Conservation management effects on soil organic matter

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Soil carbon (C) sequestration is a major agriculturally based strategy for mitigating rising atmospheric concentrations of greenhouse gases. Soil organic carbon (SOC) levels are dynamic, depending on C additions and losses. Carbon is added from unharvested plant residues and roots, organic amendments, and erosional deposits. Carbon is lost through decomposition of organic materials and C transport via soil erosion. Conversion of native lands to agricultural production results in a 20 to 60% loss of SOC within 40 to 50 years.

IMPACT

Adequate soil organic carbon (SOC) levels are critical for agricultural productivity and contribute to carbon sequestration that can mitigate rising concentrations of greenhouse gases. Conversion of native lands to agricultural production results in a 20 to 60% loss of SOC within 40 to 50 years, but practices such as reduced tillage can partially restore these levels.

SOC levels vary widely across the REACCH region and within fields. The REACCH project is assessing this variability and the feasibility of using recently developed methods to quantify nutrient supplies and other soil health issues related to soil organic matter.

Agricultural practices that can partially restore depleted SOC include: (1) adoption of conservation tillage; (2) intensification of cropping by eliminating fallow, increasing cover crops, and including more perennial vegetation; and (3) improving biomass production through the use of soil amendments (manures), fertilizers, and high-yielding crop varieties. Rates of soil C sequestration following a change from conventional tillage (CT) to no-tillage (NT) are predicted to peak within 5 to 10 years, with SOC reaching a new steady-state 20 to 100 years following the management change or until soil storage capacity is reached. The SOC sequestration potential, rate of SOC accumulation, and time required to obtain maximum SOC are region- and site-specific.

Figure 1. Active soil organic matter, roots, and other soil biological constituents help bind soil particles together to form stable aggregates known as "peds."

Native SOC in the Palouse region of eastern Washington and northern Idaho varied considerably within a given landscape, ranging from about 2% on summit positions to almost 4.5% on north-facing foot slopes. Dryland agriculture has had a tremendous influence on native SOC, primarily due to shifts from perennial bunch grass-dominated vegetation to annual cropping, coupled with inversion tillage that has resulted in historical soil erosion rates of over 25 Mg soil yr-1. Previous research has estimated that 50 to 70% of SOC had been lost from upland soils.

The large variability in reported soil C sequestration rates and overall storage is a consequence of multiple factors, including: (1) initial levels of SOC and degree of system SOC saturation; (2) soil properties, such as texture and aggregation (Figure 1); (3) soil erosion; (4) artificial drainage; (5) soil disturbance and crop rotation; and (6) productivity and time. Field SOC heterogeneity occurs as a function of complex interactions of biological and physical processes (e.g., C inputs from crop residues and roots; soil organic matter (SOM) decomposition; and soil erosion processes). Greater understanding of field-scale variations in SOC and the processes and factors contributing to SOC dynamics is key to quantifying SOC sequestration, developing more sophisticated SOC models, and promoting improved land use and management decisions.

Recognizing that management impacts on SOC are primarily on the active, readily decomposable portions of total SOC, interest has grown among scientists and farmers regarding how this rapidly cycling SOC can be measured (Figure 2). While total SOM or SOC are standard soil tests, these tests are not always representative of the active soil C fraction that contributes to nutrient cycling, soil structural stability, and overall soil health. Consequently, scientists have been exploring measures that assess this more active pool of SOM to determine how management factors impact SOM dynamics. While a number of testing methods look promising, interpretation, sensitivity, speed, reliability, cost, and other factors must be assessed to identify measurements that are most useful. One goal of REACCH is to assess different SOC tests that aid quantification of nutrient supplies and other soil health issues related to SOM.

Overall objectives under REACCH regarding SOC are to: (1) continue to quantify agricultural impacts on SOC sequestration for dryland cropping systems in different agroecological zones (AEZs) of the Pacific Northwest; (2) characterize site-specific changes in SOC (0 to 1.53 m) due to management practices within fields typical of the region; and (3) assess chemical, physical, and biological methods of measuring active SOC pools.

In previous work, Brown and Huggins summarized management impacts on SOC storage across the dryland AEZs and associated farming systems from the known Pacific Northwest literature. They reported SOC changes under different soil management scenarios: native conversion, adoption of NT, and use

Table 1. *Summary of profile changes in soil organic carbon (SOC) calculated from the mean and cumulative probability function for native conversion, adoption of no-till (NT), and use of a mixed perennial-annual rotation.*

Management	AEZ[1]	Number of studies	Period covered by data (Mean years)	Mean SOC change[2,4]	Cumulative probability estimate of SOC change[3,4]		
				------------------ Mg C ha^{-1} yr^{-1} -----------------			
					25th	50th	75th
Native conversion							
	2	7	74	-0.84 (±0.17)	-0.70	-0.82	-0.92
	3	4	55	-0.53 (±0.18)	-0.35	-0.48	-0.58
	5	3	7	-0.69 (±0.52)	-0.14	-0.47	-0.80
No tillage							
	2	12	14	0.71 (±0.63)	0.21	0.64	1.04
	3	5	10	0.21 (±0.10)	0.12	0.19	0.25
Mixed perennial-annual							
	2	8	12	1.03 (±0.41)	0.69	0.94	1.12

[1] AEZ = Agroecological zone, where 2 = annual cropping, 3 = crop/fallow transition, and 5 = grain/fallow.
[2] Values in parentheses indicate plus or minus 1 standard deviation from the mean value.
[3] The 25th, 50th, and 75th percentiles of the cumulative probability function.
[4] To convert rate of SOC change from Mg C ha^{-1} yr^{-1} to the carbon trading units of metric tonnes of CO_2 equivalents per acre per year (MT CO_2e ac^{-1} yr^{-1}), multiply Mg C ha^{-1} yr^{-1} by 1.48277.

of a mixed perennial-annual rotation (Table 1). These analyses showed that 75% of converted native land lost at least 0.14 to 0.70 Mg C ha^{-1} yr^{-1} over an average of 55 to 74 years depending on AEZ. Converting from CT to NT was predicted to increase SOC at least 0.12 to 0.21 Mg C ha^{-1} yr^{-1} over 10 to 12 years in 75% of studies analyzed and was also AEZ specific. Compared to annual cropping, mixed perennial-annual systems would be expected to gain at least 0.69 Mg C ha^{-1} yr^{-1} over 12 years in 75% of AEZ 2 (annual cropping) sites. Regional assessments of active SOM pools in long-term REACCH study areas in each of three dryland AEZs as well as an irrigated site were initiated in 2013.

In addition to variability across the region, SOC and SOC responses to management can vary considerably within fields. Soil (0 to 1.5-m depth) at the Washington State University Cook Agronomy Farm (37 ha) was sampled and analyzed for SOC from a systematic, non-aligned grid of 177 geo-referenced locations in 1998 and again in 2008 after a 10-year conversion from CT to NT. Profile (0 to 153-cm) SOC from the 1998 sampling ranged from 54 to 272 Mg C ha-1 over the 37-ha field, and landscape SOC redistribution via soil erosion was evident (Table 2). Redistribution of SOC via erosion increases field SOC heterogeneity and must be quantified if SOC sequestration and management impacts are to be adequately assessed. Completion of analyses for the 2008 sampling will likely show that changes in SOC are greatly influenced by landscape and soil characteristics.

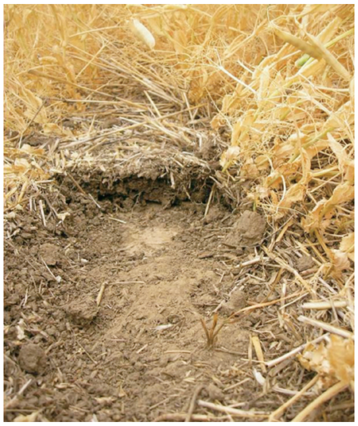

Figure 2. *No-till management positively impacts active soil carbon levels at the surface, thereby improving soil health. Photo by Fred McClellan.*

Table 2. *Soil series, taxonomic classification, field area, and soil organic carbon (SOC) on the 37-hectare Washington State University Cook Agronomy farm.*

Soil series (Field survey)	Taxonomic classification	Field area (%)	SOC (0–30 cm)[1] (Mg ha^{-1})	SOC (30–153 cm)[1] (Mg ha^{-1})	SOC (0–153 cm)[1] (Mg ha^{-1})
Staley	Fine-silty, mixed, superactive, mesic Calcic Haploxerolls	9	49a (20)	48a (38)	97a (25)
Naff	Fine-silty, mixed, superactive, mesic Typic Argixerolls	16	54ab (19)	69bc (35)	122bc (26)
Palouse	Fine-silty, mixed, superactive, mesic Pachic Ultic Haploxerolls	42	55b (17)	77cd (38)	132c (26)
Thatuna	Fine-silty, mixed, superactive, mesic Oxyaquic Argixerolls	25	59c (17)	84d (39)	143d (27)
Latah	Fine, mixed, superactive, mesic Xeric Argialbolls	7	59bc (21)	80bcd (39)	139bcd (27)
Caldwell	Fine-silty, mixed, superactive, mesic Cumulic Haploxerolls	1	59ns (1)	103ns (2)	163ns (1)
ALL		100	56 (18)	75 (40)	131 (28)

[1] Mean separation ($p \leq 0.1$) using Tukey; coefficient of variation (CV) in parentheses.