doi:10.2489/jswc.72.3.47A

RESEARCH INTRODUCTION

Crops, climate, culture, and change

Lois Wright Morton and Lori J. Abendroth

The future of agriculture will depend on how well we negotiate change and adapt. A changing climate is one of many drivers of change. Increased variability in distribution and timing of precipitation, along with changing temperatures, bring about greater volatility in global agricultural production and markets. Growing competition for water resources and increased water pollutants are altering the hydrology, biology, and chemistry of streams, lakes, and rivers. Concurrently, long-term productivity of agricultural lands is reduced in many row crop fields due to soil erosion, compaction, and nutrient depletion. Each growing season, a series of invasive species, diseases, and pests challenge the practices put in place to control them, requiring ever more intensive management by farmers. End users and consumers will continue to demand efficient and economical production while desiring more varied and resource-intensive diets, biofuel feedstocks, and food security as populations grow and developing countries gain wealth (Garnett et al. 2013; Bennett et al. 2014).

The Upper Midwest, with its fertile soils and abundant rainfall, reported an unprecedented 384 billion kg (15.1 billion bu) of corn (*Zea mays* L.) harvested in 2016, with many state averages reaching all-time highs: Indiana at 10,859 kg ha^{-1} (173 bu ac^{-1}); Minnesota at 12,115 kg ha^{-1} (193 bu ac^{-1}); Illinois at 12,366 kg ha^{-1} (197 bu ac^{-1}); and Iowa at 12,742 kg ha^{-1} (203 bu ac^{-1}) (USDA NASS 2016). Record corn and soybean (*Glycine max* [L.] Merr.) yields in 2014 and 2016 have been paired with commodity prices that are the lowest in a decade resulting in cost of production estimates higher than prices paid to farmers.

Lois Wright Morton is director and Lori J. Abendroth is project manager of the Climate and Corn-based Cropping Systems Coordinated Agriculture Project, College of Agriculture and Life Sciences, Iowa State University, Ames, Iowa.

Looking backward and anticipating forward, the only constant is change. Markets are dynamic, continually fluctuating; and economies emerge, mature, decline, and transform. Scientific discoveries and new technologies make some farming approaches obsolete and inefficient, and rediscovery of past techniques, like cover crops, solve new problems and find acceptance and advocates. Managing change in agriculture requires constant attention to what is happening at the field, farm, and landscape levels; anticipating weather and climate conditions; and interpreting environmental, economic, social, and cultural signals to be prepared to re-solve, re-negotiate, and innovate in light of new information.

In this special issue, the sustainability of corn-based cropping systems in the US Midwest under changing conditions is explored. Researchers from the USDA–National Institute for Food and Agriculture (NIFA) Sustainable Corn Coordinated Agricultural Project (Sustainable Corn CAP) present findings on corn-based cropping systems to better understand how a suite of management practices affect the carbon (C), nitrogen (N), and water footprints under increasingly variable weather and climate. The local knowledge, experiences, and perceptions of midwestern farmers are woven throughout the work of this project, linking their specialized knowledge to the growing body of scientific findings to better assess the agronomic, environmental, social, and economic effects of producing corn.

SUSTAINABLE AND RESILIENT AGRICULTURAL SYSTEMS

Agriculture is fundamental for human well-being and a major source of environmental decline (Bennett et al. 2014). The need to increase production to achieve food security for all is only part of the sustainability equation (Garnett et al. 2013). Some agricultural intensification strategies developed to meet the needs of expanding populations, and improved output to input ratios have caused some managed ecosystems to cross critical thresholds—soil organic C (SOC) lost from lands not protected from wind and water erosion, freshwater resources degraded by too much N and sedimentation, and irrigation practices that modify hydrologic cycles and lead to soil salinization. These realities inevitability turn to questions about agricultural sustainability. How can we better respond to changing conditions in ways that support and strengthen agroecosystem functions and services? What are the practices and policies that create productive and profitable agricultural systems and concurrently promote the environment and improve the quality of life for farmers and society now and into the future?

The key to improving agricultural sustainability lies in enhancing the resilience of social-ecological systems, not in optimizing isolated components of the system (Walker and Salt 2006). Resilience is the ongoing capacity to adapt and adjust to disturbances, uncertainties, and shifting conditions without catastrophic loss of form or function (Park et al. 2013). While few people will deny that sustainable agriculture is critical to the future of our earth, "we are awash in conflicting definitions of what it means to be sustainable, how we achieve sustainability and the roles of science," technology, farmers, and agribusiness in fostering it (Beachy 2010). The 1990 Farm Bill provides a statutory definition that encompasses its multidimensionality: economic, environmental, and social (figure 1). The language of sustainability and the recent addition of the concept of resilience reflect individual and institutional goals, and have captured the imagination and resources of agribusiness, university researchers, and government agencies. The difficult work still lies ahead of us, however, negotiating the tradeoffs in evaluating integrated systems rather than their component parts and creating multiple pathways rather than single solutions to achieve sustainable, resilient agricultural systems.

Science has given us the green revolution; genomics, nanotechnology, and

Figure 1

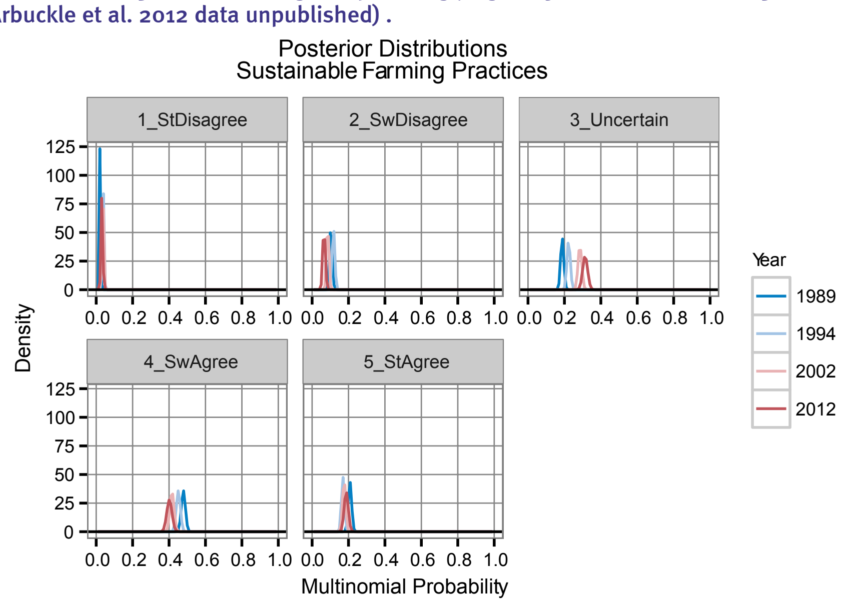
The 1990 Farm Bill definition of a sustainable agriculture system from Title VII, the Agriculture Title of the United States Code. Definitions are in Chapter 46, Research, Extension and Teaching (Beachy 2010).

The 1990 Farm Bill defines five outcomes of sustainable agriculture systems:

- Satisfies the human need for food and fiber
- Enhances environmental quality and the natural resource base upon which agriculture depends
- Makes efficient use of nonrenewable resources and on-farm resources and integrates natural biological cycles and controls
- Sustains the economic viability of farm operations
- Enhances the quality of life for farmers and society as a whole

Figure 2

In farmer survey data from the 1989, 1994, 2002, and 2012 Iowa Farm and Rural Life Poll, shifts to increased uncertainty from 1989 (18.8%) to 2012 (31.4%) primarily came from those who somewhat and strongly agreed. The question corresponding to the data shown read, "There is increasing public concern about the safety of some modern agricultural practices. What is your opinion of this statement? Increased use of sustainable farming practices would help maintain our natural resources. Rate your level of agreement or disagreement: Strongly disagree (1); somewhat disagree (2); uncertain (3); somewhat agree (4); strongly agree (5)" (Morton et al. 2013; Arbuckle et al. 2012 data unpublished) .



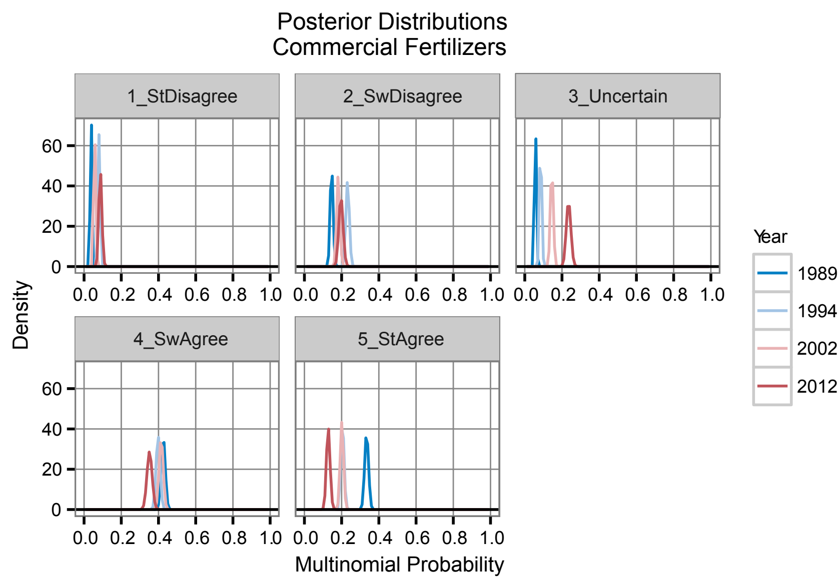
biotechnology; improved hybrids and cultivars to increase yield; finely tuned fertilization regimes; decision support tools to process weather data and optimize pest and disease management; and a growing array of technologies. These technological innovations have disproportionately favored production efficiencies with minimal advancement in addressing the environmental quality, natural resource enhancement, or social aspects of the sustainability goal. This shortcoming is reflected in longitudinal random sample survey data from 1989 to 2012 of Iowa farmers that reveals an increasing uncertainty over time about the relationship of sustainability to their farming practices (figure 2). The question is framed as "public concern about the safety of some modern agricultural practices," whether "increased use of sustainable farming practices help maintain our natural resources," and whether "modern farming relies too heavily upon commercial fertilizers" (Morton et al. 2013). In 1989, 69% of farmers agreed/strongly agreed sustainable practices help maintain our natural resources; 12% disagreed/strongly disagreed, and 19% were uncertain.

Twenty-three years later, 31% of farmers were uncertain whether sustainable practices help maintain our natural resources, and agreement dropped to 59% (figure 2). Concern about heavy dependence on commercial fertilizers decreased during this period; 76% agreed/strongly agreed it was a concern in 1989, but by 2012 less than half agreed it was a concern (48%) and uncertainty rose from 6% (1989) to 24% in 2012 (figure 3). These changes in farmer perspectives over time about sustainability and production inputs reveal a weakening connection among farm management practices, impacts on our natural resource base, and sustainability goals. Farmers seem to increasingly perceive productivity as separate from the environmental dimension of sustainability, and uncertainty is rapidly increasing.

This growing uncertainty is a window of opportunity for agriculture to rethink how we achieve the multidimensionality of the sustainability goal. Developing sustainable, resilient agricultural systems will require the following: (1) knowledge of which agricultural crops and management practices fit specific climates, geographies, and social-cultural contexts; (2) continuous monitoring that provides feedback enabling adaptive management strategies to be implemented rapidly; and (3) managers who are prepared to transform their operation and land uses when adjustments are insufficient and fundamental changes are necessary (Bennett et al. 2014). The genetics x environment x management (GxExM) framework proposed by Hatfield and Walthall (2015) offers an integrated strategy for realizing cropping systems' potential to "close the yield gap" and increase production to meet societal food and energy needs by using water and nutrients more efficiently and with ecological integrity. The revolutionary premise of this approach is the equal weighting given to human management with genetics and the production

Figure 3

In farmer survey data from the 1989, 1994, 2002, and 2012 Iowa Farm and Rural Life Poll, shifts toward increased uncertainty from 1989 (5.7%) to 2012 (23.6%) primarily came from those who somewhat and strongly agreed. The question corresponding to the data shown read, "There is increasing public concern about the safety of some modern agricultural practices. What is your opinion of this statement? Modern farming relies too heavily upon commercial fertilizers. Rate your level of agreement or disagreement: Strongly disagree (1); somewhat disagree (2); uncertain (3); somewhat agree (4); strongly agree (5)." Farmer change in beliefs about insecticides and herbicides show a similar pattern toward increased uncertainty from 1989 (5.3%) to 2012 (23.7%) (Morton et al. 2013; Arbuckle et al. 2012 data unpublished).



environment (e.g., soil, water, climate, etc.) in affecting the capacity to increase actual yields and overall productivity of the system. It follows that investments in evaluating management practices based on system- and landscape-level impacts in tandem with understanding farmer decision making are necessary if we are to redirect management decisions to support sustainability outcomes.

MANAGING CORN-BASED CROPPING SYSTEMS

The central theme of papers in this issue is the robustness of the agroecosystem and inherent productivity of corn-based systems. Specifically, authors examine variability in climate and weather; a variety of management practices; and C, water, and N footprints using field experimental data and modelling. Several papers pay particular attention to how farmers think about their management practices and the effects on yield, field conditions, and the larger agroecosystem.

During the 2016 growing season, Sustainable Corn CAP communication specialist Lynn Laws interviewed five midwestern row crop farmers (Laws 2017). In her paper, she offers a close-up look at what sustainability means to them and how it influences their management decisions. Each, in different ways, convey personal values and beliefs as they talk about the effort it takes to balance production and environmental goals and stay in business. Brian Boge from Isabella County, Michigan, explains, "Meeting the economic needs of my family through my farm operation and being accountable to our environment…sometimes those two don't mesh…I think about…this balancing act all the time." Nathan Clarke from central Michigan references the continuous monitoring needed to effectively adapt to changing conditions. He says, "We're always measuring soil fertility and keeping track of that," and explains how this information guides his management decisions in reducing tillage and increasing the use of cover crops. Tim Hoenert of Indiana describes sustainable farming as "a loop that keeps working, that doesn't in the process eliminate something that's vital in that loop."

There is appreciation for science and technology by these farmers, but an expectation that it be useful to them. "We can collect mountains of data," says James Droege of Indiana, but, "how do we put it all together to make some intelligent management decisions?" These farmers are active managers that are changing their management decisions as they observe changes occurring in their fields. Frank Bender, from southwest Indiana, talks about how his understanding of his soil has shifted from when he first initiated no-till and cover crops to slow erosion. He has moved to paying attention to the microbes and biological activities of his soil and reflects, "It's kind of evolved, where I'm more interested in what's happening underground…the erosion part…is probably 25%…; 75% is the benefit of the biological things that are happening in the soil and the aggregation...the structure…the water infiltration capacity—all these things that I will never understand but I see happening."

To understand how farmers overcome economic and agronomic challenges to achieve success with cover crops in corn–soybean systems, Basche and McNally (2017) invited 29 Iowa farmers to attend four focus groups in July of 2014. In their paper, they present a synthesis of these farmers' priorities and identify three areas where farmers think more research would improve their cover crop decisions: (1) revalue soil resources to better account for the economic benefits associated with cover crops at farm and landscape scale, (2) expand cover crop research beyond cereal rye (*Secale cereale* L.) to provide a wider array of suitable options, and (3) more systems-level cover crop research. Farmers especially wanted more multifactor experiments more closely resembling real life trade-offs they have to make between yields and environmental impacts.

The conversion of natural ecosystems to cultivated cropland has eroded the capacity to efficiently retain and sequester SOC, according to Olson et al. (2017). In their paper, they discuss the essential functions of SOC stocks and the interdependence of soil ecosystem services and human management. Degraded soils that have lost rooting depth, soil structure and aggregation, SOC, and that have reduced water holding capacity have little resilience to extreme rainfall events. As a result the soil has lower capacity to store water for crop use and there is an increase in soil crusting, runoff, sediment movement, and nutrient loss.

Soil properties and the effect from inclusion of a cereal rye cover crop in the corn–soybean rotation is the basis of experimental field trials in southeastern Indiana by Rorick and Kladivko (2017). They find water stable soil aggregates measured at 0 to 10 and 10 to 20 cm (0 to 4 and 4 to 8 in) increased over a four year period, evidence that cereal rye cover crop can increase soil aggregation and structure in a relatively short time. However, bulk density, water retention, total soil N, and SOC showed no change between cover crop treatments during this time period. They conclude four years is likely too short a time to detect increases in SOC and note that prior longer term experiments of eight years or more have shown an increase in SOC from cereal rye cover crops.

Winter cover crops have shown many environmental benefits such as improvement in nutrient cycling, water conservation, and erosion control. However, for cover crops to be a recommended practice that leads to sustainable corn systems, the effect on yields is particularly critical. Marcillo and Miguez (2017) offer a meta-analysis of 65 studies across the United States and Canada reported in peer-reviewed literature on corn yield response to winter cover crops. They find evidence that winter cover crops did not affect yields nor did they have the potential to increase corn yields. On average, they report grass cover crops neither increased nor decreased corn yields. Legume winter cover crops resulted in higher corn yields in general, and mixed cover crops increased corn yields by 30% when the cover crop was terminated zero to six days before planting corn.

Beehler et al. (2017) examine SOC accrual using cereal rye cover crops in topographically diverse terrain. Their Michigan experimental trials measured SOC, particulate organic C, and water retention on summit, slope, and depression locations. They find in slopes and summits the particulate organic C was greater with the addition of a cover crop. Like Rorick and Kladivko, they found no statistical difference in total organic C or soil water retention and similarly conclude longer experimental trials are needed to detect changes in these soil properties.

Soil organic C models are constructed using soil data from two long-term agricultural research sites in Ohio under no-till (NT) and plow-till (PT) with projected future climate change in the paper by Maas et al. (2017). Results vary by site and management; however, total SOC is projected to decrease at all sites in the topsoil layers under all management and climate projections. The only exceptions to this decrease was with NT at two sites and PT at a third under the low-emission scenario.

Selecting sustainability metrics to evaluate complex and dynamic corn production management outcomes is not easy. While SOC is place-based and observable, with rate of formation and rate of loss fairly easy to quantify, water quality metrics are less straightforward. Robert Anex, lead modeling scientist and life cycle analyst on the Sustainable Corn CAP has stated that water quality depends on biology and chemistry of the receiving water body and is not a simple mass balance. He further explains the timing and magnitude of discharges determines what can be absorbed by a water body, and the biological response is nonlinear and hysteretic. This means "one big pulse can irreversibly change the nature of the system and its ability to withstand future discharges." Several papers in this issue examine the hydrologic system under current and future climate and associated impacts on corn-based cropping systems. The practice investigated most widely involves drainage water management and the resultant effect on the water table, crop available water, nitrate-nitrogen (NO_3-N) losses to surface waters, and crop yield.

Using the DRAINMOD hydrologic model, Pease et al. (2017) simulate subsurface drainage discharge at a field site in the headwaters of the Western Lake Erie Basin using future climate patterns projected by 20 general circulation models (GCM). They determine that despite a projected increase in rainfall for this region by the late twenty-first century, subsurface discharge will likely decrease. The greatest decline was projected to occur during autumn and is attributed to increased temperatures and evapotranspiration occurring.

One solution for managing this redistribution of water in the water cycle is controlled drainage systems, which use outlet control structures to artificially raise and lower the elevation of subsurface drainage, and potentially retain more crop available water in the soil profile. Experimental plots in Iowa are used to evaluate the effects of shallow, controlled, conventional, and undrained drainage treatments on crop yields, soil water storage, and reduction of NO_3-N loads discharged to nearby streams in the paper by Schott et al. (2017). This five-year study finds controlled and shallow drainage reduced annual flow by 60% and 58% and reduced NO_3-N loads by 61% and 49%, respectively, when compared to conventional, free flow drainage. They report no effect on crop yields except for lower yields from the undrained treatment.

The influence of drainage on soybean seedling health is the subject of the Han et al. (2017) paper. Like Schott et al., they compare four drainage treatments at a field experiment in Iowa. This experiment offers an opportunity to compare the effect of subsurface drainage in 2012 (a dry year) and 2013 (a wetter than 2012 year). Root rot was greater in soils with no drainage or shallow drainage while *Fusarium* incidence was least in the areas where no drainage occurred. This difference is due to differing soil conditions favoring each with root rot occurring more under high moisture conditions while *Fusarium* were more frequently isolated on roots in well-drained soils.

The environmental benefits of conservation agricultural practices on runoff under different climate scenarios are explored using reverse auctions in the paper by Valcu-Lisman et al. (2017). A points system measuring the efficiency of five conservation practices in reducing N and P runoff are estimated using the

Soil and Water Assessment Tool (SWAT) in the Boone River watershed of Iowa. Using the points system, Conservation Reserve Program (CRP) and cover crops are identified as providing the greatest environmental benefits. They conclude that reverse auctions can be an effective public policy strategy for estimating field level conservation practice efficiencies in reducing nutrient losses.

To improve in-season nutrient management, farmers can benefit from tools to improve N fertilizer application to match crop demand. Improving the decision making criteria behind N sensing decisions, which then allow for higher prediction capabilities for appropriate synthetic N fertilizer rates in corn, is the objective of research by Barker and Sawyer (2017). They test and compare variable rate N management including split-N applications with a portion applied in spring followed by a portion applied in-season based on canopy sensing technology, and an N-rescue strategy that applies all expected N in the spring but adds more N if excess rainfall or other conditions occur based on canopy sensing in-season. They find that variable rate applications using remote sensing during the mid-vegetative stages (ten-leaf) are less likely to be accurate during drought conditions. They also report that canopy sensing was not able to detect adequate to excess N in ten-leaf (V10) corn, with both split application strategies leading to more N than the crop needed.

The last two papers use random sample survey methodologies to measure farm characteristics, perceptions of climate change, and how different structural and personal characteristics influence decisions to adaptively manage their farm operation. Uncertainty about the impacts of climate change and its effect on current agricultural practices is explored by Morton et al. (2017). They define uncertainty as to be unsure or have doubt about a situation, a person, or a decision; and they report that most midwestern farmers are conveying they need a lot more certainty about the impacts of climate change on their farm to justify making changes in their practices. Judgements of uncertainty are significantly associated with climate change beliefs, concern about heat stress on their crop, and their personal agricultural networks. The authors ask, how much certainty is required in climate change projections for farmers to justify investments in adaptation? In addition, can climate science deliver this level of certainty?

Arbuckle et al. (2017) build on a six-class typology previously published (Arbuckle et al. 2014) by measuring 33 observable farm enterprise characteristics, land management practices, and demographics. They conclude six types of farmers—the concerned, the uneasy, the uncertain, the unconcerned, the confident, and detached—look very much alike. Farmers who deny climate change is happening and do not support adaptive management have very similar farm characteristics and management practices to those that believe climate change is happening and they should do something. The authors conclude that agricultural partners, such as Extension educators and crop advisors, should use caution when looking to observable traits to facilitate audience segmentation.

ACKNOWLEDGEMENT

This research was funded by the USDA–National Institute of Food and Agriculture (NIFA), Award No. 2011-68002-30190, Cropping Systems Coordinated Agricultural Project: Climate Change, Mitigation, and Adaptation in Corn-based Cropping Systems.

REFERENCES

Arbuckle, J.G., J. Hobbs, A. Loy, L.W. Morton, L.S. Prokopy, and J. Tyndall. 2014. Understanding Corn Belt farmer perspectives on climate change to inform engagement strategies for adaptation and mitigation. Journal of Soil and Water Conservation 69(6):505-516, doi:10.2489/jswc.69.6.505.

Arbuckle, J.G., J. Hobbs, and L.W. Morton. 2012. Data from the 2012 Iowa Farm and Rural Life Poll, unpublished. Ames, IA: Iowa State University, Department of Sociology.

Arbuckle, J.G., J.C. Tyndall, L.W. Morton, and J. Hobbs. 2017. Climate change typologies and audience segmentation among Corn Belt farmers. Journal of Soil and Water Conservation 72(3):205-214, doi:10.2489/jswc.72.3.205.

Barker, D.W., and J.E. Sawyer. 2017. Variable rate nitrogen management in corn: Response in two crop rotations. Journal of Soil and Water Conservation 72(3):183-190, doi:10.2489/jswc.72.3.183.

Basche, A.D., and G.E. Roesch-McNally. 2017. Research topics to scale up cover crop use: Reflections from innovative Iowa farmers. Journal of Soil and Water Conservation 72(3):59A-63A, doi:10.2489/jswc.72.3.59A.

Beachy, R.N. 2010. Science and sustainability: The emerging consensus. BioScience (June) 60(6):406-407.

Beehler, J., J. Fry, W. Negassa, and A. Kravchenko. 2017. Impact of cover crop on soil carbon accrual in topographically diverse terrain. Journal of Soil and Water Conservation 72(3):272-279, doi:10.2489/jswc.72.3.272.

Bennett, E., S.R. Carpenter, L.J. Gordon, N. Ramankutty, P. Balvanera, B. Campbell, W. Cramer, J. Foley, C. Folke, L. Karlberg, J. Liu, H. Lotze-Campen, N.D. Mueller, G.D. Peterson, S. Polasky, J. Rockstrom, R.J. Scholes, and M. Spierenburg. 2015. Toward a more resilient agriculture. Solutions for a Sustainable and Desirable Future 5(5):65-75. https://www.thesolutionsjournal.com.

Garnett, T. M.C. Appleby, A. Balmford, I.J. Bateman, T.G. Benton, P. Bloomer, B. Burlingame, M. Dawkins, L. Dolan, D. Fraser, M. Herrero, I. Hoffmann, P. Smith, P.K. Thorntom, C. Toulmin, S.J. Vermenulen, and H.D.J. Godfray. 2013. Sustainable intensification in agircutulre: premises and policies. Science 341(July 5):33-34.

Han, G. Y.R. Kandel, L.F.S. Leandro, M.J. Helmers, L.R. Schott, and D.S. Mueller. 2017. Influence of drainage on soybean seedling health. Journal of Soil and Water Conservation 72(3):266-271, doi:10.2489/jswc.72.3.266.

Hatfield, J.L., and C.L. Walthall. 2015. Meeting global food needs: Realizing the potential via genetics x environment x management interactions. Agronomy Journal 107:4:1215-1226.

Laws, L. 2017. Agricultural sustainability: Five midwestern row crop farmers share their views. Journal of Soil and Water Conservation 72(3):53A-58A, doi:10.2489/jswc.72.3.53A.

Maas, E.D.v.L., R. Lal, K. Coleman, A. Montenegro, and W.A. Dick. 2017. Modeling soil organic carbon in corn (*Zea mays* L.)-based systems in Ohio under climate change. Journal of Soil and Water Conservation 72(3):191-204, doi:10.2489/jswc.72.3.191.

Marcillo, G.S., and F.E. Miguez. 2017. Corn yield response to winter cover crops: An updated meta-analysis. Journal of Soil and Water Conservation 72(3):226-239, doi:10.2489/jswc.72.3.226.

Morton, L.W., J. Hobbs, and J.G. Arbuckle. 2013. Shifts in farmer uncertainty over time about sustainable farming practices and modern farming's reliance on commercial fertilizers, insecticides, and herbicides. Journal of Soil and Water Conservation 68(1):1-12, doi:10.2489/jswc.68.1.1.

Morton, L.W., G. Roesch-McNally, and A.K. Wilke. 2017. Upper Midwest farmer perception: Too much uncertainty about impacts of climate change to justify changing current agricultural practices. Journal of Soil and Water Conservation 72(3):215-225, doi:10.2489/jswc.72.3.215.

Olson, K.R., M. Al-Kaisi, R. Lal, and L.W. Morton. 2017. Soil ecosystem services and intensified cropping systems. Journal of Soil and Water Conservation 72(3):64A-69A, doi:10.2489/jswc.72.3.64A.

Park, J., T.P. Seager, P.S.C. Rao, M. Convertino, I. Linkov. 2013. Integrating risk and resilience approaches to catastrophe management in engineering systems. Risk Analysis 33(3):356-367.

Pease, L.A., N.R. Fausey, J.F. Martin, and L.C. Brown. 2017. Projected climate change effects on subsurface drainage and the performance of controlled drainage in the Western Lake Erie Basin. Journal of Soil and Water Conservation 72(3):240-250, doi:10.2489/jswc.72.3.240.

Rorick, J.D., and E.J. Kaldivko. 2017. Cereal rye cover crop effects on soil carbon and physical properties in southeastern Indiana. Journal of Soil and Water Conservation 72(3):260-265, doi:10.2489/jswc.72.3.260.

Schott, L., A Lagzdins, A.L.M. Daigh, K. Craft, C. Pederson, G. Brenneman, and M.J. Helmers. 2017. Drainage water management effects over five years on water tables, drainage, and yields in southeast Iowa. Journal of Soil and Water Conservation 72(3):251-259, doi:10.2489/jswc.72.3.251.

USDA NASS (USDA National Agricultural Statistics Service). 2016. 2016 Corn Yield. Washington, DC: USDA NASS. https://www.nass.usda.gov/Charts_and_Maps/Field_Crops/cornmap.php.

Valcu-Lisman, A.M., P.W. Gassman, R. Arritt, T. Campbell, and D.E. Herzmann. 2017. Cost-effectiveness of reverse auctions for watershed nutrient reductions in the presence of climate variability: An empirical approach for the Boone River watershed. Journal of Soil and Water Conservation 72(3):280-295, doi:10.2489/jswc.72.3.280.

Walker, B., and D. Salt, 2006. Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Washington, DC: Island Press.