Soil organic matter content and nutrient turnover in Thin Black Oxbow soils after intensive conservation management.

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Abstract

Cultivation and frequent fallowing has a significant impact on soil organic matter (SOM) concentration and soil bulk density. Conservation tillage systems, such as direct seeding, minimize mixing and disturbance of the surface soil which, in turn, is thought to improve SOM characteristics. This study was initiated to determine the extent to which four highly diverse management systems conserve SOM and influence potential nutrient supply. Conservation managements investigated in this study included a Brome grass seed-down and a direct seeded cereal-oilseed rotation. A third site was selected from an area managed under conventional fallow-wheat (with intermittent fertilizer) from 1930 to present. Uncultivated native prairie was also analyzed and used as a control. Concentrations of organic C, N and S were highest in the native sod, followed by brome grass, direct seeded and conventional fallow-wheat. Soil bulk density indicated a significant increase in the mass of soil in the 0 to 5 cm rooting layer with increased disturbance and soil mixing. The inverse trend between % SOM and bulk density resulted in management having no significant effect on the mass of organic nutrients in the top 5 cm of the rooting volume (CV 9.6%). More important to crop growth however, is the potential supply of mineral nutrients from SOM, which was significantly influenced by conservation management. Managements which improve residue input and reduce soil mixing, although not changing the actual mass of nutrients per rooting layer, enhance the turnover of organically held N and S in the 0 to 5 cm root zone.

INTRODUCTION:

Soil managements which deplete soil organic matter (SOM) have been extensively studied over the past 100 years. Frequent fallowing has been reported as most deleterious to soil quality, causing large losses in % organic carbon (C) and nitrogen (N) relative to uncultivated prairie (Shutt, 1923; Newton et al., 1945).

Concerns over interpreting losses of SOM C and N on the basis of % by weight have been raised (Tiessen, 1982; Ellert, 1991), prompting some to question the value of past estimates of SOM decline and soil degradation (Anderson, 1989). Calculation of SOM decline based on the mass of SOM per area to the depth of solum have been suggested as a more equitable method of assessing soil degradation. However, one must assume that the initial solum thickness was the same prior to imposing new managements. Such an assumption can limit the value of total SOM mass per area as a descriptor of soil degradation. A more functional approach to assessing soil quality is to determine the fraction of the total SOM which is easily mineralized (Janssen, 1984). Describing the SOM lability, along with the total content, will allow more valid comparisons among widely varying managements and soils.

Conservation tillage systems which maintain residue cover, minimize soil mixing and protect against soil erosion, will improve soil organic matter levels and quality (Carter and Rennie, 1982). Grass or hay periods are also useful in sustaining SOM and soil productivity (Greer, 1989). The objective of this study was to assess the soil biological properties commonly associated with soil quality on fields which have been under conservation and conventional managements.

MATERIALS AND METHODS:

Soil samples were collected in the fall of 1990 from four differently managed Oxbow loam soils near Indian Head, Sk. The fields varied widely in the degree of tillage, residue additions and fertilizer applications. Seventy years of summerfallow-spring wheat (FW) rotation returned the least residues and was most intensively tilled. The Brome grass field was previously managed under a FW system for 57 years, direct-seeded to a spring cereal-oilseed rotation for 6 years, and underseeded to grass for the last 7 years. Direct seeding of a spring cereal-oilseed rotation began on the Conservation tillage field following 50 years of FW cropping and 7 years of brome grass seed production. A control site was chosen from a nearby Native prairie area.

Ten soil cores were taken from each field and divided into 0 to 5 and 5 to 10 cm depths. Deeper layers were not sampled since surface deposition of residues has the largest effect on SOM and related properties (Carter, 1982). Bulk density was determined on each core. Further detailed analysis of SOM was made on four randomly selected cores from each treatment and depth. These samples were sieved field moist to 2 mm and subsampled for determination of mineralizable N and S using a 12 week leaching-incubation (Stanford and Smith, 1972). The remaining sample was air-dried and ground for determination of total N by peroxide-perchloric digestion. Total S was measured on air-dried, ground samples using a Fisher® Sulfur analyzer. Organic N and S was calculated as the difference between total and inorganic N and S ($CaCl_2$ extract).

Statistical analysis was performed in STATWORKS® as a completely randomized design. Replication of treatments was not performed within each field sampled. Hence randomly selected cores were used as replicates.

RESULTS AND DISCUSSION:

Concentration of organic N and S.

Soils from the FW rotation contained the lowest mass of organic N and S in the surface 5 cm layer (Table 1). Conservation tillage and Brome grass had significantly more organic N and S per kg of soil. However, uncultivated Native prairie concentrated almost twice as much organic N and S per kg of soil in the surface layer.

Mass of organic N and S per mass of soil was not significantly affected by treatment in the 5 to 10 cm depth. Less soil mixing in the Conservation tillage, Brome grass and Native fields resulted in significantly more organic N in the upper layer. Organic S followed a similar trend in distribution with depth. However, only the Native site contained significantly lower organic S in the 5 to 10 cm depth. Mixing of the 0 to 5 and 5 to 10 cm layers with tillage results in uniform concentrations of organic N and S in the more frequently tilled FW rotation (Unger, 1991).

Table 1. Field management effect on the concentration of organic N, organic S and soil bulk density in the surface depths of an Oxbow loam, Indian Head, Sk.

Treatment	depth (cm)	organic N ($mg \cdot kg^{-1}$)	organic S ($mg \cdot kg^{-1}$)	Bulk density ($Mg \cdot m^{-3}$)
FW rotation	0 to 5	2386	378	1.27
	5 to 10	2407	385	1.32
Conservation tillage	0 to 5	2904	394	0.99
	5 to 10	2387	403	1.20
Brome grass	0 to 5	3228	451	0.88
	5 to 10	2595	411	1.28
Native	0 to 5	4275	580	0.63
	5 to 10	2100	300	1.24
$LSD_{0.05}$	0 to 5	492	62	0.17
	5 to 10	ns	84	ns
	among depths	429	70	0.16

Bulk density was also significantly different among fields (Table 1). Frequently tilled FW rotation had the highest density in the surface layer, which was statistically similar to that found in the lower layer. Less soil mixing reduced density in the surface of the Conservation tillage, Brome grass and Native fields, respectively. Reducing tillage can reduce soil bulk density directly, by allowing lighter crop residues to remain on the surface forming a thatch layer, or indirectly through reduced degradation of naturally occurring structure (MacRae and Meyhus, 1985). Soil bulk densities of the 5 to 10 cm layer, although following a similar trend, were not statistically different among the four fields. This suggests that cropping systems impact bulk density through surface litter deposition and dilution of the bulk soil.

Dilution of surface SOM with tillage can cause a significant apparent reduction in the concentration of SOM. Tiessen (1982) suggested that mass of SOM per area to a given depth was a more equitable basis for comparing soil managements. Apparent dilution of SOM is accounted for when the mass of the organic material is compared on a per area basis.

Mass of organic N and S per rooting layer.

Mass of organic N in the 0 to 5 cm layer was not significantly affected by management (Table 2). Although Native prairie contained the highest mass of N per mass of soil (Table 1), there was the least mass of soil in an equivalent rooting volume because of the low bulk density. The product of these two variables result in a mass of SOM N that is not significantly different from that found in the 0 to 5 cm layer of other managements.

Similar trends in the mass of organic N per rooting layer were found the 5 to 10 cm depth. However, all cultivated soils contained significantly more organic N than the uncultivated Native prairie. It appears that past mixing of residues to depth is responsible for the increased organic N in levels in the 5 to 10 cm layer of the Conservation tillage and Brome grass fields.

Organic S followed a trend similar to that of organic N in both soil layers, although with increased statistical significance among fields. FW cropping resulted in the greatest mass of organic S in the surface layer, followed by Conservation tillage, Brome grass, and Native prairie.

Table 2. Field management effect on the mass of organic N and S per area in the surface depths of an Oxbow loam, Indian Head, Sk.

Treatment	depth (cm)	organic N ($g \cdot m^{-2}$)	organic S ($g \cdot m^{-2}$)
FW rotation	0 to 5	151	24
	5 to 10	159	25
Conservation tillage	0 to 5	144	20
	5 to 10	143	24
Brome grass	0 to 5	142	20
	5 to 10	166	26
Native	0 to 5	136	18
	5 to 10	130	19
LSD$_{0.05}$	0 to 5	ns	2
	5 to 10	26	5
	among depths	ns	4

Results obtained from analysis of the surface 10 cm layer indicate that the FW rotation contains the same mass of organic N and higher organic S than the other managements. It is possible that the mass of organic N and S per area, when measured over the entire depth of solum, is significantly less in the cultivated system. Nevertheless, the surface soil properties, especially the ability of the SOM to supply nutrients, have a large impact on crop growth. Hence from a soil productivity perspective, total mass of organic N and S per mass or volume may not adequately describing the impact of management. Nutrient supply from the SOM present in each layer is likely to be a more meaningful parameter when assessing the impact of management on soil productivity.

Mineralization of N and S.

The fraction of the total organic N and S mineralized was significantly affected by field management (Table 3). FW rotations, despite having a similar or slightly greater mass of organic N and S in the surface layer, had the lowest fraction of the total organic N and S mineralized during a 12 week incubation. Conservation tillage, which received fertilizer and minimum soil mixing, contained twice as much mineralizable N and two and one half times more mineralizable S. Significantly higher S mineralization in the Conservation tillage field is a direct result of canola residues added in the fall of 1990. Roppel (1991) reported that as much as 26 % of the S mineralized during a 77 day incubation was derived from canola residue.

Table 3. Field management effect on the fraction of the total organic N and S mineralized in the surface depths of an Oxbow loam, Indian Head, Sk.

Treatment	depth (cm)	mineralizable N (% of total)	mineralizable S (% of total)
FW rotation	0 to 5	3.0	1.7
	5 to 10	1.2	1.2
Conservation tillage	0 to 5	6.0	5.1
	5 to 10	1.7	1.4
Brome grass	0 to 5	7.7	3.9
	5 to 10	2.6	1.4
Native	0 to 5	7.9	3.8
	5 to 10	2.8	2.1
LSD0.05	0 to 5	1.2	1.0
	5 to 10	ns	ns
	among depths	0.7	1.3

Comparisons of no-till and shallow tillage systems reveal similar trends in mineralizable N fractions (Carter and Rennie, 1982). Higher proportions of readily mineralizable carbohydrates, amino acids and aliphatic compounds have also been found in soil conserving No-till cropping systems (Arshad et al., 1990). Such substrates are likely responsible for the enhanced turnover of N and S in the Conservation tillage field.

Brome grass and Native prairie had the largest fraction of mineralizable N (Table 3). As well, the fraction of total organic S mineralized was significantly larger than the FW rotation. Improved residue addition under Brome grass appears to rebuild the soils ability to supply N and S. Similar results have been found where long term cereal-hay rotations were compared to unfertilized FW on Indian Head heavy clay soils (Greer, 1989).

CONCLUSIONS:

Management had a significant influence on the concentration of organic N and S found in the 0 to 5 cm layer. Less mixing and dilution of the SOM caused highest concentrations in the Native, followed by the Brome grass and Conservation tillage. A significant decrease in soil bulk density associated with increased organic N concentrations resulted in the same mass of organic nutrients per area in the 0 to 5 cm layer. Mass of organic N was significantly lower in the 5 to 10 cm layer of the uncultivated Native prairie, suggesting that tillage and soil mixing is causing SOM accretion at depth. Mass of organic S per rooting layer was highest in the FW, followed by Conservation tillage and Brome grass and least in the Native. Such a ranking in total mass of organic nutrients per soil layer is intuitively inconsistent with reports of declining crop yield on unfertilized spring wheat rotations (Zentner et al., 1986). Therefore one must conclude the quantity of organic nutrients alone, may not be the best indicator of soil productivity. Organic matter quality, indicated by the ability to mineralize organically held nutrients, is more useful in ranking soil quality.

Mineralizable fraction of the total organic N and S was least in the FW rotation. Conservation tillage improve the mineralizable fraction through fertilization and residue addition. Brome grass improved the mineralizable fraction of organic N and S to a level equal to the Native prairie. Such results suggest that a grass period can quickly rebuild the mineralizable fraction of degraded FW rotations.

REFERENCES:

Anderson, D.W. 1989. Soil degradation in Saskatchewan, a pedological perspective. Proc. Soils and Crops Workshop. Saskatoon, SK. pp. 11-26.

Arshad, M.A., M. Schnitzer, D.A. Angers, and J.A. Ripmeester. 1990. Effects of till vs no-till on the quality of soil organic matter. Soil Bio. Biochem. 22: 595-599.

Carter, M.R. 1982. Nitrogen cycling in zero tillage farming systems. Ph. D. Thesis, Univ. of Sk., Saskatoon, Sk.

Carter, M.R. and D.A. Rennie. 1982. Changes in soil quality under zero tillage farming systems: Distribution of microbial biomass and mineralizable C and N potentials. Can. J. Soil Sci. 62: 587-597.

Ellert, B.H. 1991. Kinetics of nitrogen and sulfur cycling in gray Luvisol soils. Ph. D. Thesis, Univ. of Sk., Saskatoon, Sk.

Greer, K.J. 1989. Evaluating the soil quality of longterm crop rotations at Indian Head. M.Sc. Thesis, Univ. of Sk., Saskatoon, Sk.

Janssen, B.H. 1984. A simple method for calculating decomposition and accumulation of 'young' soil organic matter. Plant Soil. 76: 297-304.

MacRae, R.J. and G.R. Mehuys. 1985. The effect of green manuring on the physical properties of temperate-area soils. *in* B.A. Stewart (ed.) Advances in Soil Science, Vol. 3. Springer-Verlag, New York. pp. 71-90.

Newton, J.D., F.A. Wyatt, and A.L. Brown. 1945. Effects of cultivation and cropping on the chemical composition of some western Canada prairie province soils. Part III. Sci. Agric. 25: 718-738.

Roppel, C.J. 1991. Plant available nitrogen and sulfur from canola residue. M.Sc. Thesis, Univ. of Sk., Saskatoon, Sk.

Shutt, F.T. 1923. Western prairie soils: Their nature and compostion. Dominion of Can. Dept. of Agric. Bull. 22, Ottawa.

Stanford, G. and S.J. Smith. 1972. Nitrogen mineralization potentials of soils. Soil Sci. Soc. Am. Proc. 36: 465-472.

Tiessen, H. 1982. Changes in soil organic matter and phosphorus during cultivation of grassland soils. Ph. D. Thesis, Univ. of Sk., Saskatoon, Sk.

Tiessen, H., J.W.B. Stewart, and J.R. Bettany. 1982. Cultivation effects on the amounts and concentration of carbon, nitrogen and phosphorus in grassland soils. Agron. J. 74: 831-835.

Unger, P.W. 1991. Organic matter, nutrient and pH distribution on no- and conventional-tillage semiarid soils. Agron. J. 83: 186-189.

Zentner, R.P., E.D. Spratt, H. Reisdorf, and C.A. Campbell. 1987. Effect of crop rotation and N and P fertilizer on yields of spring wheat grown on a Black Chernozemic clay. Can. J. Soil Sci. 67: 965-982.