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Predicting long term cover crop impacts on soil quality using a cropping systems model

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Abstract
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Keywords
cover crops, double crops, strip cropping

Disciplines
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Co-investigators:
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Budget:
$15,481 for year one
$1,667 for year two
$6,252 for year three

Q What are the long-term impacts of a cover crop on soil and crop yields in corn and soybean crop rotations?

ECOLOGY

A A cropping systems model platform, using field data from a research site in central Iowa, predicted that the continuous use of a winter rye cover crop in a corn-soybean crop rotation did not increase or decrease crop yields. It did reduce soil erosion by 18-29 percent, decreased nitrous oxide emissions by up to 34 percent and reduced soil carbon decline by three percent over the 45-year simulation period.

Background

Increased attention is being paid to cover crops as an option to reduce water pollution and decrease soil degradation in Iowa. More producers are experimenting with cover crops to increase soil productivity. However, when this project began there was little research to demonstrate the long-term impacts that cover crops have on crop yields. There were no estimates to quantify how much environmental benefit a cover crop could provide in terms of erosion and soil carbon changes. Such estimates are beneficial to demonstrate the long-term improvements that a cover crop affords in Iowa, particularly for corn-soybean rotations where the winter planting window is narrow, presenting a significant short-term challenge for producers. Using a cropping systems model such as APSIM (Agricultural Production Systems sIMulator) can offer estimates of potential benefits for farmers and policy makers which might take many years to observe in a traditional field trial.

The objectives of this research were to:

- Measure crop growth and soil properties at a representative corn-soybean field site with a winter rye cover crop to provide specific parameters necessary to establish and test APSIM and to analyze field data for treatment effects of the cover crop.
- Use APSIM simulations to estimate the impact of long-term cover crops on soil carbon, soil erosion, soil water dynamics, and average main crop yields as well as cover crop impacts following more variable rainfall seasons, a projected climate change impact for the Midwest United States.

Approach and methods

An extensive period of crop and soil data collection and of testing the performance of the cropping systems platform showed that the model appropriately matched data from a research field site near Ames, Iowa. The team collected data from two crop rotations (a no-till corn-soybean rotation and a no-till corn-soybean rotation with a winter rye cover crop included every year) at the field site and then conducted

Researchers taking soil samples with a deep probe. (Photo courtesy Andrea Basche)

simulations for them. They utilized a cropping systems model (APSIM) with a series of future climate change scenarios for 45 years, from 2015 to 2060.

Results and discussion

The results showed that a warmer future climate paired with more variable rainfall led to crop yield declines of one to two percent per decade through 2060. The use of a cover crop was not enough to offset these yield declines. APSIM predicted that in future years with lower rainfall (approximately 690mm per year, or 25 percent below normal), the cover crop may lead to water competition with corn or soybeans. Given warmer temperatures and lower crop yields, APSIM predicted that soil carbon in both the cover and no-cover crop simulations declines in the future relative to current soil conditions. However, the cover crop was predicted to slow the carbon loss significantly. The predicted reduction in soil erosion from the cover crop ranged from 11-29 percent while also decreasing nitrous oxide emissions up to 34 percent.

After performing an extensive analysis of the soil water record, the investigators noted encouraging results related to the soil water impacts of a cover crop. From 2008 to 2014, which included some of the wettest, hottest and driest years in the long-term record, analysis of project field data indicated that the cover crop consistently increased soil water storage as well as water content in the soil during the mid-summer period. The team collected soil samples to measure the water retained in the soil at the pressures associated with field capacity and permanent wilting point, the upper and lower end of plant-available water, respectively. From these measurements they calculated an overall increase in plant available water of 21-22 percent from the use of a winter rye cover crop for 13 years.

Conclusions

Study results confirm that in the long-term a winter rye cover crop had neutral effects on corn and soybean yields. However, climate change scenarios predict yield declines in both of the treatments. An average cover crop biomass of 1300 kg per ha-1 for year 1 results in significant improvements to environmental impacts, including an average erosion reduction of 11-29 percent. Although soil carbon declines at lower depths in the soil profile (>15cm) in both treatments and weather scenarios, the cover crop simulation is able to offset that loss by three percent.

In the future climate scenarios, general circulation model-generated predictions, carbon decline results from declining crop yields and increasing soil temperatures. This analysis also found an increased likelihood that soil N_2O emissions would be reduced with a winter rye cover crop. These results show that with future climate change, a winter rye cover crop does not lead to soil carbon increases and cannot offset future projected yield declines; however, soil N_2O emissions decreased and erosion prevention increased. Thus, there is evidence that a cover crop improves outcomes under future climate conditions, but perhaps not enough to offset all potential future changes that the region may experience. Also, the model simulations do not fully reflect changes in soil structure, pest populations, diseases, and nutrient cycling that

Andrea Basche standing in a soybean field which has a cereal rye cover crop established by broadcasting. (Photo courtesy Jacob House)

the cover crop might cause over time. Given the current understanding of regional climate changes, this research demonstrates that it will continue to be a challenge to design cropping systems that enhance future soil and water resources. Future modeling efforts could investigate the potential benefit of carbon dioxide increases, longer growing seasons, and improved cover crop cultivars or species mixes to offset more of the anticipated climatic change in the Midwest United States.

Analysis of the field data showed that over a seven-year period, including years that were wetter, hotter and drier than normal, the consecutive use of a winter rye cover crop contributed to improved soil water content and soil water storage in a corn-soybean cropping system. There was evidence of soil water use from a transpiring cover crop in the spring, but rainfall replenished the soil to the same level in both the cover crop and no cover crop treatments by the time of corn and soybean planting in most springs. The cover crop increased the water retained in the soil by 10-11 percent at water potentials associated with field capacity (-33 kPa) as well as increasing plant available water by 21-22 percent. In the last two years of the experiment the winter rye cover crop did not have any negative effects on corn or soybean biomass, leaf area, and yield. Researchers' analysis suggests that the long-term use of a winter rye cover crop, if managed appropriately, can improve soil water dynamics.

Impact of results

This research has important implications for Iowa agriculture. In both the modeling study and the field data analysis, investigators found that the use of a winter rye cover crop in a corn-soybean crop rotation, the predominant land use in the state, can offset negative impacts of climate change. However, an explicit finding of the modeling study was that relying solely on a cover crop as a climate adaptation practice would not negate all of anticipated effects of a warmer climate with more erratic rainfall. This result in particular has important policy implications. It suggests that there is still time to begin incentivizing practices that will "climate proof" the landscape, as most experts anticipate that major climate impacts will not be felt until the middle of the 21st Century. This research demonstrates that climate adaptation can be done through conservation practices in a way that protects soil and water quality and does not rely only on government-subsidized crop insurance payments.

The major research objectives were achieved. The team successfully collected and analyzed pertinent field data for establishing the long-term cover crop model simulations. APSIM performed very well relative to the field data. There were interesting treatment effects of the cover crop shown in analysis of the field data, including increases in water retained in the soil at field capacity, plant-available water and soil water storage. Finally, the project provided the first estimates of long-term cover crop impacts for the Midwest on corn and soybean yields, soil carbon, soil erosion and nitrous oxide emissions.

An eventual longer-term goal of this research is to serve as a scientific foundation to improve the information available in the Midwest Cover Crops Council (MCCC) Selector Tool. The MCCC Selector Tool provides farmers with species and planting date recommendations to coincide with their management decisions. Estimations of

cover crop growth at most locations across the state or for different planting dates are not based on any actual data but rather "expert guesses." Therefore, a model like APSIM, which uses a mechanistic approach to predicting cover crop growth, should provide a more reasonable estimate than the current approach. The researchers engaged in conversations and annual conferences with the MCCC. During the period of this project there was not enough capacity to incorporate specific APSIM predictions into the selector tool; however, many ideas were exchanged for how this might be done in the future.

Education and outreach

Scientific publications

Basche, A.D., Archontoulis, S.A., Kaspar, T.K, Jaynes, D.B., Parkin, T.B. Miguez, F.E. 2016. Simulating long-term impacts of cover crops and climate change on crop production and environmental outcomes in the Midwestern United States. *Agriculture, Ecosystems and the Environment*. 218, 95-106

http://www.sciencedirect.com/science/article/pii/S0167880915301468

Basche, A.D., Kaspar, T.K., Archontoulis, S.A., Jaynes, D.B., Parkin, T.B., Sauer, T.S., Miguez, F.E. Soil water improvements with the long-term use of a cover crop. Accepted in *Agricultural Water Management*.

Media

Video and blog created in collaboration with Lynn Laws and Maggie McGinty of the CSCAP project, Spring 2015. http://sustainablecorn.org/blog/?p=647

Modeling project results were presented to the APSIM workshop attendees, including U.S. and international collaborators, June 2015, at Iowa State University (approximately 50 people); at a CARD lab meeting in March 2015, at Iowa State University (approximately 15 people); and were included in the presentation of Sotirios Archontoulis in the Agronomy Department's weekly seminar series in November 2015 (approximately 100 attendees). Results of the modeling projects and field data analysis were presented at 16 larger scientific conferences from 2013-2015.

Leveraged funds

This project was complementary to the Corn Systems Coordinated Agricultural Project (www.sustainablecorn.org). USDA-NIFA award 2011-68002-30190. The USDA-NIFA grant was awarded before this grant and it was for $20M. In addition, there was a USDA-SARE grant for "Economic Evaluation of Cover Crops in Midwest Row Crop Farming" ($183,969).

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