2014

What drives corn yield stability in the context of climate variability?

Michael J. Castellano
Iowa State University, castelmj@iastate.edu

Kirsten S. Hofmockel
Iowa State University, khof@iastate.edu

Jim R. Rouse
Iowa State University, rouse@iastate.edu

What drives corn yield stability in the context of climate variability?

Abstract
The links between nitrogen fertilizer rates and varying crop rotation schemes are examined in this project. The role that organic matter inputs play in supporting corn-soybean rotations also was investigated.

Keywords
Agronomy, Ecology and Evolutionary Biology, Climate change greenhouse gas emissions, Life Cycle Assessment

Disciplines
Agronomy and Crop Sciences | Ecology and Evolutionary Biology | Plant Biology

Competitive Grant Report E2011-07

LEOPOLD CENTER
FOR SUSTAINABLE AGRICULTURE

What drives corn yield stability?

Abstract: The links between nitrogen fertilizer rates and varying crop rotation schemes are examined in this project. The role that organic matter inputs play in supporting corn-soybean rotations also was investigated.

Principal Investigator:

Michael Castellano
Agronomy

Co-investigators:
Kirsten Hofmockel
Ecology and
Evolutionary Biology

Jim Rouse
Iowa Crop Improvement
Association
Agronomy
Iowa State University

Budget:
$37,906 for year one
$42,205 for year two

ECOLOGY

Q How do nitrogen fertilizer inputs impact long-term soil sustainability?

A The researchers used long-term nitrogen fertilizer rate trials in continuous corn and corn-soybean rotations crop systems to determine how insufficient, optimum, and excessive nitrogen fertilizer inputs affected the amount of carbon and nitrogen in soil organic matter. Four locations across Iowa were investigated. At one continuous corn system in Ames, Iowa, the soil organic matter situation was explored in much greater detail. At this site the team measured both stable soil organic matter pools that comprise the vast majority of total soil organic matter and labile soil organic matter pools that are disproportionately large contributors to the nutrient supplying capacity of the soil.

Background

Crop productivity and soil quality have a positive relationship. In the absence of livestock manure, crop residues are the primary source of soil organic matter while soil organic matter provides most of the necessary crop nutrients – regardless of the amount of fertilizer inputs. Accordingly, high crop productivity and concomitant residue production are essential to maintain soil quality. This project focused on investigations of the feedback between crop production and soil quality as it is affected by nitrogen fertilizer inputs and crop rotation diversity.

Approach and methods

This project examined long-term nitrogen fertilizer rate trials in two cropping systems (continuous corn and corn-soybean rotation) at four ISU Research Farm locations: Ames, Chariton, Crawfordsville, and Sutherland. For continuous corn systems, each location includes four replicated plots that have received the same inorganic nitrogen fertilizer rate for 13 years. For corn-soybean rotations, each site includes eight replicated plots that have received the same nitrogen fertilizer rate for 13 years in the corn phase only. Both phases of the rotation are present every year; in a given year, four of the replicated plots have corn and four have soybeans. Although the nitrogen fertilizer rates in each rotation at each site span 0-240 lbs N per acre per year, the Ames location has five rates and the remaining three sites have seven rates. All nutrients other than nitrogen and pH are maintained for optimum productivity.

In both cropping systems at all four locations, the team measured soil organic carbon and total nitrogen in 0-15 cm soil samples that were collected in 1999 and again in 2009. The agronomic optimum nitrogen rate for the same period (1999-2009) was calculated for each rotation and each site. In addition, the researchers conducted

Soil shown has been sifted into different aggregate classes. Crop systems with optimum nutrient inputs had more carbon and nitrogen in aggregates.

a more comprehensive analysis of soil organic matter in the continuous corn system at Ames.

The project also took advantage of ISU agronomy professor Matt Liebman's Marsden Farm crop systems diversity experiment in Boone County, Iowa. From this experiment, they sampled soils from the corn phase of the 2- and 3-year crop rotations. Soils were incubated in the lab for one year during which they were measured for potentially mineralizable carbon and nitrogen.

Results and discussion

The research results demonstrated that soil carbon and nitrogen levels decreased when nitrogen fertilizer inputs were below the agronomic optimum (amount of nitrogen required to maximize yield). In continuous corn systems, soil organic matter balances were neutral or increased when inorganic nitrogen fertilizer inputs were at agronomic optimum. In contrast, at three of four corn-soybean rotation systems, soil carbon and nitrogen balances decreased despite agronomic optimum inorganic nitrogen fertilizer inputs.

These results suggest that corn-soybean rotations, when maintained without additional organic matter inputs (e.g., manure or cover crops), are unsustainable in the long term. A major consequence of long-term reductions in soil organic matter is long-term reductions in crop yield potential. The project findings highlight the importance of additional organic matter inputs for corn-soybean rotations. Organic matter inputs that augment inherently low crop residue production in the corn-soybean rotation system may shift negative soil carbon and nitrogen balances to neutral or positive.

In addition to investigating 0-15 cm soil carbon and nitrogen balances in Iowa's most abundant crop systems, project team members also examined the effect of crop system diversity on potentially mineralizable nitrogen and carbon – two well-known predictors of crop-available nitrogen. These variables were compared within a conventionally managed corn-soybean rotation and a more diverse corn-soybean-small grain + red clover manure rotation at the Marsden Farm experiment site.

Results demonstrated that the more diverse crop system with lower external inorganic nitrogen fertilizer inputs had 49 percent greater potentially mineralizable nitrogen than the conventional 2-year rotation. This is an important result given that soil organic matter, rather than fertilizer, is the dominant source of crop nitrogen uptake – regardless of the amount of inorganic nitrogen fertilizer inputs. This result may be one factor explaining the "rotation effect," that is, higher corn yields appear in the 3- vs. 2-year crop rotations.

Conclusions

Iowa corn and soybean rotations receiving agronomically insufficient inorganic nitrogen fertilizer applications will experience long-term soil organic matter decline.

Soil fertility plot showing some crops with too little N inputs next to plots with sufficient N inputs.

The corn-soybean rotation in Iowa is currently unsustainable if the only organic matter inputs are crop residues. In addition, these data were collected from experiments with little to no erosion. As a result, the data should be interpreted as minimum levels of soil organic carbon and nitrogen loss. Erosion would represent an additional loss mechanism that is not incorporated into the project's experimental design since the experimental plots had little or no slope.

Although 0-15 cm SOC stability was measured in sufficiently inorganic N tests, results from more detailed investigation of the Ames continuous corn experiment suggest that excessive inorganic nitrogen fertilizer inputs are rapidly lost to air and water resources. This conclusion is supported by the lack of detectable differences in soil organic matter amounts or properties between the agronomic optimum rate and the excessive rate. Thus, the project data complement agronomic assessments of the environmental nitrogen losses that demonstrate nitrous oxide emissions and nitrate leaching exponentially increase when agronomic optimum nitrogen fertilizer input is surpassed.

Data from the Marsden Farm work suggest enhanced nitrogen availability may be one factor contributing to the higher corn yields in more diverse crop rotations that have been reported by Liebman and his team. Moreover, the lower carbon-to-nitrogen ratio of potentially mineralizable organic matter in the 3-year vs. 2-year rotations (calculated as: potentially mineralizable carbon/potentially mineralizable nitrogen) suggest higher quality labile organic matter (i.e., lower C/N ratio organic matter) in more diverse rotations may contribute to enhanced nitrogen availability.

Impact of results

The project results will be helpful to both applied and basic research. Investigations of nitrogen fertilizer effects on soil organic carbon and nitrogen stocks in Iowa cropping systems should impact farmers by demonstrating that the corn-soybean rotation, when maintained with inorganic nitrogen fertilizer and no additional organic matter inputs beyond crop residues, is unsustainable in the long term. Results should encourage the use of additional organic matter inputs (e.g., manure or cover crops) to shift soil carbon and nitrogen balances in corn-soybean rotations from negative to neutral or positive.

Education and outreach

Publications:

Brown KH, Bach E, Drijber RA, Hofmockel K, Jeske EA, Sawyer JE, Castellano MJ. 2014. A long-term nitrogen fertilizer gradient has little effect on soil organic matter. *Global Change Biology* doi: 10.1111/gcb.12519

The investigators expect at least two more publications to be prepared from data collected through this project.

Leveraged funds

Kimberly Brown's work at the Ames continuous corn site resulted in a grant from the USDA Agriculture and Food Research Initiative:

> PI M. Castellano, co-PIs D. Olk, J. Sawyer, J. Six. 2014-2016. Microbial Communities in Soil Foundational Program. "Integrating soil carbon stabilization concepts and the nitrogen cycle," $499,000.

Alison King's work at Marsden Farm also resulted in a grant from the USDA Agriculture and Food Research Initiative:

> PI K. Hofmockel, co-PIs L. Halverson, M. Castellano. 2013-2015. Microbial Communities in Soil Foundational Program. "Improved N retention through plant-microbe interactions," $499,000.

For more information, contact *Michael Castellano, 2104L Agronomy Hall, Iowa State University, Ames, Iowa 50011-1010; (515) 294-3963, e-mail castelmj@iastate.edu*