The Effect of Nitrogen Source and Rate on Soil Fertility Parameters over an 18-Year Period

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Abstract

An ongoing cropping systems study was initiated in 1988 at the NDSU Carrington Research Extension Center to determine the effects of annual crop rotation, tillage, and nitrogen (N) level and source on crop yield. Published data from this study indicated no interaction between crop yield, N source or tillage. We analyzed 18 years of soil test data to determine effects of N source and tillage on soil fertility parameters. During the 18 years, N treatments were 0, 45 (1X) and 90 (2X) kg N ha^{-1} applied annually as ammonium nitrate and a once every four year application of composted beef feedlot manure (CBM) to supply 45 kg N ha^{-1} annually. Triple-super-phosphate was applied twice throughout the study to non-manured plots based on soil analysis. Tillage treatments were conventional (T), minimum (M), and no-till (NT). Fall soil samples were taken annually from each plot, sectioned into 0-15, 15-30, and 30-60 cm depths, and analyzed for nitrate-N, Olsen P, and soil organic matter (SOM). Soil test data were analyzed using SAS GLM procedures with significant differences expressed at the $P<0.05$ level. Significant interactions were observed between tillage and SOM level with NT>M>T indicating that tillage and SOM levels are inversely related. However, SOM levels in the 0-15 cm depth decreased in all treatments over time indicating a net soil carbon (C) loss. A significant interaction was also observed between N source and rate and SOM level with CBM=1X>2X. Nitrogen rate and source significantly affected nitrate-N test levels regardless of sampling depth with 2X>CBM=1X. Olsen P levels were also significantly different with CBM>1X>2X at the 0-15 cm depth. These results indicate that long-term N additions at these rates and cropping systems based on annual crops have a negative impact on SOM levels and C sequestration regardless of tillage or N source.

Introduction

Crop rotation, tillage practices and fertility management have a direct effect on soil quality and health. Soil organic matter (SOM) and fertility levels are measurable constituents of soil quality and health. Soil organic matter levels are also a measure of carbon sequestration in the soil. Soil testing is an accepted quantitative tool for managing soil fertility. Soil fertility levels can change fairly rapidly however, SOM levels respond more slowly to natural or anthropogenic activities.

To better understand the impacts of cropping system components on soil quality and soil fertility trends, long term research trials are needed. Because of this requirement, very little data is available to quantify the effect of cropping system components on long term soil fertility parameters in the Upper Great Plains. In response to this need, a cropping systems trial was initiated at the Carrington Research Extension Center, Carrington, ND in 1987 to investigate the effects of annual crop rotation, tillage and nitrogen (N) level and source on crop yield and soil fertility parameters.

Soil fertility data collected over an 18 year period from this trial was analyzed to determine the effects of tillage and N rate and source on soil nitrate-N, Olsen phosphorous (P) and SOM levels. Previously published data investigated the impact of these components on crop yield and showed no consistent significant impact.

Table 1. Abbreviations

1x	45 kg N ha^{-1}
2x	90 kg N ha^{-1}
CBM	Composted Beef Manure
N	No-Tillage
T	Conventional Tillage
M	Minimum Tillage

Materials and Methods

A long-term cropping systems study was initiated at the NDSU Carrington Research Extension Center in 1987 on a Heimdal (course-loamy, mixed Udic Haploborolls) soil." . The study consists of three, four-year, crop rotations with three replicates. Each crop in each rotation occurs annually. Within each crop (main plot) in a rotation, four fertility treatments are imposed (sub-plots) (Figure 1.). They are ammonium nitrate broadcast applied each spring to non-leguminous, non-fallow plots at 0, 45, (1x) or 90 (2x) kilograms of N per hectare or as composted beef feedlot manure (CBM) applied once in the spring at 180 kilograms per hectare of N the first year of each four-year rotation to all plots. CBM was applied in 1991, 1995, 1999, and 2003. These treatments are imposed perpendicular to the three tillage systems, resulting in twelve sub-sub-plots within each crop. The tillage systems are conventional (T), minimum tillage (M), and no till (N). Table 1 is a summary of abbreviations used (Table 1).

Fall soil samples were taken annually from each plot and sectioned into 0-15, 15-30 and 30-60 cm depths. The samples were analyzed for nitrate-N, Olsen P and SOM by AgVise Labs, Northwood, ND. Soil test data were analyzed using SAS GLM procedures with significant differences expressed at the $P<0.05$ level.

Results

According to Figure 2, no-till showed consistently higher SOM levels over time than conventional or minimum tillage. All three tillage systems showed a significant decrease in SOM over time (Figure 2).

According to Table 2, after 18 years, CBM use as a fertilizer source led to a significantly higher SOM level than synthetic N fertilizer or no fertilizer. However, Olsen P soil test levels were significantly higher for CBM when used as an N source (Table 2). Table 2 also shows that the 2x rate of N showed a significantly higher level of soil nitrate at all soil depths

Figure 3 shows that over time, no-tillage leads to significantly higher SOM levels than tillage systems regardless of N source. At the N rates applied in this study, SOM levels declined over an 18 year period regardless of N source or tillage system (Figure 3). The 1x N rate did not behave any differently than the 2x N rate when comparing SOM vs. tillage and N source over time (data not shown).

Both Figures 2 and 3 show that no-tillage led to a significant increase in SOM in the early years of the study but declined significantly in later years. Tillage led to a quicker decline in SOM than no-tillage regardless of N source (Figures 2 & 3).

Figure 1. Layout of the study

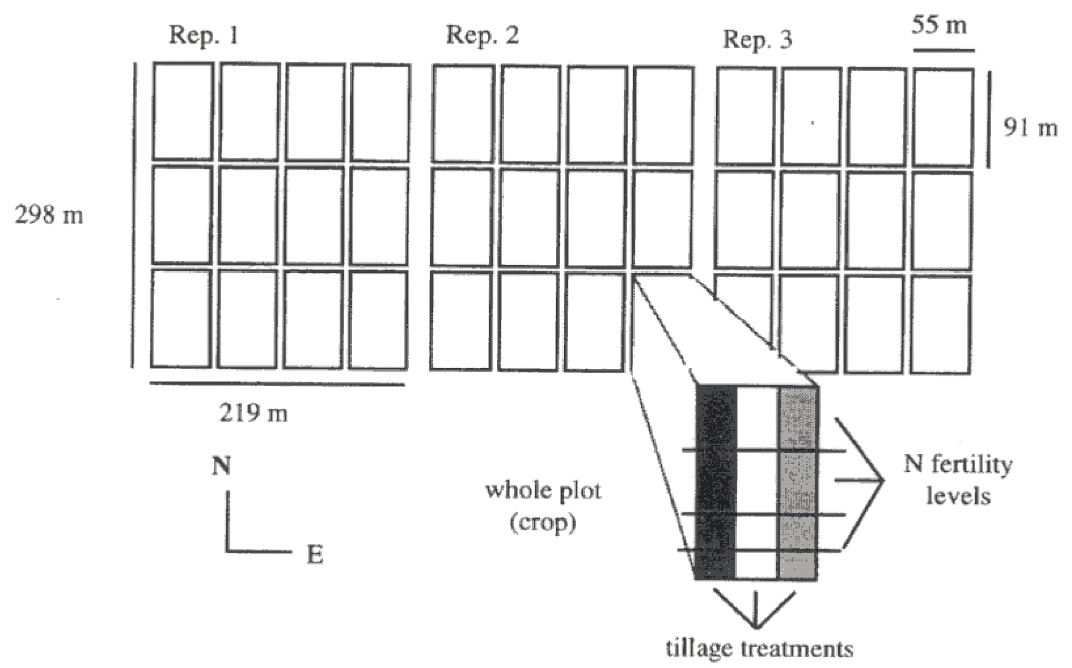


Figure 2. SOM 0-15 cm Over Time vs. Tillage

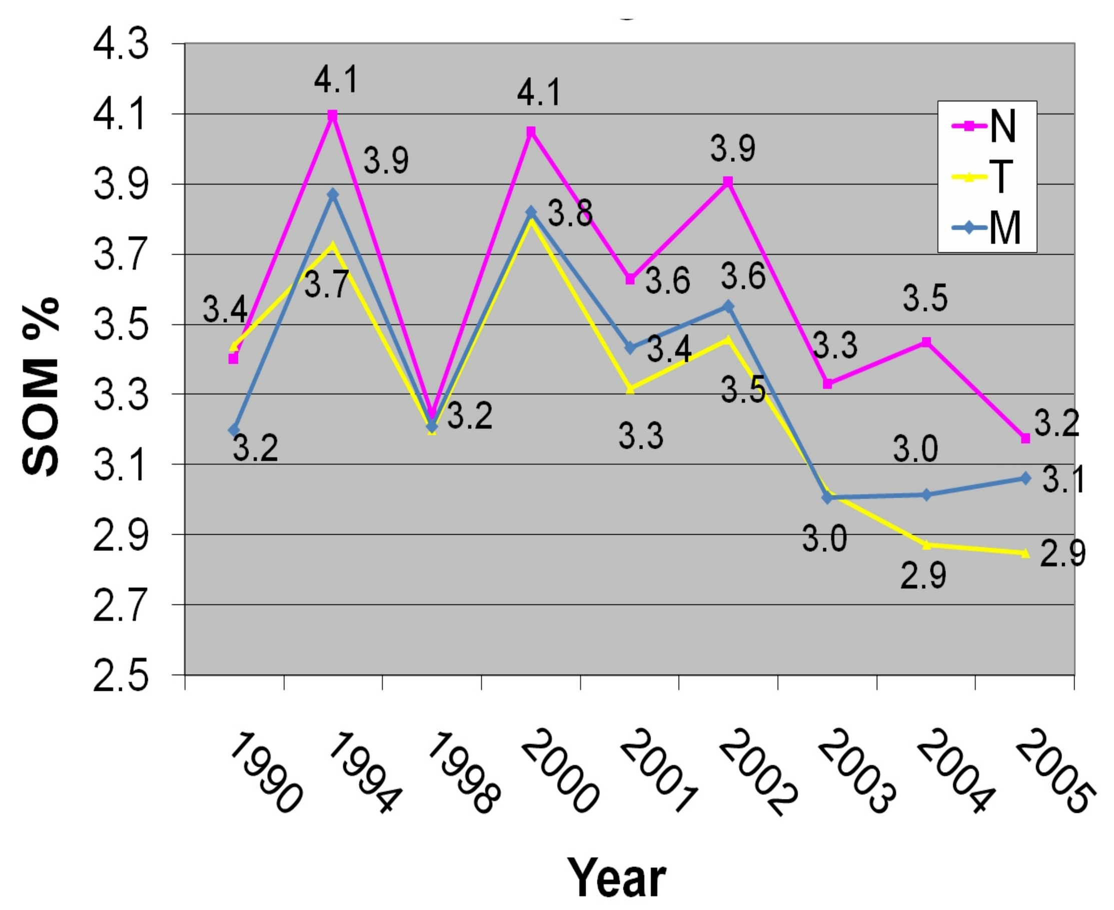
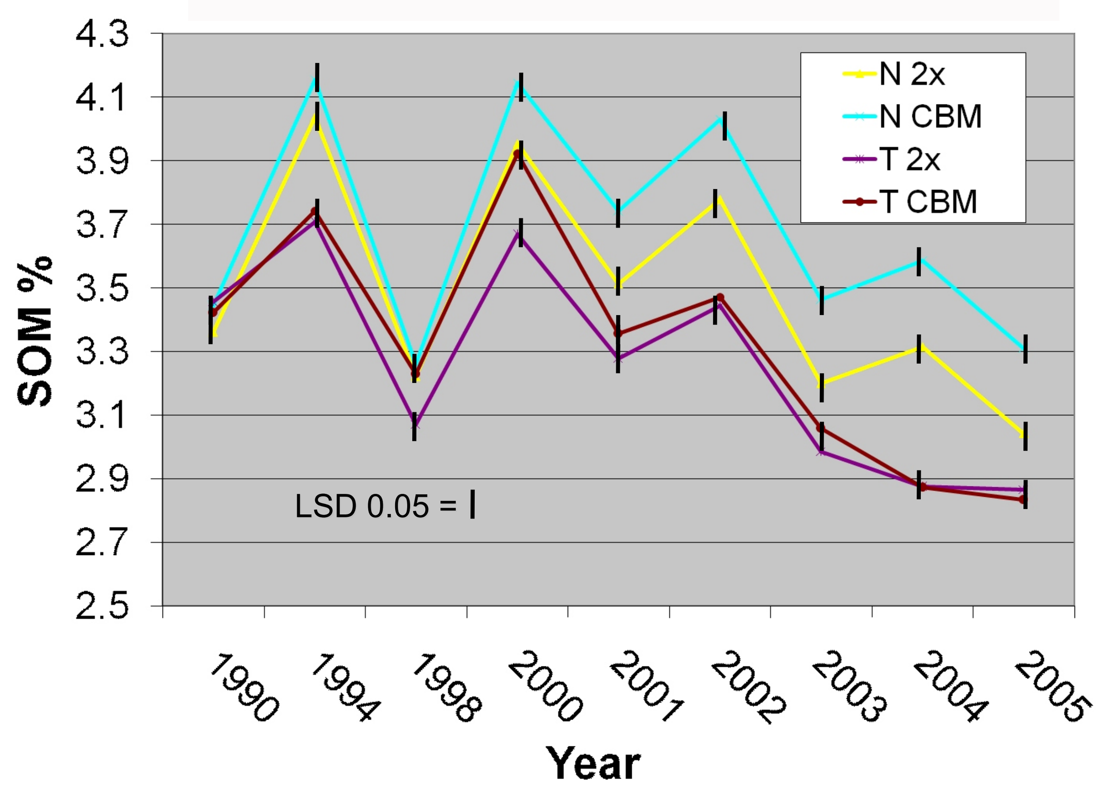


Table 2. Soil parameter response to N source and rate combined over 18 years

N rate	ppm N 0-15 cm	ppm N 15-30 cm	ppm N 30-60 cm	ppm N 0-60 cm	P (ppm)	SOM %
0	9.4	3.7	4.7	18.5	10.5	3.3
1x	12.2	5.2	7.3	26.7	10.1	3.4
2x	17.3	8.7	14.5	46.5	8.8	3.3
CBM	13.2	5.0	6.4	25.7	29.0	3.5
LSD 0.05	*1.0*	*0.6*	*0.8*	*2.0*	*0.8*	*0.1*

Figure 3. SOM 0-15 cm vs. Tillage and N Rate/Source Over Time



Discussion

If SOM is an indicator of C sequestration, this study shows the difficulty in maintaining or storing C in the soil whenever annual agronomic crops are grown regardless of N rate, source or tillage system. CBM was applied equal to the 1x N rate which was a deficient N rate for some crops in the rotations. If CBM was applied at the 2x rate to better meet N crop requirements, SOM or soil C levels may be maintained in annual cropping systems especially under no-tillage.

Conclusion

When synthetic N fertilizer or low rates of CBM are applied in annual cropping systems, C sequestration in soils is negatively impacted regardless of tillage system.

Figure 4. No-till Planting Wheat into Soybean Stubble That Followed Corn