2017

Crop diversity effects on soil organic matter and nitrate retention in surface and subsoils

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Competitive Grant Report E2015-17

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FOR SUSTAINABLE AGRICULTURE

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Abstract:

Much of the available soil organic carbon (SOC) is in subsoil, yet few studies have evaluated how crop rotation affects SOC below the plow layer. This project looks at whether crop rotations with greater belowground C inputs would increase SOC stocks by delivering C to subsoil with relatively low SOC levels.

Principal Investigator:

Michael Castellano

Co-investigators:
Hanna Poffenbarger
Matthew Liebman
Agronomy
Iowa State University

Budget:
$8,707 for year one
$9,992 for year two

ECOLOGY

Q How do differences in above- vs. belowground allocation of plant carbon inputs, mediated by differences in crop rotation, affect the storage of soil organic carbon in surface- and subsoils?

A Extended crop rotations had higher soil organic carbon concentrations than the simple rotations down to 1m depth in two of three long-term field experiments. The proportion of organic matter in different physical and chemical fractions was similar for simple and extended rotations. The rate of soil organic carbon storage over the last 12 years was greater at depth than at the surface, but was not affected by crop rotation.

Background

Ecosystem models estimate that Iowa soils have been losing soil organic carbon (SOC) to a depth of 100cm over the past four decades. Empirical research has confirmed this result, demonstrating ongoing SOC losses in the state's dominant corn-soybean rotations despite optimum management for nutrients and pH. Soil organic matter (SOM), of which SOC is the major component, is positively correlated with crop yield, so it plays a critical role in nutrient supply and water-holding capacity.

A large proportion of SOC is found in the subsoil, yet few studies have evaluated crop rotation effects on SOC below the plow layer. The researchers hypothesized that crop rotations with greater belowground C inputs would increase SOC stocks by delivering C to the relatively C-depleted subsoil.

The objectives of this project were to:

- determine the effects of extended vs. corn-soybean rotations on SOC and total nitrogen content, labile and stable SOM fractions, and SOM biochemical composition at different depths to 100cm, and
- compare estimated annual C inputs and change over time in SOC stocks for extended vs. corn-soybean rotations.

Approach and methods

Using three long-term field trials in Iowa (study durations of 60, 35, and 12 years), the team examined the effects of crop rotations (corn-soybean-oat/alfalfa-alfalfa or corn-corn-oat/alfalfa-alfalfa vs. corn-soybean rotation) on SOC content at different depths throughout the soil profile and changes in profile SOC between 2002 and 2014.

Soil samples were collected from the extended and corn-soybean rotations of three Iowa State University long-term cropping system experiments following corn harvest and before tillage. Six 4cm diameter cores per plot were taken to a depth of 100cm using a hydraulic soil probe. The cores were split into 0-15, 15-30, 30-60, 60-90, and

Collecting soil cores at the Marsden Farm experiment station.

90-100cm depth increments, and the segments from the six cores within each plot were composited to form five samples per plot. The samples were weighed and a subsample was dried at 105 degrees C for moisture content determination. Each sample was passed through an 8mm sieve and allowed to dry at room temperature. A portion of each air-dried sample was finely ground for determination of soil pH in water, sand content, and C and N concentrations by dry combustion analysis. Carbonates were removed prior to dry combustion analysis by the acid fumigation method.

Results and discussion

Average annual C inputs were similar for both rotations, but the proportion of C delivered belowground was approximately 30 percent greater in the extended rotations. The study found that SOC stocks tended to be greater in the extended rotations at two out of three sites (Kanawha and Nashua), but that current rates of SOC change are the same for both rotations at these sites. Therefore, it seems that changes in SOC stocks due to management took place in the years immediately following experimental establishment. Currently, both rotations are changing at a rate that maintains their relative SOC stocks. Interestingly, the rate of SOC storage increased with depth, but not at the surface.

The research team is currently exploring possible mechanisms for this observation (including changes in yield and weather patterns over time) using a cropping systems model. The percentages of SOC found in different physical SOM fractions and biomarker compounds were not affected by crop rotation, suggesting that mechanisms for SOC storage were similar in both rotations despite differences in allocation of C inputs. Surprisingly, the greatest proportion of total SOC as particulate organic matter (POM) was observed in the shallowest and deepest sampled layers (0-15 and 60-90cm). The positive correlation between the percent of total SOC as POM C and percent of total SOC as phenol C suggests that the delivery of plant lignin C to the subsoil may lead to accumulation of POM.

Conclusions

The study extends beyond previous studies because it not only quantified crop rotation effects on SOC and total N content, change in SOC stocks over time, and annual C inputs, but it also investigated the stability and biochemical composition of SOM in surface and subsoils. Because stable SOM pools saturate more quickly than labile SOM pools, measuring C concentrations in labile and stable SOM fractions can provide information on how soils compare in their extent of C saturation. The team recommends that future research investigate the quality of residue inputs by different crops to predict which crop(s) may contribute positively to the accumulation of POM at depth.

Impact of results

By quantifying the rates of SOC storage in surface soils and subsoils, this study should improve the accuracy of C sequestration predictions for Iowa cropland. An important next step will be to determine the mechanism(s) for SOC storage in subsoils. Project results suggest that the quantity of C delivered belowground vs. aboveground does not explain SOC storage at depth, but residue quality (i.e., lignin content of plant residue)

Soil samples from 0-15, 15-30, 30-60, 60-90, and 90-100cm depth increments (left to right).

may play a role. Understanding the causes for SOC accumulation will help agronomists develop practices for improved SOC storage and predict how SOC may change in future climate scenarios.

Education and outreach

Team members gave presentations on the project at two international scientific meetings: Soil Science Society of America annual meeting, November 2016, and European Geophysical Union, April 2017. In addition, an undergraduate student (Jordan Kersey) who helped with project's biochemical analyses, presented these results at the Iowa State Research in the Capital Symposium, as well as the Iowa State University Undergraduate Research Symposium in spring 2017.

Two scientific journal articles are currently being prepared. The first will focus on SOC storage mechanisms with depth and will feature data collected on SOM fractions and biochemical compounds. The second article will center on SOC change over time with depth and will use a cropping systems model to explain these results.

Leveraged funds

Additional resources leveraged by this project include:

- USDA AFRI Competitive Grant 2014-2017. Evaluation of weed management systems and agroecosystem health using multiple performance criteria. Matt Liebman (PI). $500,000
- USDA NIFA Competitive Grant 2014-2017. Integrating soil carbon stabilization concepts and nitrogen cycling. Michael Castellano (PI). $500,000

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