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Great Plains Soils May be C Sinks

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By David E. Clay, Gregg C. Carlson, Sharon A. Clay, James Stone, Kurtis D. Reitsma, and Ronald H. Gelderman

Numerous studies with wide-ranging results have been conducted to resolve if Great Plains soils are a C source or sink. The authors addressed the source/sink question by examining the results from producer soil samples and production surveys that were analyzed and archived by the South Dakota Soil Testing Laboratory. Results showed that between 1985 and 2010, soil organic C content increased at a rate of 326 lb C/A/year, for a total increase of 24%. The increase was attributed to planting better adapted varieties and using better management practices that on average increased corn grain yields 2.29 bu/A/year. Higher soil organic C has impacts on water quality, soil productivity, and plant nutrition. For example, if we assume that the C:N ratio of organic matter is 10:1, then these findings would indicate that soils during this 25-year period were a sink for both C and N, and could have influenced the N needed to optimize crop yields.

Life-cycle-analysis (LCA) methodology is being used to determine the C footprint of agricultural products through cradle-to-grave environmental accounting (Clay et al., 2006; Wang et al., 2007; Wang 2008; Liska et al., 2009; Plevin, 2009, Carlson et al., 2010). The power of the LCA approach is that different products can be compared quantitatively and independently. For example, typical C footprints for coal, gasoline, and grain-based ethanol have been reported to be 134, 96, and 65 g CO_2eq/MJ (Liska et al., 2009), respectively. These values are influenced by many factors including production requirements, shipping distance, and manufacturing inputs. In these calculations, soil C sequestration is often not considered, or it is considered as a C source, thereby adding to the C footprint.

Common Abbreviations and Notes: N = nitrogen; C = carbon; SOC = soil organic carbon; CO_2eq/MJ = carbon dioxide equivalents per Mega Joule.

The fate of soil C is influenced by many factors ranging from tillage intensity to the amount of non-harvested C (NHC) returned to the soil (Clay et al., 2006, 2010). In agriculture, our ability to calculate accurate footprints has been limited by the availability of accurate SOC benchmarks. One source of benchmark information is producer soil samples that were analyzed for by public and private laboratories. These laboratories generally follow strict analytical protocols and the analysis results are often archived. These laboratory databases can contain many thousands of analyses and associated production surveys. Using South Dakota soil testing laboratory databases, this study's objective was to determine if eastern South Dakota soils are C sources or sinks. The study used 95,214 surface

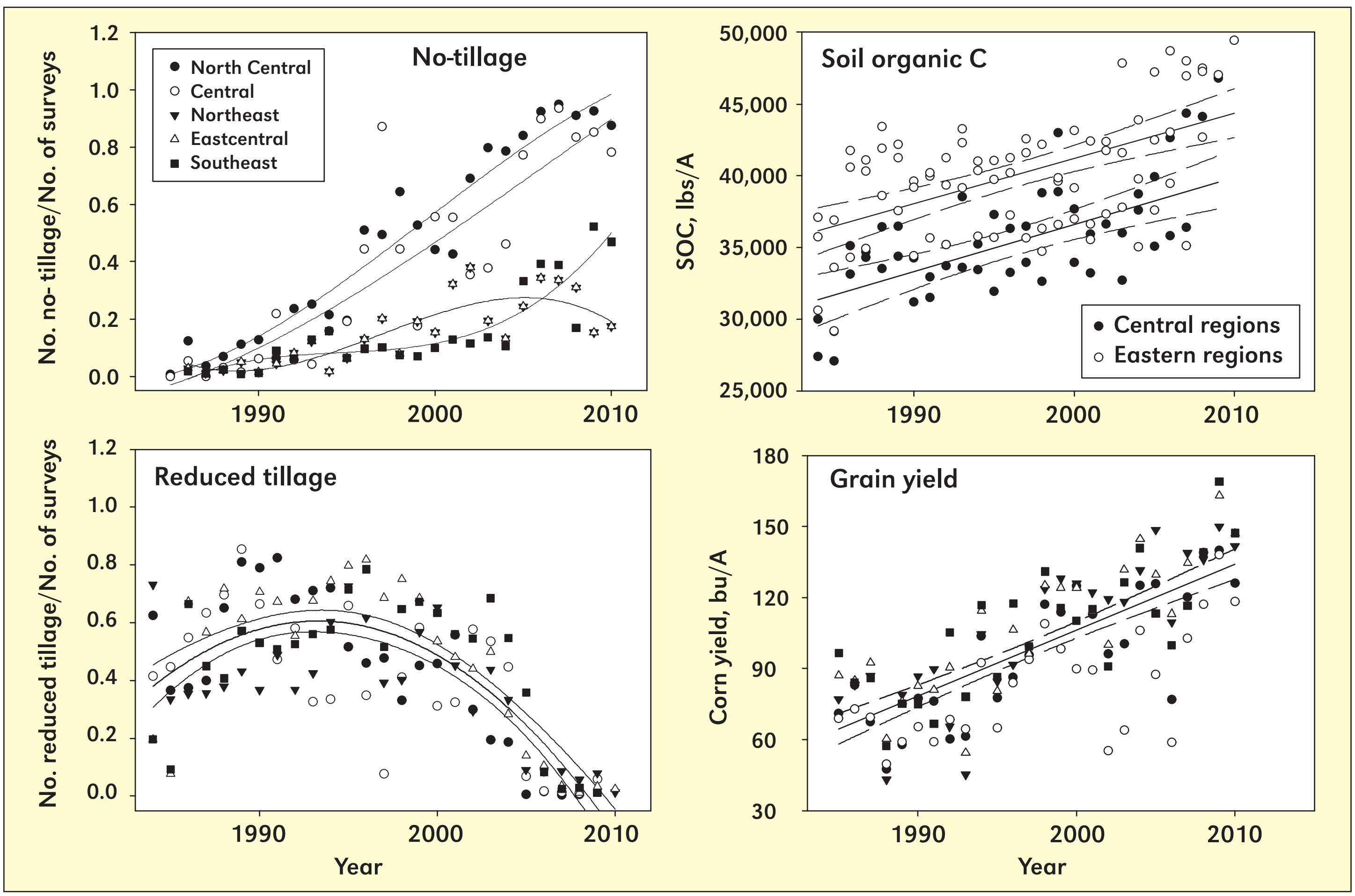

Figure 1. The influence of year and 5 sampling regions on no-tillage adoption, average corn grain yields, and soil C storage. In these graphs, the relative use of no-tillage, SOC, and grain yields are shown.

soil samples and 74,655 production surveys collected between 1985 and 2010.

Carbon Source or Sink

The temporal SOC changes in producer soil samples indicates that over the past 25 years, surface 6-in. SOC amounts have increased at a rate of 326 lb C/A/year (**Figure 1**). These results were attributed to at least three factors. The first factor is the gradual yield increase of 2.29 bu/A/year, which also increased the amount of NHC returned to soil (Allmaras et al., 2000). For example, a 10 bu/A yield increase results in an additional 380 lb C/A returned to soil annually. The second factor is the adoption of reduced, minimum, and no-tillage farming systems. Rapid no-tillage adoption rates are attributed to improved planting equipment, and genetically modified crops that improved and simplified pest management. The third factor is over 100 years (from the late 1900s to the late 20th century) of intensive tillage that reduced native soil organic matter contents from 40 to 60%.

Simulation analysis was used to assess if these factors could account for temporal changes in SOC. This analysis showed that the gradual but constant yield increases over this long period of time in combination with reduced tillage could result in periods of time where the soil behaved as a C source and then a C sink (**Figure 2**). The decrease in SOC values following the initial breaking of the prairie sod is consistent with historical records. Based on values from Puhr and Olsen (1937), and those in this report, it is estimated that 42% and 60% of the SOC contained in the 1880s soil was lost by 1937 and 1985, respectively. These findings are in agreement with Allmaras et al. (2000).

Our analysis suggests that the switch from source to sink occurred in the 1980s and 1990s. Since Allmaras et al. (2000), no-tillage adoption in the glaciated regions of South Dakota increased from <10% in 1998 to a regional average of 44% in 2004 and 2007 with some regions having near 100% no-till adoption. In addition, average South Dakota corn grain yields increased from 84 bu/A in 1985 to 135 bu/A in 2010. This 51 bu/A increase resulted in more C (2,000 lbs C/A) being returned to the soil.

Partial Carbon Footprints

A simulation model was used to determine the SOC sequestration potentials and associated partial C footprints for 5 corn-growing regions in South Dakota (**Table 1**). Corn grain yields for the 2004 to 2007 and 2008 to 2010 time periods were obtained from NASS (2011). Sequestered C was converted to g CO_2eq/MJ using appropriate calculations (Clay et al., 2012). When soil functions as a C sink rather than a source, C sequestration can have a large impact on C footprints. The calculations showed that the partial C footprints associated with corn production ranged from -5.1 to -14.9 g CO_2eq/MJ for the time period between 2004 and 2007 (**Table 1**). Slightly higher C sequestration potentials (more negative footprint) were observed between 2008 and 2010. This more negative footprint was attributed to higher yields and larger amounts of NHC returned to the soil.

Carbon sequestration can have a huge impact on the calculated LCA footprint for an ethanol plant. For example, if a surface soil has a C sequestration potential of -15.4 g CO_2eq/MJ (average value from 2008 to 2010) rather than not being considered, then the C footprint for an ethanol plant with a previously determined footprint of 58 g CO_2eq/MJ would now be determined to be 42.6 g CO_2eq/MJ. This value would meet the proposed California advanced fuel standard (Arons et al., 2007). If the 58 CO_2 eq contained a value for soil being a C source, this modified footprint could be even lower.

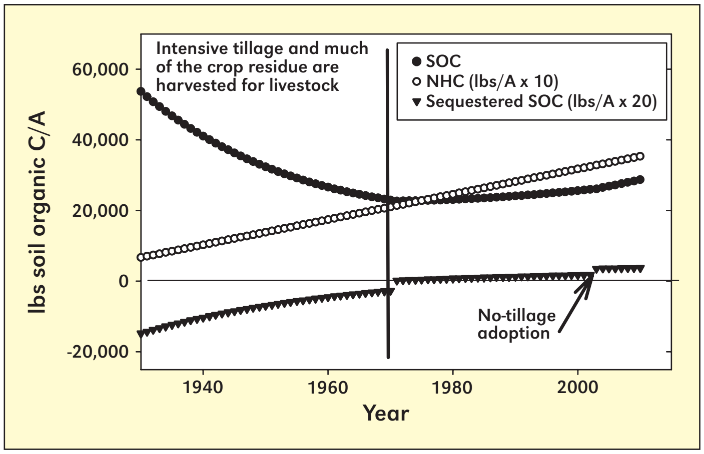

Figure 2. Simulated temporal changes in SOC resulting from conservation and no-tillage adoption and increasing amount of non-harvested C (NHC) returned to soil. In this chart, NHC is multiplied by 10, while sequestered C is multiplied by 20.

Currently, most corn-based ethanol LCA calculations do not consider soil as a C sink (Mueller and Unnasch, 2007; Wang, 2008; Liska et al., 2009). For example, Wang (2008) considered corn production as a C source (+0.9 g CO_2eq/MJ), whereas switchgrass was treated as a C sink (-6.73 g CO_2eq /MJ). This research suggests that annually cropped South Dakota surface soils under current management practices should be treated as a C sink. Additional research is needed to expand this conclusion to other regions. Archived information obtained by soil testing laboratories may provide information needed to quantify change.

In summary, analysis suggests that C is being sequestered in many Northern Great Plains surface soils. These results are attributed to: 1) SOC mining that occurred following homesteading, 2) gradual crop yield increases, which increased NHC returned to soil; and 3) wide scale adoption of reduced tillage and then no-tillage. Others have reported similar results

Table 1. The influence of South Dakota NASS sampling region and calculated short-term sequestered C rates on partial C footprints for the 2004 to 2007 and 2008 to 2010 time periods.

	2004 to 2007		2008 to 2010	
	Sequestered C	Partial C footprint	Sequestered C	Partial C footprint
	lbs SOC/A/yr	g CO_2eq/MJ	lbs SOC/A/yr	g CO_2eq/MJ
North-central	205	-14.9	369	-19.6
Central	62	-5.10	295	-14.8
Northeast	163	-8.86	207	-12.0
East-central	113	-6.31	236	-11.4
Southeast	203	-14.9	406	-19.2

(West and Post, 2002; Allmaras et al., 2000). The difference between this study and previous study is that this study used benchmarks from producer fields to document improvements. These results are different than a general perception that annually cropped soils in the Northern Great Plains are losing C. These findings may have ramifications relative to water quality and soil resilience. This assessment provides an excellent example of how universities in collaboration with our federal and private industry partners can work together to enhance the economic and environmental well-being of the clientele we serve. BC

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IPNI Launches New Website

The International Plant Nutrition Institute has launched its new website, still accessible at http://www.ipni.net. The beautifully redesigned site, created by Brian Green, IPNI IT Manager, was planned with the international scope of IPNI and its subscribers in mind.

The site now has the ability to change content dynamically based on the user's language preference and location in the world. The site also features a much-improved Google search engine for more precise results. Most notably is the new modern design, with a more intuitive, topical based navigation. The homepage also has new categories for our most popular content; "News", "Research" and "Publications". Visit the site today and enjoy all of the improved features.

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