Impacts of Crop Sequence and Tillage Management on Soil Carbon Stocks in South-Central North Dakota

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Increased emphasis has been placed on developing Great Plains agroecosystems that are robust enough to resist or recover from external stressors, yet adaptable so as to be productive, profitable and environmentally benign under fluctuating economic and climatic trends. This has been a response in part to the recognition and appreciation that traditional management practices have contributed to the biological chemical and physical degradation of soil that limit agronomic productivity and enhance erosion

After 18 years of a study to evaluate effects of crop sequence and tillage, we measured soil properties at various depths to 91.4 cm (3 ft) and estimated soil carbon. We hypothesized that accrual of soil organic carbon (SOC) would be favored by no-till compared to minimum tillage and by continuous cropping sequences compared to cropping sequences with a fallow phase. The experiment, near Mandan, ND, was a split-plot design, with crop sequence as whole plots and tillage (minimum tillage or no-till) as subplots. Crop sequences included continuous spring wheat with crop residue retained or removed, spring wheat–millet, spring wheat–safflower–fallow, spring wheat–safflower–rye, and spring wheat–fallow. We estimated soil carbon using two approaches, by fixed depth and by equivalent soil mass.

Soil organic carbon, calculated by the equivalent mass method (SOC_{em}), was consistently higher (P<0.001) than when calculated by the fixed depth method (Table 1). Disparities between the two methods, greatest near the soil surface, were attributable to tillage. Estimates of SOC_{em} were not affected by cropping sequence at any depth, averaging about 26, 47, 73, 114, and 156 Mg ha^{-1} in the 0-7.6, 0-15.2, 0-30.5, 0-61.0, and 0-91.4 cm partitions. Tillage had no influence at depths <30.5 cm but no-till plots contained more SOC_{em} than minimum tillage plots in the 0-61 cm (115 vs 112 Mg ha^{-1}) and 0-91.4 cm (158 vs 153 ±2.3 Mg ha^{-1}) partitions (P<0.05). Soil organic carbon in the 0-7.6 cm depth increased by an average 3.2 Mg ha^{-1} or 16% since 2001.

Results from this study suggest estimates of SOC, determined with the equivalent mass method, are likely to be similar to those calculated by the fixed depth method in soil under reduced tillage, at depth, or for increasing layer thickness. The absence of treatment differences in SOC after 18 years was somewhat unexpected. Although differences among the cropping sequences or between minimum and no-till might become more apparent with time, the current data provided only limited support for our hypothesis that accrual of SOC would be favored by no-till compared to minimum tillage, and did not support our hypothesis of higher SOC accrual with continuous cropping sequences compared to cropping sequences with a fallow phase. Carbon sequestration in soil appears less impacted by the choice of crop sequence than other management choices like tillage

Halvorson, J.J., Liebig, M.A., Archer, D.W., West, M.S., Tanaka, D.L. 2016. Impacts of crop sequence and tillage management on soil carbon stocks in south-central North Dakota, USA. Soil Science Society of America Journal. doi:10.2136/sssaj2015.09.0331.

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Table 1 Stocks of soil organic carbon and total nitrogen under different crop sequences†, adjusted to an equivalent mass of soil (SOC_{em}, TNem) ‡, compared to estimates based on a fixed depth basis (SOCv, TNv).

Depth (cm)	SOC_{em} (Mg ha^{-1})							SOC_v (Mg ha^{-1})							
	SW-F	SW-S-F	SW-S-R	SW-M	CSW-	CSW+	Average	SW-F	SW-S-F	SW-S-R	SW-M	CSW-	CSW+	Average	Δ%§
0-7.6	24.3	24.3	26.0	26.7	27.2	27.0	25.6	22.1	22.1	23.1	24.0	24.1	23.9	23.0	11.5
0-15.2	46.6	45.5	47.2	47.7	48.7	47.9	46.9	44.2	43.2	44.1	45.2	45.3	44.8	44.2	6.2
0-30.5	74.8	71.6	72.3	72.9	72.9	74.2	72.8	72.3	69.0	69.4	70.2	70.0	71.3	70.1	3.8
0-61	113.2	113.4	111.4	115.3	116.0	115.8	113.6	109.2	109.5	106.5	110.4	110.4	111.2	109.1	4.1
0-91.4	159.9	153.7	155.8	153.5	159.5	155.5	155.9	153.8	149.2	148.4	147.3	152.1	149.9	149.8	4.0
	TN_{em} (Mg ha^{-1})							TN_v (Mg ha^{-1})							
0-7.6	2.19	2.19	2.34	2.39	2.37	2.41	2.29	1.99	1.99	2.07	2.16	2.10	2.14	2.06	11.5
0-15.2	4.19	4.13	4.28	4.35	4.27	4.37	4.25	3.98	3.92	3.99	4.12	3.96	4.08	4.00	6.2
0-30.5	6.98	6.79	6.83	6.60	6.55	6.94	6.79	6.73	6.52	6.54	6.37	6.28	6.67	6.53	3.8
0-61	10.78	10.55	10.45	9.91	9.90	10.36	10.38	10.39	10.19	10.00	9.52	9.42	9.97	9.98	4.1
0-91.4	13.22	12.90	12.78	11.93	11.66	12.46	12.62	12.88	12.61	12.36	11.57	11.31	12.14	12.27	4.0

† Crop sequences include spring wheat–fallow (SW–F), spring wheat–safflower–fallow (SW–S–F), spring wheat–safflower–rye (SW–S–R), spring wheat–millet (SW–M) continuous spring wheat with crop residue removed (CSW−), and continuous spring wheat with crop residue left on the soil surface (CSW+).

‡ Estimated using the approach of Ellert and Bethany (1995) assuming an equivalent baseline soil mass of 1163, 2318, 4459, 9108 and 13937 Mg ha-1, for the 0-7.6, 0-15.2, 0-30.5, 0-61.0, and 0-91.4 cm depths, based on the heaviest plot value. For a given partition, data for each plot was adjusted by including additional amounts from a thickness of the adjacent subsurface layer required to attain the equivalent soil mass.

§ $\Delta\% = 100 \times (SOC_{em} - SOC_v) / SOC_v$. Values for nitrogen are identical to those for carbon because they are based on the same adjustments for equivalent mass.