ARS Scientists Eye Management Impacts on Soil Inorganic Carbon

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After 18 years of a long term study, conducted at the USDA-ARS Northern Great Plains Research Lab near Mandan, ARS scientists observed a general trend of increasing soil C, but did not detect significant differences among the various crop sequences. They concluded that various cropping strategies could increase soil organic matter (Halvorson et al., 2016). In addition to organic forms of soil C, the scientists also noted significant amounts of inorganic-C present at depth together with a trend of increasing pH (Fig. 1). Because the pH scale is logarithmic, the pattern they observed in the research plots showed the soil was 1000 times more acidic near the surface than at 4 feet of depth. Not only was the change of pH large, but it also traversed across a critical range; from acidic conditions (< pH 7) near the surface to alkaline conditions with depth. Associated with this pattern was a clearly apparent change in the distribution of organic and inorganic forms of C in the soil.

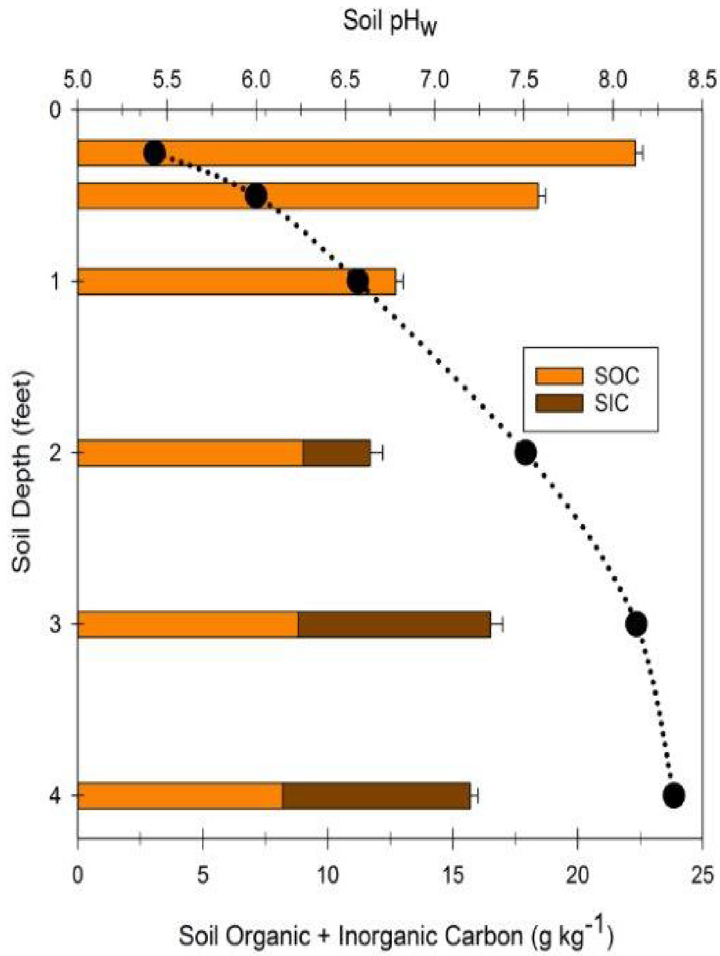

Figure 1. Average concentrations of soil organic (SOC) and inorganic (SIC) carbon as a function of depth and soil pH.

Organic-C in soil originates from plant inputs while inorganic-C results from weathering of the soil parent material or from reactions of soil minerals with atmospheric CO_2. On research plots, total soil C in the top 4 feet averaged about 69% organic C and 31% inorganic-C (carbonates). However, organic soil C was the dominant form near the soil surface, where the pH was relatively low, accounting for 100 and 81% of the total soil carbon at the 0-1 and 1-2 foot depths, respectively. However, at depths below about 2 feet, where pH was higher, both organic and inorganic forms of C were present in about equal proportions. When added to organic-C, the inorganic-C increased estimates of total standing stocks of soil C from 114, 156, and 196 Mg ha^{-1} to 126, 209, and 286 Mg ha^{-1}, in the surface 2, 3, and 4 feet respectively. Importantly, the lowest amounts of total C were found to occur at about 2 feet depth suggesting a management critical zone where inputs of organic-C were relatively small and losses of inorganic-C were relatively large.

The impact of different management strategies on pH and organic and inorganic-C in soil requires further study because total soil C may be more responsive to different crop sequences than organic-C alone (Fig. 2). Management of organic-C in soil is tied to the balance between inputs from crop plants or manure and losses due to soil microbial activity. Management of inorganic-C is linked to soil pH and emphasizes retention of existing pools because the rate of its formation is relatively slow compared to the rate of potential losses. Dissolution of inorganic-C occurs at a soil pH of less than about 7, but may not occur as a gradual response to decreasing pH. Instead, there may be a critical threshold of pH below which dissolution occurs rapidly. In North Dakota this critical pH may vary with depth and soil characteristics, and vary with location.

A growing appreciation of the implications of changing patterns of soil pH with depth, together with its

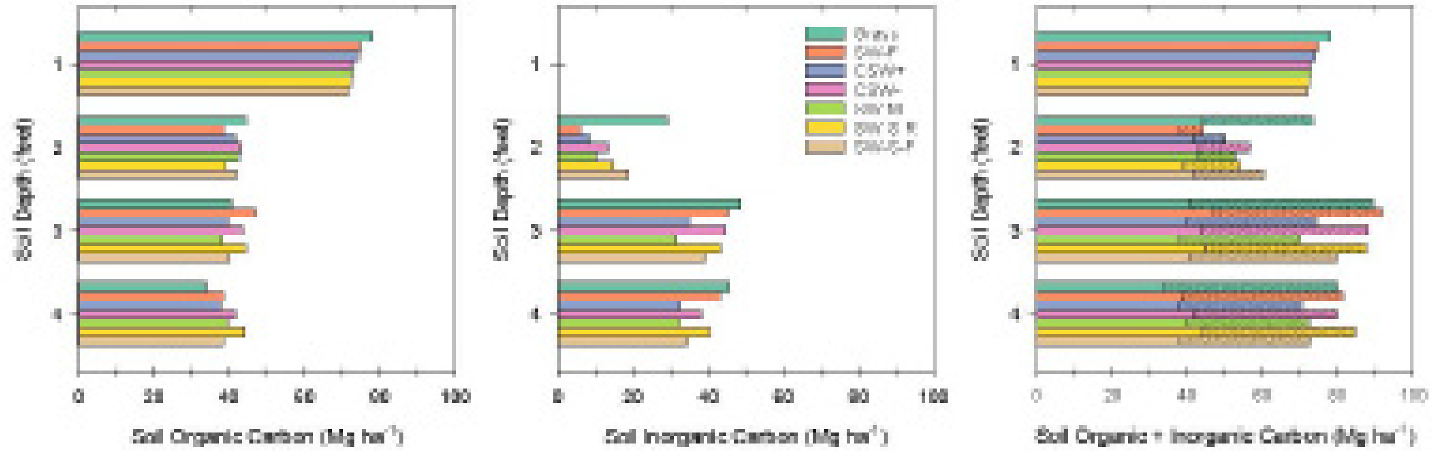

Figure 2. Distribution of organic, inorganic, and total soil C as a function of depth. Treatment averages are presented on an equivalent mass basis for grass (Grass, n=3), spring wheat–fallow (SW–F, n=12), continuous spring wheat with crop residue left on the soil surface (CSW+, n=6), continuous spring wheat with crop residue removed (CSW−, n=6), spring wheat–millet (SW–M, n=12), spring wheat–safflower–rye (SW–S–R, n=18), and spring wheat–safflower–fallow (SW–S–F, n=18).

link to management practices, has led to new research questions for NGPRL scientists, (Reeves and Liebig, 2016). These require studies to detect subtle changes in patterns of soil pH and their effects on soil functions particularly fertility and C sequestration. Such basic information, in turn, must be linked to knowledge of those management practices that affect soil pH in both the short and long term. In addition, the consequences and possible mitigation of the less manageable drivers of pH change such as the projected patterns of increased temperature and moisture need to be considered. Another important property, related to pH and affected by soil C, is buffering capacity, a measure of soil ecosystem resilience. Little is currently known about how buffering capacity in managed soils has changed historically or in response to agricultural management.

Halvorson, J. J., M. A. Liebig, D. W. Archer, M. S. West, and D. L. Tanaka. 2016. Impacts of crop sequence and tillage management on soil carbon stocks in South-Central North Dakota. Soil Science Society of America Journal 80: 1003-1010.

Reeves, J. L., and M. A. Liebig. 2016. Depth Matters: Soil pH and dilution effects in the northern Great Plains. Soil Science Society of America Journal 80: 1424-1427.

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