Restoring Productivity of Eroded Soils with Manure Applications

Lawrence J. Cihacek, Associate Professor, Soil Science Department
North Dakota State University, Fargo, ND.

Introduction

Erosion removes not only soil material but also organic matter and nutrients contained in the soil resulting in reduced productivity. This lost productivity is difficult to restore with just fertilization because changes in soil texture, structure, bulk density and water holding capacity cannot be replaced by fertilizer. Efforts to restore lost productivity require that some of these factors be restored through amending the soil with plant material or animal manures or through major changes in residue management. Greenhouse work by Er-Raji (1990) showed that adding animal manures gave greater improvement in productivity of an eroded soil than additions of contributions of fertilizer and crop residues.

Annual manures are readily available in western North Dakota but may be limited in quantity in a given year for application to eroded soils to improve soil productivity. This study was established to evaluate applications of long-term low rates of animal manure to eroded soils and to study the effects of these applications on soil productivity and changes in selected physical and chemical soil properties.

Materials and Methods

The study was initiated in October of 1990 at the NDSU Dickinson Research and Extension Center Ranch Headquarters near Manning, North Dakota. The study included 4 treatments and 3 replications in a randomized complete block design. Treatments included: (1) no manure; (2) 10 T/A applied in the first year of the study only; (3) 10 T/A applied in the first and second years of the study; and (4) 10 T/A applied in all three years of the study which ended with the growing season of 1993. In October of 1993, a second treatment cycle was initiated with the same treatments but with the manure rate being increased to 20 T/A per application (Table 1). This resulted in annualized average rates of 0, 5, 10 or 15 T/A rates of manure.

The soils at this site are classified as a complex of Cabba (loamy, mixed (calcareous), frigid, shallow Typic Ustorthents) and Chama (fine-silty, mixed Entic Haploborolls) soils formed from siltstone. These soils occupy a concave hilltop position with slopes of 1-6% with an

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easterly and southerly aspect. These soils have been severely eroded with long-term cultivation and an approximate 10 acre area directly to the west of this site was previously reseeded to grass due to the low productivity. Depth to siltstone is approximately 15 inches for the Cabba soils and 30 inches for the Chama soils.

Soils are being sampled to a depth of 4 feet, when possible, for available water and NO_3-N content each spring and fall. Fertility is also being measured on the surface 6 inches each spring and fall. Bulk soil samples are being collected with a flat bottomed shovel to a depth of 2 inches for water stable aggregate and aggregate distribution analysis.

Cultural practices include the standard production practices used in the surrounding field. Tillage included moldboard plowing during the first treatment cycle and no-till during the second treatment cycle. However, due to a buildup of manure on the soil surface under no-till culture, a light tillage with a field cultivator was used prior to seeding in 1996.

The second cycle of manure applications was concluded in 1996 and a third cycle of manure applications using a 20 T/A manure rate was initiated in the fall of 1996 to be continued through 1999. A fertilizer treatment based on an average of the soil test values of 3 plots was added in the spring of 1997.

Data on soil profile sampling depth, and long-term changes in soil organic matter and soil nitrate-N have been previously reported (Cihacek, 1996). This report presents long term data on changes in water stable aggregates, soil aggregate distribution and soil test nutrient status of the surface 0-6 inch soil zone through the end of the 1996 growing season.

Results and Discussion

Changes in soil physical condition (tilth) was first observed in the fall of 1996. Visual observations indicated that manure treated plots appeared to be well aggregated with lower bulk density than plots without manure applied.

Water Stable Aggregates

Water stable aggregate analysis for fall collected surface samples ($\leq$ 2 in. depth) are shown in Table 2. Significant increases in water stability of aggregates over the untreated control (Treatment 1) were observed for 1995 and 1996. Absolute differences in percent water stable aggregates appear to have increased between 1995 and 1996. Year to year differences within each treatment may be due to climatic differences from one year to the next.

Soil Aggregate Distribution

Geometric mean diameters (GMD) and mean weight diameters (MWD) for 1994 through 1996 as determined by sieving with a compact rotary sieve are shown in Table 3. Both GMD and MWD showed significant decreases due to manure application only in 1996.

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A decrease in either GMD or MWD indicates an increase in soil aggregation with the formation of smaller, more granular aggregates due to the manure treatments. Larger GMD or MWD indicates a more massive soil structure with less aggregation.

Soil Test Values

Table 4 shows the soil test value distribution in the surface 6 inches of soil by manure treatment. This is an examination of initial soil test values and natural variability that may impact soil productivity responses to manure treatments in 1990 at the initiation of the study. No significant differences were observed by assigned treatment for all nutrients except Zn. The Zn difference, though significant, is small and all Zn values are considered to be very low.

Soil test values after six years of manure applications are shown in Table 5. Significant increases due to the manure applications were observed for P, K, Zn, Fe and Mn. pH, Cu and EC were not affected by the manure applications.

Summary

Low rates of manure application (5-15 T/A/year) do not appreciably change soil quality in a given year but require repeated applications to influence soil chemical and physical characteristics. In this study, soil aggregation and aggregate resistance to erosion required long term applications of manure (six years) show a measurable change. Changes in soil chemical characteristics as determined by soil tests showed increases over the long term with the greatest changes occurring at higher manure application rates. Manure applications may also require time to become incorporated into the soil and decompose before they effect changes on soil quality. Research is still needed to determine the length of time that a particular change in soil quality is maintained after manure is no longer applied to the soil.

Table 1. Application Times and Rates of Manure Applications through 1996[1].

Treatment	**Manure Rate**	**Times of Application**	**Total Application**
	-------- T/A --------	month/year	-------- T/A --------
1	0	No manure applied	0

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2	10	10/90	50
	20	10/93, 10/96	
3	10	10/90, 10/91	80
	20	10/93, 10/94, 10/96	
4	10	10/90, 10/91, 10/92	110
	20	10/93, 10/94, 10/95, 10/96	

[1]1996 manure applications were applied after the 1996 growing season and data beyond the 1996 growing season is not presented in this report.

Table 2. Aggregate Stability in Water as Affected by Manure Application Treatment.

	Water Stable Aggregates[1]		
Treatment	**1994**	**1995**	**1996**
	%		
1	84.1a	87.9a	76.4a
2	82.2a	92.1b	81.5ab
3	80.6a	88.7ab	76.7a
4	84.6a	91.1ab	83.6b

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[1]Values followed by the same letter are not significantly different at P 0.05 as determined by LSD.

Table 3. Geometric Mean Diameter and Mean Weight Diameter of Soil Aggregates as Affected by Manure Treatment.						
	Geometric Mean Diameter[1]			**Mean Weight Diameter[1]**		
Treatment	**1994**	**1995**	**1996**	**1994**	**1995**	**1996**
1	1.58a	1.37a	1.53b	6.45a	7.04a	6.06b
2	1.65a	1.51a	1.43a	7.05a	8.77a	5.12a
3	1.61a	1.33a	1.40a	6.61a	7.24a	4.72a
4	1.56a	1.46a	1.42a	6.34a	8.21a	5.11a

[1]Values followed by the same letter are not significantly different at P 0.05 as determined by LSD.

Table 4. 1990 Soil Test Values Prior to Manure Application by Treatment.						
	Soil Test Values[1]					
Treatment	**pH**	**P**	**K**	**Zn**	**Fe**	**EC**
		mg/kg				mmhos/cm
1	7.9a	4.8a	156a	0.1a	3.7a	0.30a
2	7.9a	4.3a	150a	0.1a	3.7a	0.30a
3	8.0a	5.0a	173a	0.1a	3.7a	0.30a
4	8.0a	4.3a	153a	0.2b	4.0a	0.31a

[1]Values followed by the same letter are not significantly different at P 0.05 as determined by LSD.

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Table 5. 1996 Soil Test Values After Six Years of Manure Applications.								
	Soil Test Values[1]							
		mg/kg						mmhos/cm
Treatment	**pH**	**P**	**K**	**Zn**	**Fe**	**Mn**	**Cu**	**EC**
1	8.4a	4a	130a	0.2a	3.4a	5.2a	0.5a	0.35a
2	8.4a	9b	270b	0.4b	4.3a	5.7ab	0.6a	0.38a
3	8.4a	31c	410c	0.8c	6.7b	5.7ab	0.5a	0.35a
4	8.4a	63d	593d	1.4d	10.0c	7.0b	0.7a	0.32a

[1]Values followed by the same letter are not significantly different at P 0.05 as determined by LSD.

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References

Bremer, J.M., and D.R. Keeney . 1965. Steam distillation methods for determination of ammonium nitrate and nitrite. Anal. Chem. Acta 32:485-495

Bremer, J.M., and C.S. Mulvaney . 1982. Nitrogen-total. p.595-624. In A.L. Page et al.(ed.) Methods of Soil Analysis. Part 2 . 2nd ed. Agron. Monogr 9. ASA, Madison, WI.

Er-Raji, M. 1990. Soil erosion effect on hillslope productivity and its correction with straw or manure. M.S. Thesis, North Dakota State University.

Nelson, D.W., and L.E. Sommers . 1975. A rapid and accurate procedure for estimation of organic carbon in soil. Proc. Indiana Acad. Sci. 84:456-462.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean . 1954. Estimation of available phosphorus in soils by extraction with sodium

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bicarbonate. USDA Circ. 939. USDA, Washington, DC.

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