The Marsden Farm Experiment: A Long-term Investigation of How Cropping System Diversification and Crop-Livestock Integration Affect Sustainability

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Summary

Sustainable farming practices are intended to minimize the use of non-renewable resources, decrease the emission of pollutants into water and air, retain and regenerate soil, and protect human health. They are also intended to maintain or increase farm productivity and profitability while reducing reliance on purchased inputs. A central tenet of sustainable farming systems is that careful stewardship of diverse ecological communities can be used to replace a substantial portion of the mineral fertilizers, synthetic pesticides, and petrochemical energy used in conventional farming systems.

Since 2001, we have used a 9-hectare (22-acre) field experiment at the Iowa State University Marsden Farm to investigate how cropping system diversification and crop-livestock integration affect productivity, profitability, and environmental quality. Three systems have been compared within the experiment: a 2-year corn/soybean rotation, a 3-year corn/soybean/oat + red clover rotation, and a 4-year corn/soybean/oat + alfalfa/alfalfa rotation. The 3-year and 4-year systems have periodically received cattle manure. By 2006, each of the plots had passed through at least one complete cycle of its respective rotation system.

For the 'core set' of comparisons among experimental treatments, the 2-year corn-soybean system has been managed with conventional rates of mineral fertilizers and herbicides, whereas the more diverse 3-year and 4-year systems have been managed with lower rates of agrichemicals. The experiment has also been used for a number of short-term component studies investigating a wide range of factors that can affect agroecosystem performance, including weed seed consumption by mice and insects, nitrogen mineralization from soil organic matter, and weed and crop responses to different 'technology packages' involving crop genotypes (transgenic versus non-transgenic) and weed control regimes (broadcast herbicides versus banded herbicides plus interrow cultivation).

Key results that have emerged from the study are as follows:

- During the period of 2006-2016, mineral N fertilizer use was 86% and 91% lower, and herbicide use was 96% and 97% lower in the 3-year and 4-year systems, respectively, than in the 2-year system.
- Corn yield has averaged 4% higher ($p<0.0003$) and soybean yield has averaged 16% higher ($p<0.0001$) in the more diverse systems compared with the 2-year system.
- Weed management has generally been effective regardless of rotation, with weed biomass in corn and soybean averaging <22 kilograms per hectare (20 lb per acre) in all systems.
- Incidence and severity of sudden death syndrome, a key disease affecting soybean in the Corn Belt, have been markedly lower in the longer rotations than in the 2-year rotation.
- Three indicators of soil quality–particulate organic matter carbon, microbial biomass carbon, and potentially mineralizable nitrogen–were 22% to 51% higher in the 3-year and 4-year rotations than in the 2-year rotation.
- Spring (March-May) concentrations of nitrate in drainage water collected from corn in the more diverse systems were 57% lower ($p<0.005$) than from corn in the 2-year system.

- Soil erosion was 25% lower, fossil energy consumption was 59% lower, and freshwater toxicity associated with herbicide use was 93% lower in the more diverse systems than in the conventional system.
- During 2008-2016, increases in rotation length led to greater labor requirements and decreased gross revenue. However, production costs also dropped substantially as cropping system diversity increased. Consequently, net returns to land and management did not differ among systems (p=0.56, mean=$845 per hectare per year, $342 per acre year), though profitability tended to rise as rotation length increased.

Collectively, results of this long-term study indicate that diversification of conventional corn-soybean systems with small grains and forage legumes, coupled with integration of those systems with livestock, can allow for large reductions in the use of mineral fertilizers and herbicides and lead to less environmental damage, equivalent profitability, improved soil quality, and higher crop productivity. Thus, the diversified, integrated crop-livestock systems we have investigated are in many ways more sustainable than a conventionally managed corn-soybean rotation. Translating these potential gains in agricultural sustainability into broad-scale changes in the U.S. Corn Belt will likely depend on combinations of factors that include government policies, farmer confidence, technical support, and markets for 'non-conventional' products.

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