Diversified Cropping Can Balance Productivity, Profitability, and Environmental Health

Matt Liebman

Corn harvest rotation.

One of the key challenges of the 21st century is how to produce adequate amounts of food and farm income while protecting environmental quality. The need to answer this question is particularly acute in the midwestern U.S., one of the largest regions of intensive, rainfed agriculture in the world. Crop production in this region currently relies heavily on synthetic N fertilizer and herbicides to manage soil fertility and weeds. Concomitantly, N and herbicides emitted from Midwestern cropland are detected regularly in the groundwater and surface waters. Midwestern cropping systems also use considerable amounts of fossil energy embodied in inputs such as mineral fertilizers, fuel for machinery operations and grain drying, and pesticides. Volatility in fossil energy prices leaves farmers vulnerable to serious constraints to profitability.

Diversified, low external input (LEI) cropping systems offer a possible approach for maintaining adequate productivity and profitability while reducing use of agrichemicals and fossil energy. LEI systems rely heavily on ecological processes for soil fertility and pest management, but they can also include some use of synthetic fertilizers and pesticides. Unlike organic systems, which often receive price premiums for crop and livestock products, LEI systems generally do not receive price premiums.

To date, evidence for the ability of LEI systems to produce high yields and sufficient income with reduced levels of agrichemical inputs has been inconsistent, especially in regions of high potential yield. Consequently, a team of investigators based at Iowa State University conducted a multiyear, 9 ha (23 acre) field experiment to determine whether the yield, profit, and other performance characteristics of LEI systems can match or exceed those of a conventional system. The experiment included a two-year corn-soybean rotation, a three-year corn-soybean-small grain + red clover rotation, and a four-year corn-soybean-small grain + alfalfa-alfalfa rotation. The latter two rotations are representative of diversified farming systems in the region, which often include livestock.

Spring triticale was used as the small grain in 2003-2005, and oat was used thereafter. Mineral fertilizers were applied in the two-year rotation at conventional rates, whereas composted cattle manure and reduced rates of synthetic fertilizers were applied in the three-year and four-year rotations. Weed management in the two-year rotation was based on conventional rates of herbicides, whereas in the three-year and four-year systems, herbicides were applied in bands over the corn and soybean rows rather than broadcast sprayed, interrow areas were cultivated, and no herbicides were applied in the small grain and forage legume crops. The experiment was conducted in Boone County, Iowa, within an area of high production potential.

Soybean (top), alfalfa (middle), and oat (bottom) harvest.

Over the study period (2003 to 2011), mineral N fertilizer use was 80% and 86% lower in the three-year and four-year LEI systems, respectively, than in the two-year conventional system. Similarly, herbicide use was reduced by 86% and 89%, respectively, in the three-year and four-year LEI systems. Fossil energy inputs were on average 49% lower in the LEI systems than in the conventional system. Corn yields were on average 4% higher and soybean yields were 9% higher in the LEI systems as compared with the conventional system, and matched or exceeded average yields on commercial farms in Boone County. Weed dry matter production was low in all systems, and weed seed population densities in the soil declined in all systems. Thus, lower herbicide inputs did not lead to increased weed problems.

With regard to environmental impacts, analyses conducted using the Revised Universal Soil Loss Equation 2 (RUSLE2) and USEtox models indicated that sheet and rill erosion were on average 28% lower in the LEI systems than in conventional system, and that over the last six years of the experiment, herbicide-related aquatic toxicity potential was more than 200-fold lower in the LEI systems than in the conventional system.

Economic performance over the 2003-2011 period, assessed without considering possible government crop or insurance subsidies, indicated that the LEI and conventional systems were similar in their net returns to land and management, with an average annual profit of $775 per hectare ($313 per acre). Labor requirements were higher for the three-year and four-year LEI systems than for the two-year conventional system, but variation in economic returns was lower for the LEI systems, i.e., profitability was more stable over time.

This study indicates that more diverse, three-year and four-year rotations can be successful at the farm or micro-economic scale. Such rotations are a practical solution for reaching multiple goals: reducing environmental impact and maintaining on-farm profitability. Nonetheless, understanding how diverse and integrated crop-livestock systems work on regional and national scales would require macro-economic modeling that wasn't included in this study. Federal and state policies, environmental regulations, and market opportunities are all likely to play important roles in farming decisions. Modeling in future research can address these issues.

Results of this study were published in October 2012 in the peer-reviewed, open-access journal *PLOS ONE*. It has since been viewed or downloaded more than 40,000 times. Funding for the work was provided by the USDA, the Leopold Center for Sustainable Agriculture, the Iowa Soybean Association, and the Organic Center.

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Red clover photo courtesy of Paula R. Westerman. All other photos courtesy of David N. Sundberg.

Further reading

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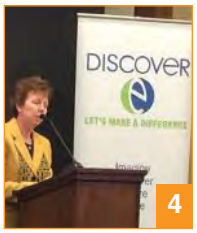

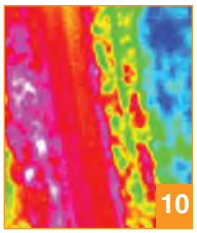

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