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Impacts of conventional and diversified rotation systems on crop yields, soil functions and environmental quality: Stage II/Year 2

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Abstract
Research continued at a long-term crop rotation testing site near Boone, Iowa. In this stage of the trial, attention was directed to estimating soil erosion with the RUSLE2 model, measuring soil nitrogen transformations and nitrogen uptake by corn, and assessing the farm economics of these more varied crop production scenarios using enterprise budgeting techniques.

Keywords
Agronomy, Multi-year rotations low-external input, Nutrient management, Climate change greenhouse gas emissions, Life Cycle Assessment, Economic and environmental impacts, Integrated crop-livestock systems and diversity, Soils and agronomy

Disciplines
Agronomy and Crop Sciences | Soil Science

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FOR SUSTAINABLE AGRICULTURE

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$43,625 for year one – XP2013-01
$46,482 for year two – XP2014-01

Q Could diversifying corn- and soybean-based cropping systems with oat, red clover, and alfalfa improve environmental performance characteristics while maintaining or improving profitability?

A Results of this project contribute to a growing understanding of the performance characteristics of diversified cropping systems, including economic costs and returns, and basic biophysical processes like soil erosion and nutrient cycling.

Background

The project investigators sought to gain new information and assess additional performance indicators in the long-running cropping systems experiment at Iowa State University's Marsden Farm in Boone County, Iowa. They estimated soil sheet and rill erosion potential and assessed soil nitrogen-related processes that can strongly influence crop productivity and environmental quality. They also quantified economic characteristics of the contrasting cropping systems.

Approach and methods

Since 2002, a 9-hectare (22-acre) field experiment has been conducted at the Marsden Farm to assess yields, profitability, weed dynamics, soil functions, and other performance characteristics of one simple and two more diverse crop rotation systems. Starting in 2008, two contrasting weed management regimes were inserted into each of the three rotation systems to create a 3 x 2 factorial set of treatments. The rotations comprise a 2-year corn-soybean system; a 3-year corn-soybean-oat plus red clover system; and a 4-year corn-soybean-oat plus alfalfa-alfalfa system. The latter two systems periodically receive cattle manure applications. The two weed management regimes comprise broadcast applications of herbicides at conventional rates for corn and soybean, or banded applications of low levels of post-emergence herbicides in corn and soybean coupled with inter-row cultivation.

During 2013 and 2014, the project focused on:

1. estimating sheet and rill erosion in the conventional and more diverse crop rotation systems;
2. measuring soil and plant parameters to learn if increased crop diversity maintained or improved corn nitrogen (N) uptake while reducing the amount of leachable inorganic nitrogen present in the soil;
3. assessing input costs and net returns for the different crop rotation systems; and
4. distributing results to farmers, agricultural professionals, extension personnel, scientists, and policy makers.

Alfalfa. (Photo credit: David N. Sundberg)

Results and discussion

Project results showed that the 3-year and 4-year rotation systems could reduce sheet and rill erosion by 21 to 36 percent compared with the simpler, 2-year corn-soybean rotation. Mineral N fertilizer inputs, mineral N pool sizes in the soil, and nitrate-N losses to leaching were smaller in the more diverse systems than the simpler system, whereas N cycling rates and corn grain yields were higher in the more diverse systems than in the simpler system.

Economic results from 2013-2014 indicated that for the low-herbicide regime, net returns were highest for the 4-year rotation ($852 ha-1 yr-1, $345 acre-1 yr-1), lowest for the 2-year rotation ($601 ha-1 yr-1, $243 acre-1 yr-1), and intermediate for the 3-year rotation ($766 ha-1 yr-1, $310 acre-1 yr-1). Similarly, for the conventional herbicide regime, average net returns to land and management were highest for the 4-year rotation ($831 ha-1 yr-1, $336 acre-1 yr-1), lowest for the 2-year rotation ($582 ha-1 yr-1, $236 acre-1 yr-1), and intermediate for the 3-year rotation ($736 ha-1 yr-1, $298 acre-1 yr-1).

Conclusions

Results indicate that diversified crop rotation systems (corn-soybean-oat plus red clover and corn-soybean-oat plus alfalfa-alfalfa) could reduce sheet and rill erosion substantially compared with a simpler corn-soybean rotation.

Evaluation of long-term crop, soil and water data from the Marsden Farm experiment indicated that nitrogen inputs, mineral N pool sizes in the soil and N losses to leaching were smaller in the more diverse systems than the simpler corn-soybean system. These patterns are consistent with the team's hypothesis that the conventional system has greater dependency on mineral N fertilizer applications to satisfy corn N demand, whereas the more diverse 3-year and 4-year systems are more reliant on in-season mineralization of organic N, which occurs at a higher rate than in the simpler conventional system.

Net economic results from 2013-2014 indicate that farmers who use a low-herbicide regime can maintain high profitability by adding oats plus red clover, and oats and alfalfa to a conventional corn-soybean rotation. It should be noted, though, that labor requirements included in these calculations were greater for the more diverse systems, and that economic assessments include costs for handling and spreading of manure, but not purchase of manure. Profitability would be reduced if there were a cost for the manure applied to the fields.

Impact of results

The research team accomplished project objectives related to

(1) assessments of soil erosion potential,

(2) assessments of cropping system economic performance,

(3) outreach and extension of the findings, and

(4) a preliminary investigation into soil nitrogen dynamics.

Oat harvest. (Photo credit: David N. Sundberg)

They did not finish analyzing all samples and data related to soil processes affecting nitrogen transformations, but that work is well underway and they expect it to be completed within 12 months.

Results of this project contribute to a growing understanding of the performance characteristics of diversified cropping systems, including economic costs and returns, and basic biophysical processes like soil erosion and nutrient cycling. The long-term nature of the Marsden Farm experiment and the consistency of results from it suggest that diversification of Iowa corn and soybean-based cropping systems with small grains and forages is a viable pathway toward reduced dependence on purchased agrichemicals, improved environmental quality, and maintenance of profitability.

This project was successful in extending information about economic results and other findings to a wide range of scientific, farm, and student audiences and readers.

Education and outreach

Peer-reviewed research papers and book chapters

Liebman, M. and L.A. Schulte. 2015. Enhancing agroecosystem performance and resilience through increased diversification of landscapes and cropping systems. *Elementa: Science of the Anthropocene*, doi:10.12952/journal.elementa.000041.

Chen, X., X. Wang, M. Liebman, M. Cavigelli, and M. Wander. 2014. Influence of soil quality on carbon mineralization response to residue and nitrogen fertilizer additions. *PLoS ONE* 9(7): e103720, doi: 10.1371/journal.pone.0103720.

Liebman, M., Z.J. Miller, C.L. Williams, P.R. Westerman, P.M. Dixon, A.H. Heggenstaller, A.S. Davis, F.D. Menalled, and D.N. Sundberg. 2014. Fates of *Setaria faberi* and *Abutilon theophrasti* seeds in three crop rotation systems. *Weed Research* doi: 10.1111/wre.12069.

Tomer, M.D. and M. Liebman. 2014. Nutrients in soil water under three rotational cropping systems, Iowa, USA. *Agriculture, Ecosystems and Environment* 186: 105-114.

Asbjornsen, H., V. Hernández-Santana, V., M. Liebman, J. Bayala, J. Chen, M.J. Helmers, C.K. Ong, and L.A. Schulte. 2013. Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services. *Renewable Agriculture and Food Systems* doi: 10.1017/S1742170512000385.

Gómez, R., M. Liebman, and G. Munkvold. 2013. Weed seed decay in conventional and diversified cropping systems. *Weed Research* doi: 10.1111/wre.12052.

Liebman, M., M.J. Helmers, L.A. Schulte, and C.A. Chase. 2013. Using biodiversity to link agricultural productivity with environmental quality: results from three field experiments in Iowa. *Renewable Agriculture and Food Systems* 28: 115-128, doi:10.1017/S1742170512000300.

Published abstracts

Castellano, M.J., M. Liebman, W.R. Osterholz, J.E. Sawyer, and F. Miguez. 2014. Nitrogen conservation in high-input low diversity and low-input high-diversity agroecosystems. Abstracts of the 2014 American Society of Agronomy–Crop Science Society of America–Soil Science Society of America International Meetings. On-line at: https://scisoc.confex.com/scisoc/2014am/webprogram/Paper85421.html.

Gómez, R., M. Liebman, and M.E. Colvin. 2014. Cropping system effects on giant foxtail (*Setaria faberii*) population dynamics: modeling analyses. Abstracts of the 2014 American Society of Agronomy–Crop Science Society of America–Soil Science Society of America International Meetings. On-line at: https://scisoc.confex.com/scisoc/2014am/webprogram/Paper88383.html.

Osterholz, W.R., M.J. Castellano, M. Liebman, and J. Iqbal. 2014. Increasing rates of gross mineralization in diversified Midwestern cropping systems. Abstracts of the 2014 American Society of Agronomy–Crop Science Society of America–Soil Science Society of America International Meetings. On-line at: https://scisoc.confex.com/scisoc/2014am/webprogram/Paper87868.html.

Leandro, L., M. Liebman, C. Chase, and M.E. O'Neal. 2013. Long-term research on extended rotations for corn and soybeans. Abstracts of the 2013 Entomological Society of America Annual Meeting. On-line at: http://esa.confex.com/esa/2013/webprogram/Paper74726.html.

Popular and scientific presentations
Sixteen, including several ISU crop presentations, were delivered over the grant period. Among them were:

- The Nature Conservancy and Green Lands, Blue Waters, telecast workshop, Iowa Central Community College, Webster City, Iowa (August 2014).
- Field tour, University of Connecticut class on U.S. agricultural production systems, ISU Agronomy and Agricultural Engineering Farm, Boone, Iowa (May 2014).
- Utah State University, Department of Plants, Soils, and Climate, Apogee Instruments/Campbell Scientific Lecture, Logan, Utah (March 2014).
- Pennsylvania State University, Department of Plant Science, seminar, State College, Pennsylvania (March 2014).
- Middlebury College, seminar, Middlebury, Vermont (March 2014).
- Agribusiness Association of Iowa, Ag Industry and Crop Management Conference, Des Moines, Iowa (February 2014).
- University of Minnesota-Twin Cities, Green Lands, Blue Waters conference, Minneapolis, Minnesota (November 2013).
- University of Wisconsin–Madison, Agroecology Program seminar, Madison, Wisconsin (May 2013).
- University of Missouri, Division of Plant Sciences seminar, Columbia, Missouri (February 2013).

Leveraged funds

Leopold Center funds for this project complemented funds from these extramural grants and Iowa State University programs.

Castellano, M.J., A. Shaviv, R. Linker, and M. Liebman. Bi-national Agriculture Research and Development Fund. Improving nitrogen availability indicators by emphasizing correlations between gross nitrogen mineralization and the quality and quantity of labile soil organic matter fractions. 2012-2015. $341,580.

Halverson, L., T. Lubberstedt, M. Castellano, M. Liebman, K. Rajan, and K. Hofmockel. Iowa State University Plant Sciences Institute. Center for optimizing nitrogen efficient cropping systems. 2013-2014. $250,000.

Hofmockel, K., L.J. Halverson, M.J. Castellano, and M. Liebman. U.S. Department of Agriculture¬¬—Agriculture and Food Research Initiative. Improved N retention through plant-microbe interactions. 2014-2017. $499,873.

Leandro, L., A. Robertson, D. Mueller, M. Liebman, S. Cianzio, and C. Chase. Iowa Soybean Association. An integrated management approach for soybean sudden death syndrome. 2011-2013. $346,262.

Leandro, L., D. Mueller, M. Liebman, and M. Helmers. Iowa Soybean Association. Effects of soil conservation practices (cover crops, crop rotations, and tillage) on soybean sudden death syndrome. 2013-2016. $104,601.

Liebman, M., J.D. Hill, and C.A. Chase. U.S. Department of Agriculture, Agriculture and Food Research Initiative. Evaluation of weed management systems and agroecosystem health using multiple performance critieria. 2014-2016. $499,836.

In addition, $129,000 was provided from the ISU Department of Agronomy Premium Fellowship Fund and the ISU Graduate College Miller Fellowship Fund for three years of stipend support plus full payment of tuition and fees for Ph.D. student William Osterholz, who studied soil nitrogen dynamics in the Marsden Farm experiment.

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