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REMEDIATION/RESTORATION OF DEGRADED SOIL TO IMPROVE PRODUCTIVITY IN THE CENTRAL GREAT PLAINS REGION

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ABSTRACT

The quality and productivity of some farmlands in the central Great Plains Region (CGPR) have been lost through wind and water erosion induced by tillage and poor soil management. Productivity of degraded/eroded soils can be restored using organic amendments such as manure and improved crop and soil management. Our objectives are to: **(i)** identify optimal rates of manure to supply nutrients to typical dryland crops in the CGPR; **(ii)** determine the rate of improvement of crop yield associated with dryland manure management of eroded soils; and **(iii)** quantify the advantage of restoring eroded soils using manure as an amendment versus managing those same soils with chemical fertilizer. The experiment is being conducted on two sites. The first site is on a farmer's field near Akron, Colorado and the second site is at the Agricultural Research Center in Hays, Kansas. Tillage practices include conventional tillage (CT) i.e. sweep tillage and no-tillage (NT). Two N-sources (manure, M; and commercial fertilizer, F) are used and applied at two rates. The experimental design is a randomized complete block with four replications. The preliminary data suggest that manure additions have a potential of increasing the productivity of eroded soils in both sites studied. In subsequent years it will be important to determine the improvement in different soil parameters and to document yield effects from different management practices. Several additional "benchmark" measurements (physical, chemical, and biological) are being made on the soils in these plots and measurements will be repeated periodically throughout the duration of the experiment.

INTRODUCTION

The quality and productivity of some farmlands in the CGPR have been lost through wind and water erosion induced by tillage and poor soil management. In addition to wind and water erosion, numerous studies have indicated that soil degradation is a result of soil organic matter lost through increased soil disturbance and decomposition (Angers et al., 1993; Lal et al., 1995). Productivity and quality of degraded/eroded soils can be restored using organic amendment and reduce tillage practices. Applying manure as the fertilizer source is a management practice that can improve the nutrient status of the soil (Vitosh et al., 1997) and increase soil organic carbon levels (Mikha and Rice, 2004). Mikha and Rice (2004) reported that the protection of soil labile carbon and nitrogen was significantly greater with manure amendment when compared with chemical fertilizer treatment.

Tillage practices can reduce soil organic matter, promote soil erosion (Blevins and Frye, 1993; Beare et al., 1994; Paustian et al., 1997), and affect soil physical condition Kladivko (2001). No-tillage systems increase surface soil organic matter as a result of increased residue accumulation, less soil disturbance, proliferation of root growth, and decreased risks of soil erosion (Eghball et al., 1994; Lal et al., 1994; Six et al., 1999). Many studies have shown that increased soil organic matter with no-tillage management (Beare et al., 1994; Six et al., 199 improves soil aggregation and aggregate protected soil organic matter (Mikha and Rice, 2004 Manure amendment can have a positive effect on reducing soil bulk density (Miller et al., 200 McVay et al., 2006) and improving soil porosity, preventing crust formation (Pagliai et a 2004), soil compaction, and improving plant productivity. Previous research showed that th negative effects of excessive tillage on grain yield and soil organic carbon conservation can b mitigate by organic amendment addition (Eghball and Power, 1999; Mando et al., 2005).

The impact of multiple years of beef manure application combined with different tillag systems on restoring soil productivity of eroded soil are not well documented for drylan cropping systems,. The objectives of this study are; (i) Identify optimal rates of beef manure to supply nitrogen to typical dryland crops in the CGPR; (ii) Determine the rate of improvement o crop yield associated with dryland manure management of eroded soils; and (iii) Quantify the advantages of restoring eroded soils using manure as an amendment versus managing those same soils with chemical fertilizer.

MATERIALS AND METHODS

The first experimental site is on a farmer's field near Akron, Colorado. The second experimental site is at Kansas State University Agricultural Research Center in Hays, Kansas. The experiments were established on eroded and low-production soil with two tillage treatments, conventional tillage (CT) defined as sweep tillage at 5 inch cm depth and no-tillage (NT). Two N sources (manure and commercial fertilizer) are applied at two rates, low and high (Table 1). The crop sequence is typical to the region where every year the crop in rotation will be chosen according to weather conditions of temperature and precipitation. The rotation currently being used in Colorado is corn (2006) – proso millet (2007) – forage winter triticale (2008) – winter wheat (2009). Plots at Akron are 45 feet wide and 50 feet long. The rotation currently being used in Kansas is grain sorghum (2006) – forage oat (2007) – winter wheat (2008). Plots at Hays are 21 feet wide and 45 feet long. The experimental design at both sites is a randomized complete block with four replicates.

Table 1. Nitrogen source addition relative to treatment.

Site	Frequency	Manure		Fertilizer	
		Low	High	Low	High
		lb N a^{-1}			
Akron, CO	Annual	30	86	30	60
Hays, KS	Annual	60	120	60	120

In Akron, Colorado, solid beef manure and commercial fertilizer (urea) were applied (Table 1) in September of 2008 before planting winter wheat. Winter wheat (variety "Hatcher") was seeded in October at 60 lb seed a^{-1} using a John Deere 750 drill with 7.5 inch row spacing. Grain was harvested in July of 2009 using a Wintersteiger plot combine. Grain yields were determined at the 12.5% moisture. Manure was applied using a Meyer spreader. This manure spreader was used at low RPM to obtain a uniform spread width of 8.9 feet. Calibration of the manure spreader was performed by driving the manure spreader over a tarp and then weighing the manure collected on the tarp. The rear gate was left open during application and rates were controlled by changing ground speed. Beef manure was obtained from a local feedlot. In Hays, Kansas, solid beef manure and commercial fertilizer (urea) were applied (Table 1) in September of 2007 and before planting winter wheat. Winter wheat (variety "Dandy") was seeded in October at 59 lb seed a^{-1} using a Sunflower 9711 drill with 7.5 inch row spacing. Grain was harvested in July of 2008 using a Massey MF8 plot combine. Grain yields were determined at the 12.5% moisture. Beef manure was obtained from the Hays experiment station. In both sites, samples of the manure were taken and analyzed for nutrients to determine the amount of nitrogen applied to the plots.

RESULTS AND DISCUSSION

At the Akron site, the winter wheat grain yield was significantly affected ($P \leq 0.05$) by tillage practices and by tillage interactions with N source (Table 2). The combination of NT and M significantly increased wheat yield compared with NT and F treatment. Plant biomass production was significantly affected by N source only (Table 2). These data suggested that the combination of NT and M could have a positive effect on productivity while the addition of M improved plant biomass production. The lack of significance among the treatments could be due to short experiment duration (four growing seasons) where the treatments need to be imposed for longer period of time to improve soil productivity in this eroded land.

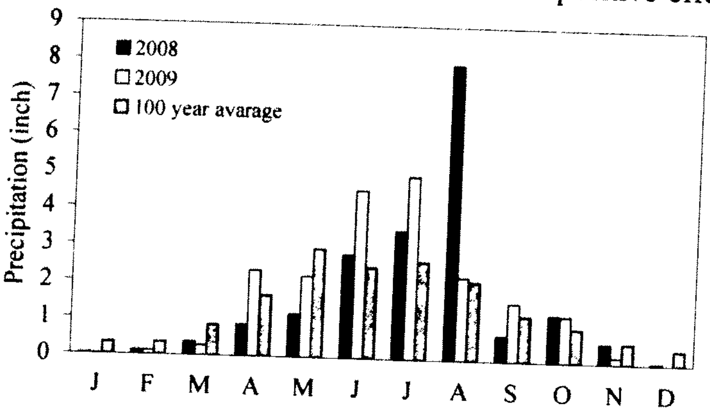

Figure 1. Akron, Colorado monthly precipitation for 2008, 2009, and 100 year average.

At the Hays site, winter wheat grain yield and biomass production (Table 3) were significantly affected ($P \leq 0.05$) by N source, N rate, and their interaction (N source * N rate). Tillage practices had no significant effect on grain yield and biomass production. The addition of manure significantly ($P \leq 0.05$) increased wheat yield and plant biomass compared with fertilizer treatment. No differences in wheat yield were observed between commercial fertilizer treatments (at both N rates) and control. It appears that the effect of treatments (tillage and N source) on crop yield and plant biomass production varies between locations (Akron *vs.* Hays). The effect of treatments is more pronounced at the Hays site compared with Akron site.

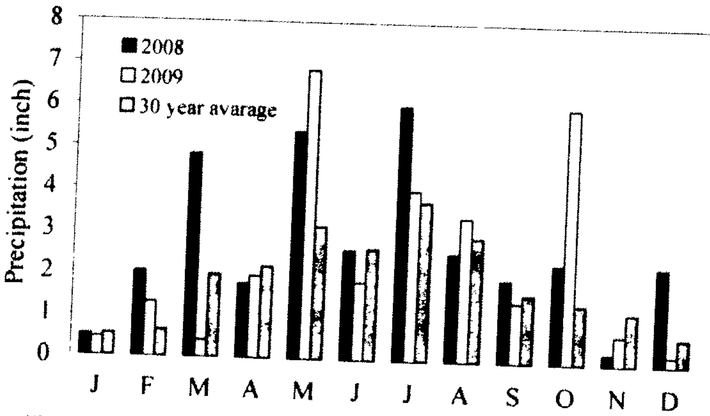

Figure 2. Hays, Kansas monthly precipitation for 2008, 2009, and 30 year average.

This could be due to the precipitation pattern (Figure 1 and Figure 2) and/or to the level on N addition that is corresponding to the precipitation in each site.

In summary, these data suggest that the addition of organic material such as manure could improve many aspects of soil quality and the productivity of eroded soils in the CGPR. In addition, the slow release of nutrients with the manure treatment could also have improved soil nutrient status compared with commercial fertilizer. No specific explanations can be given for treatment differences since we have had only four growing seasons, two of which we had a crop failure due to poor environmental conditions. In subsequent years it will be important to determine the improvement in different soil parameters and to document yield effects from different management practices. Several additional "benchmark" measurements (physical, chemical and biological) are being made on the soils in these plots and measurements will be repeated periodically throughout the duration of the experiment.

Table 2. The effect of tillage, nitrogen rate, and nitrogen source on wheat production of eroded soil in Akron, CO, 2009.

Tillage practice		Nitrogen Source	Nitrogen Rate	Grain Yield	Plant biomass
			- - lb a^{-1} - -	- - - - - bu a^{-1}	- - - - - -
No tillage		Manure	86	42	170
			30	48	131
		Fertilizer	60	34	95
			30	33	106
		Control[‡]	0	36	73
Sweep Tillage		Manure	86	39	167
			30	48	138
		Fertilizer	60	46	116
			30	45	100
		Control	0	42	89
Tillage				0.045[*]	NS[‡‡]
No tillage (mean)				38 b	115
Sweep tillage (mean)				44 a	122
Nitrogen Source				NS	0.0008[*]
Manure (mean)				44	151 a
Fertilizer (mean)				39	104 b
Control (mean)				39	82 c
Tillage * N Source				0.05[*]	NS
No tillage-manure	(mean)			45 a	150
No tillage-fertilizer	(mean)			33 b	100
No tillage-control	(mean)			36 ab	73
Sweep tillage-manure	(mean)			43 a	153
Sweep tillage-fertilizer	(mean)			45 a	108
Sweep tillage-control	(mean)			42 ab	89

‡‡ NS = No significant

* Significant at $P \leq 0.05$

The lowercase letter indicates significant differences within each group.

Table 3. The effect of tillage, nitrogen source, and nitrogen rate on wheat production of eroded soil in Hays, KS, 2008.

Tillage Treatment	N Source	N Rate	Wheat Yield	Wheat Biomass
		- - lb a^{-1} - -	- - - - - - - bu a^{-1}	- - - - - - - - - -
No tillage	Control[§]	0	24	51
	Manure	120	61	150 b
		60	48	106 c
	Fertilizer	120	24	49 d
		60	24	46 d
Tillage	Control	0	19	48
	Manure	120	61	167 a
		60	52	100 c
	Fertilizer	120	24	46 d
		67	22	48 d
Tillage			NS[†]	NS
No tillage (mean)			39	88
Conventional tillage (mean)			40	91
Nitrogen Source			0.0004[**]	0.002[**]
Fertilizer (mean)			24 b	48 b
Manure (mean)			55 a	131 a
Nitrogen Rate			0.007[**]	0.007[**]
High[‡] (mean)			43 a	104 a
Low[‡‡] (mean)			36 b	74 b
N Source * N Rate			0.03[**]	0.0001[**]
High Fertilizer (mean)			24 c	48 c
Low Fertilizer (mean)			24 c	46 c
High Manure (mean)			61 a	158 a
Low Manure (mean)			51 b	103 b
Tillage * N source * N Rate			NS	0.08[*]

[§] Control was not included with the statistic analysis.
[†] NS= Not significant
[**] Significant at P<0.05
[*] Significant at P<0.1
[‡] High rate (120 lb N a^{-1})
[‡‡] Low rate (60 lb N a^{-1})
The lowercase letter indicates significant differences within each group.

REFERENCES

Angers, D.A. A. N'Dayegamiye. and D. Cote. 1993. Tillage-induced differences in organic matter of particle-size fractions and microbial biomass. Soil Sci. Soc. Am. J. 57:512-516.

Beare, M.H., P.F. Hendrix, and D.C. Coleman. 1994. Water-stable aggregates and organic matter fractions in conventional and no-tillage soils. Soil Sci. Soc. Am. J. 58:777-786.

Blevins, R.L., and W.W. Frye. 1993. Conservation tillage: An ecological approach to soil management. p. 33-78. *In*: D.L. Sparks (ed.), *Adv. in Agro.*, v. 51. Bottner, P. 1985. Response of microbial biomass to alternate moist and dry conditions in a soil incubated with ^{14}C- and ^{15}N-labelled plant material. Soil Biol. Biochem. 17:329-337.

Eghball, B., N. L.N. Mielke, D.L. McCallister, and J.W. Doran. 1994. Distribution of organic carbon and nitrogen an a soil under various tillage and crop sequences. J. Soil Water Cons. 49:201-205.

Eghball, B., N. L.N. Mielke, D.L. McCallister, and J.W. Doran. 1994. Distribution of organic carbon and nitrogen an a soil under various tillage and crop sequences. J. Soil Water Cons. 49:201-205.

Kladivko, E.J. 2001. Tillage systems and soil ecology. Soil Till. Res. 61:61-76.

Lal, R., J. Kimble., and B.A. Stewart. 1995. World soil as a source or sink for radiatively-active gases. p. 1-8 *In*. R. Lal et al., J. Kimble, E. Levine, and B.A. Stewart (eds.), Soil management and greenhouse effect. Lewis Publ., Boca Raton, Fl.

Lal, R., A.A. Mahboubi, and N.R. Fausey. 1994. Long-term effect on Mollic Ochraqualf in northwestern Ohio. III. Soil nutrient profile. Soil Tillage Res. 15:371-382.

Mando, A., B. Ouattara, M.Sedogo, L. Stroosnijder, K. Ouattara, L. Brussaard, and B. Vanlauwe. 2005. Long-term effect of tillage and manure application on soil organic fractions and crop performance under Sudano-Sahelian conditions. Soil & Tillage Research 80:95-101.

McVay, K.A., J.A Budde, K. Fabrizzi, M.M. Mikha, C.W. Rice, A.J. Schlegel, D.E. Peterson, D.W. Sweeney, and C. Thompson. 2006. Management effects on soil physical properties in long-term tillage studies in Kansas. Soil Sci. Soc. Am. J. 70:434-438.

Mikha, M.M. and C.W. Rice. 2004. Tillage and manure effects on soil and aggregate-associated carbon and nitrogen. Soil Sci. Soc. Am. J. 68:809–816.

Miller, J. J., N. J. Sweetland, and C. Chang. 2002. Soil physical properties of a Chernozemic clay loam after 24 years of beef cattle manure application. Can. J. Soil Sci. 82: 287-296.

Pagliai, M., N. Vignozzi, and S. Pellegrini. 2004. Soil structure and the effect of management practices. Soil & Tillage Research 79:131-143.

Paustian, K., H.P. Collins., and E.A. Paul. 1997. Management controls on soil carbon. p.15-49. *In* Paul, E.A., K. Paustian, E.A. Elliott, and C.V. Cole (eds.). Soil organic matter in temperate agroecosystems: Long-term experiments in North America. CRC Press, Boca Raton, FL.

Six, J., E.T. Elliott, and K. Paustian. 1999. Aggregate and soil organic matter dynamic under conventional and no-tillage systems. Soil Sci. Soc. Am. J. 63:1350-1358.

Votish, M.L., R.E. Lucas., and G.H. Silva. 1997. Long-term effect of fertilizer and manure on corn yield, soil carbon, and other soil chemical properties in Michigan. p. 129-139. *In* Paul, E.A., K. Paustian, E.A. Elliott, C.V. Cole (eds.), Soil organic matter in temperate agroecosystems: Long-term experiments in North America, CRC Press, Boca Raton, FL.