39	2	5
	2	6.8	0.8	12	40	3	8
	3	6.7	1.1	16	39	3	8
	4	6.7	1.1	16	38	4	11
	5	6.9	1.2	17	39	5	13
	6	5.9	1.6	26	40	7	17
Glenharold	1	2.1	1.4	66	33	7	22
	2	2.0	0.7	36	33	6	20
	3	2.7	1.8	66	33	6	19
	4	2.8	1.3	47	34	6	18
	5	2.8	1.2	41	33	5	15
	6	2.6	0.7	29	31	6	20
Indianhead	1	4.8	0.6	13	26	3	12
	2	4.7	0.5	11	26	3	10
	3	4.5	0.8	18	28	4	15
	4	4.6	1.3	29	34	8	23
	5	4.5	1.3	29	33	7	21
	6	4.4	1.4	31	32	5	16
Falkirk	1	4.4	0.5	12	33	4	12
	2	4.4	0.6	13	33	4	11
	3	4.3	0.2	4	37	6	15
	4	4.2	1.2	28	32	14	13
	5	4.2	0.8	20	34	8	24
	6	3.6	1.0	29	29	8	26

For all parameters at all sites except the Glenharold site the coefficient of variation (CV) increased as the sampling area (expansion) increased. For example, at the South Beulah Mine the CV increased from 23% in expansion 1 to 65% in expansion 6. This means that about 35% of the variability in SAR from the largest expansion could be found in an area of $9m^2$. For most of the parameters the CV of expansion 1 was 30-70% of expansion 6. Therefore, a significant portion of the variability in the larger area could be found in a rather small area of regraded spoil. This seems to indicate that considerable mixing of the overburden material had occurred during the mining process.

At the Glenharold Mine the CV values for all parameters did not increase as the size of the area sampled increased and tended to decrease for EC. These data would indicate that spoil material at this site had been thoroughly mixed. Much of the mixing probably occurred in the final grading process. Material from a topographic high was spread over much of the area so that the properties of the spoil in a small area became the properties of the spoil in a much larger area. As discussed later, this extensive regrading of the spoil material causes problems in matching the regraded spoil properties with those of the original overburden.

Analysis of variance was run to determine if significant differences occurred between the sampling increments of 0.3 m in the regraded spoil. The level of significance for the Glenharold site is given in Table 2 as an example. Results were similar for the other three sites. In general, there were very few significant differences between the different sampling depths. Where significant differences did occur, they were usually in the four smallest sampling areas (expansions). These data indicate that very little additional information on the variability of regraded spoil properties can be obtained by sampling to a depth of 1.2 m rather than just sampling the surface 0.3 m.

The characteristics of the regraded spoil at the Falkirk Mine were compared with the data from eight original bore holes which would be expected to influence the properties of the regraded spoil. The percent frequency of SAR at values from 0-19 indicates a fairly close match between the regraded spoil and the original overburden properties (Table 3). Values for EC in the original overburden were concentrated in the range of 1-6 dS/m with 35% having a value of 1 ± 0.5 dS/m. In the regraded spoil EC values had a wider range of 1-9 dS/m and the highest percentage of values (17%) at 3 ± 0.5 dS/m. Some EC values were as high as 19 dS/m in the regraded spoil. Based on the frequency tables for EC the match between regraded spoil and the original overburden was poor.

The % clay in the original overburden was concentrated in the range of 20-45% with 58% of the samples having clay contents of 25-30%. The regraded spoil on the other hand was mainly in the 30-65% range with 71% of the samples having clay contents of 35 to 45%. The values for % clay in the regraded spoil and in the original overburden do not match and would suggest two different populations. The clay % in the original overburden samples did not exceed 45 while 19% of the samples in the regraded spoil exceeded this value. The only original overburden sampling point which had clay contents above 45% was located several hundred yards south of the regraded spoil sampling area. Since the pit was running east-west and the mining was proceeding northward this original

Table 2. Level of significance at the Glenharold site for differences in sampling depth for each expansion size.

Expansion	SAR	SP	EC	% Clay
	Level of Significance			
1	0.179	0.280	0.305	0.082
2	0.814	0.655	0.980	0.985
3	0.042*	0.370	0.375	0.961
4	0.653	0.073	0.262	0.586
5	0.099	0.037*	0.132	0.800
6	0.303	0.999	0.666	0.457

* A value of 0.05 or less indicates significant differences do occur.

Table 3. Percent frequency distribution for SAR, EC and percent clay in 8 original overburden bore holes (OB) and in regraded spoil (RS) from the Falkirk Mine.

SAR	OB	RS	EC	OB	RS	Clay	OB	RS
	---%---		dS/M	---%---			--------%-------	
0	2	0	0	4	0	0	0	2
1	28	11	1	35	11	5	0	0
2	19	8	2	12	8	10	0	0
3	12	17	3	13	17	15	0	0
4	9	11	4	12	11	20	8	2
5	2	11	5	12	11	25	33	0
6	3	8	6	9	8	30	25	9
7	2	11	7	3	11	35	19	18
8	3	3	8		3	40	8	39
9	3	11	9		11	45	3	14
10	3	0	10		0	50		9
11	4	3	11		3	55		2
12	6	3	12		3	60		4
13	6	0	13			65		4
14			14					
15			15					
16			16					
17			17					
18			18					
19		3	19		3			

sampling point would not normally have influenced the regraded spoil properties. In checking with the Falkirk Mining Company personnel, it was learned that this area following mining was a topographic high and had been smoothed down in the final regrading process. The material from this one spot had therefore, been spread over a much larger area including the sampling area on regraded spoil. The properties of the entire regraded spoil area on the surface were characteristic of that one site several hundred yards to the south.

Because the amount of regrading on the source of the added material in the final regrading process cannot usually be predicted before mining, it is nearly impossible to predict regraded spoil properties from original overburden bore hole data. Research is currently underway to determine whether original overburden data can predict "rough" graded spoil properties, that is, before any extensive recontouring or movement of materials has occurred. Such a predictive capacity could be useful in planning final regrade to obtain optimum surface physical and chemical properties for reclamation.

Conclusions

A sampling scheme known as an expanding square sampling scheme or a systematic radial sampling scheme was used to compare spoil variability from a small area with that in a large area. At the Indianhead, Falkirk and South Beulah mine sites the CV's of the measured parameters in the smallest sampling areas were 30-70% of the CV's in the largest sampling areas. At the Glenharold mine extensive regrading produced CV's which were uniform and independent of sampling size area.

Analysis of variance indicated that no additional information on the variability of spoil properties was gained by sampling down to 1.2 m in 0.3 m increments than from the surface 0.3 m alone.

A comparison of the properties of regraded spoil with original overburden data indicated difficulties in matching the two. In the examples used at one mine SAR values in the regraded spoil matched fairly well with the original overburden data, but the EC and especially the % clay values did not match and were considered to be from different populations. The reason for the poor match was due to the extensive recontouring and movement of spoil material from one area to another during final grading. This process makes it nearly impossible to predict regraded spoil properties from original overburden bore hole data.

Literature Cited

Barth, R. C., and B. K. Martin. 1984. Soil depth requirements of revegetation of surface mined areas in Wyoming, Montana, and North Dakota. J. Environ. Qual. 13:399-404.
http://dx.doi.org/10.2134/jeq1984.00472425001300030016x

Bauer, A., E. B. Norum, J. C. Zubriski, and R. A. Young. 1966. Fertilizer for small grain production on summer fallow in North Dakota. North Dakota Agric. Exp. Stn. Bull. 461.

Bauer, A., R. A. Young, and J. L. Osbun. 1965. Effects of moisture and fertilizer on yields of spring wheat and barley. Agron. J. 57:354-356.
http://dx.doi.org/10.2134/agronj1965.00021962005700040013x

Bower, C. A., and L. V. Wilcox. 1965. Soluble Salts. In C. A. Black et al. (ed.). Methods of soil analysis. Agron. 9:933-951.

Day, P. R. 1965. Particle fractionation and particle size analysis. In C. A. Black et al. (ed.). Methods of soil analysis. Agronomy 9:545-567.

Doll, E. C., S. D. Merrill, and G. A. Halvorson. 1984. Soil replacement for reclamation of stripmined lands in North Dakota. North Dakota Agric. Exp. Stn. Bull. 514.

Halvorson, G. A., A. Bauer, S. A. Schroeder, and S. W. Melsted. 1987. Corn and wheat response to topsoil thickness and phosphorus on reclaimed land. J. Environ. Qual. 16:73-76. http://dx.doi.org/10.2134/jeq1987.00472425001600010015x

Halvorson, G. A., S. W. Melsted, S. A. Schroeder, C. M. Smith, and M. W. Pole. 1986. Topsoil and subsoil thickness requirements for reclamation of nonsodic mined-land. Soil Sci. Soc. Am. J. 50:419-422. http://dx.doi.org/10.2136/sssaj1986.03615995005000020033x

Merrill, S. D., F. M. Sandoval and J. F. Power. 1985. Effect of disturbed soil thickness on soil water use and movement under perennial grass. Soil Sci. Soc. Am. J. 49:196-202.
http://dx.doi.org/10.2136/sssaj1985.03615995004900010039x

Peech, M. 1965. Hydrogen-ion activity. In C. A. Black et al. (ed). Methods of soil analysis. Agronomy 9:914-926.

Power, J. F., F. M. Sandoval, R. E. Ries, and S. D. Merrill. 1981. Effects of topsoil and subsoil thickness on soil water content and crop production on a disturbed soil. Soil Sci. Soc. Am. J. 45:124-129.
http://dx.doi.org/10.2136/sssaj1981.03615995004500010027x

Wilding, L. P. 1985. Spatial variability: its documentation, accommodation and implication to soil survey. p. 166-194. In D. R. Nielsen and J. Bouma (eds.). Soil spatial variability. Proceedings of a workshop of the ISSS and the SSSA (Las Vegas, Nev., November 30-December 1, 1985). PUDOC. 243 p. Wageningen The Netherlands.