Opportunities for Technology and Innovation in Support of Small Businesses Connected with Agricultural Production[1]

Dr. Douglas Jackson-Smith and Dr. Casey Hoy
Initiative for Food and AgriCultural Transformation (InFACT)
The Ohio State University

January 9, 2020

I want to begin by thanking the subcommittee leadership for the opportunity to speak to this important issue. I am a professor of water security and rural sociology in the School of Environment and Natural Resources at the Ohio State University. I have spent my career studying the drivers and implications of technological change in agriculture. I also serve on the executive committee for the Initiative for Food and AgriCultural Transformation (InFACT[2]) at OSU – a large scale effort to bring together faculty from diverse disciplines with community partners to develop innovative solutions to pressing social, economic, and environmental problems faced by the US farm and food system. I speak today on behalf of my InFACT colleagues, but specifically in partnership with Dr. Casey Hoy, the Kellogg Endowed Chair in Agricultural Ecosystem Management and Faculty Director of InFACT, who contributed significantly to this testimony.

I will set the context for our recommendations first, and then discuss the opportunities to stimulate technological innovations to support small businesses and improve quality of life in rural America. A more detailed discussion of this context can be found in a recently published paper (Hoy 2015) that is included as an attachment to this testimony (see Appendix II). The key point is that many of the challenges faced by small businesses in the US agricultural economy stem from structural disadvantages they face when competing against large-scale specialized production systems that serve global commodity markets, that favor economies of scale, and that have contributed to an ongoing reduction in the number of people, crops, farms, and economic opportunities within agricultural ecosystems[3]. Although niche opportunities for small business in these systems do exist, they have struggled to keep pace with changes taking place in local and regional agricultural economies.

That said, there are reasons for optimism and excitement about the future for small and medium-sized farm and food companies. Changes in consumer preferences, expanding markets for food products that offer social, economic, environmental, or health benefits, and – most importantly for today's hearing – cutting edge technological innovations all provide a foundation for reinvigorating small businesses in rural America.

---

[1] Testimony submitted to the Subcommittee on Innovation and Workforce Development, Committee on Small Business, U.S. House of Representatives.

[2] See https://discovery.osu.edu/food-and-agricultural-transformation-infact for more information; also the 2-page overview of the InFACT program submitted as appendix I.

[3] In our work, agroecosystems include both farms, landscapes, and neighboring communities and have economic, social and environmental dimensions (Vadrevu et al. 2008)

Diversification of Farm and Food Systems

Based on our review of the relevant literature, a key area of opportunity involves the diversification of farm production systems and food supply chains. Diversification offers comparative advantages for small businesses to meet the needs of farm families, rural communities, consumers, and society.

As background, specialized commodity production farming systems are well developed and have contributed to significant gains in productivity and efficiency in American agricultural production (MacDonald and McBride 2009). Technological innovations associated with these systems have traditionally focused on increasing the amount that a single farmer can produce or, more recently, on reducing the environmental impacts from farming on the nation's land, water, and air resources. The result has been an abundant supply of relatively affordable food, feed and fiber in the United States, with significant surpluses for export to global markets.

These are important outcomes, but specialized and increasingly large-scale farming systems have also introduced risks and vulnerabilities to our economy and environment. Dependence on global markets has left farmers and agribusinesses vulnerable to trade wars and price swings and federal policies designed to protect farmers from weather and income volatility have become increasingly expensive. Specialized farming systems also rely heavily on purchased inputs, which have been an increasing percentage of the cost of production over time, keeping farms operating on slim margins. Fertilizers, fuel and agrichemicals are also that are likely to become increasingly expensive as traditional fossil fuel energy sources become more scarce. Specialized livestock and cropping systems can also create challenges associated with carbon and water footprints and nutrient losses to the environment (Deutsch et al. 2010; Foley et al 2011).

Specialization has also been associated with consolidation in the farm sector, leaving fewer people engaged with farming and more shifting to other industries where jobs in rural areas may or may not be available (MacDonald, Korb, and Hoppe 2013). The overwhelming majority of U.S. farm households now receive very low or negative net income from their farm businesses and rely heavily on off-farm jobs to sustain their household. The forecast for 2019, based on a November 27, 2019 Economic Research Service report, is for median farm income earned by farm households to increase slightly to -$1,440 in 2019, whereas median off-farm income is forecast to increase 2.2 percent to $67,281 in 2019.[4]

Consolidation in agribusiness input and processing firms has also reduced the number of locally-owned small businesses that support America's farmers. This has contributed to declining populations in many rural communities, with negative impacts on workforce, infrastructure, and quality of life.

It has become clear that continued reliance only on large-scale specialized farming systems will be insufficient to ensure viable rural populations, livelihoods and communities. Fortunately, there is evidence that small- and medium-scale farms and agribusinesses are finding a foothold in an emerging subsector of diversified food and farming systems.

[4] https://www.ers.usda.gov/topics/farm-economy/farm-household-well-being/farm-household-income-forecast/

Specifically, while growth in specialized farming systems has defined the transformation of the US farm sector since World War II, there are important counter-movements in the US farm and food system that provide opportunities for the emergence of a more diversified and resilient farming system in the future.

While production output is largely concentrated in the hands of a relatively small number of specialized large-scale farms, the vast majority of US farmers and farm families still operate and live on small and mid-sized farms that have found ways to survive even in the face of deteriorating economic returns. Farming is still the largest and most economically competitive economic sector of small businesses in the U.S. The persistence of America's family farms is a testament to the resilient spirit of farm operators and families, and the significant non-economic benefits that a farming way of life provides to households and rural communities. At the same time, growing reliance on the off-farm income noted above has increased the importance of non-agricultural rural economic jobs to the viability of small and medium sized farms in the U.S.

Equally important, in the last 20 years, a rise in consumer interest and awareness of how their food is produced has contributed to the rapid growth of new food supply chains and markets that provide opportunities for innovation and growth in the small business sector. These include production of food under quality certifications, organic certification being chief among them (with 9% growth in 2018 according to Nielsen Homescan data), growth in sales of food directly to local consumers and businesses, and growing attention to the use of diet and custom designed food products to address chronic health issues. In most cases, farm production and food distribution systems capable of meeting this new market demand will need to be much more diverse than those which defined the last half century.

In response to growing marketing opportunities and supportive public policies, we are seeing a resurgence in use of diversified farming systems in U.S. agriculture (Iles and Marsh 2012). These include farms that are incorporating cover crops and more diverse crop rotations, efforts to reintegrate crop and livestock production, production of niche and value-added products, and more reliance on agroecosystem processes to replace the use of synthetic fertilizer and pesticide inputs in agriculture. They also include food supply chains that are more diverse and better able to meet the specialized needs of different types of consumers.

To date, most technological innovation in modern agriculture has targeted large scale and specialized farming and food systems. Given the continued growth and opportunities in that sector, we expect this to continue to be the case. However, we believe that strategic public and private investments made today can make huge contributions to help grow and energize a parallel network of more diversified farms and food supply chains. Emerging technology and innovations surrounding diversified systems also provide unique opportunities to support small businesses and rural communities.

Today, we will highlight examples of technological innovations in three areas that could help support diversified farming and food systems and that provide opportunities for small businesses and employment growth in rural America. These three include innovations that:

- *Improve the performance of diversified farming systems*
- *Improve the linkages between farms and emerging markets, and*
- *Expand opportunities for small businesses throughout the diversified farm and food system supply chain*

Improve the performance of diversified farm production systems

While diversified agricultural systems dominated the landscape prior to the rapid expansion of specialized farming after World War II, the diversified farm production systems of the 21st century are not just a return to practices used on your great grandfather's farm. Improvements in scientific knowledge and technology have opened new windows into the complex dynamics of agroecosystems. There is a rapidly expanding research literature on how diversification can be leveraged to improve agricultural production. These include efforts to capitalize on ecological complementarities that reduce pest, disease and weed pressure (Hatt et al. 2018), improve soil nutrient cycling, and provide opportunities to improve environmental quality and farm profits simultaneously (Boody et al. 2005; Davis et al. 2012).

New technology and innovation can be a critical way to support greater diversification of farming systems, and to provide opportunities for small business development. Examples include:

1. Support for Farmer Innovation: Initially, there are literally tens of thousands of innovative farmers currently working on innovative approaches to diversify crop and livestock systems. These farmers represent a reservoir of practical knowledge that will likely be the foundation for many new discoveries and technological innovations in the coming decade. Adapting traditional ecological knowledge to modern production systems may provide greater benefits than adapting technology from large scale input intensive systems to smaller scale diversified systems. Efforts to support farmer research and experimentation, and to provide opportunities for farmer innovators to interact with each other (and with scientists) is one of the most productive ways to invest public dollars in support of agricultural diversification and to help small and medium-sized farm businesses thrive.
2. Develop new farm management support systems that can help farm operators take better advantage of the economies of scope found on diversified farms. Economies of scope reflect different economic advantages than traditional economies of scale (Bowman and Zilberman 2013). These include spreading market and weather risks across a more diverse portfolio of crops, taking advantages of opportunities to recycle nutrients between crops and livestock, and finding combinations of crops and enterprises that maximizes use of farm labor throughout the calendar year. Managing complex diversified operations can be difficult, and new digital technologies offer potential to help farmers organizes records and identify areas of

synergy (or minimize risks of negative feedbacks) that are required to achieve the potential economic advantages associated with diversification.

3. Use breeding and genetics to develop crop and livestock varieties optimized for diversified production systems. A century of crop and livestock breeding has produced varieties that are optimally suited to specialized production systems. Traditional breeding methods and cutting-edge genetic editing tools could be deployed equally well to develop new crops and livestock breeds that are optimized for complex crop rotations and integrated crop-livestock systems.
4. Better understand and use agroecological processes to address farm production challenges. Growing scientific understanding of the complexity of agroecosystems is opening doors for technological innovations that better utilize natural agroecological processes to meet nutrient requirements of crops, prevent weed, insect, and disease problems, and provide buffers against extreme weather events. Examples include techniques to manage the soil microbiome to improve nutrient use efficiency and address pest pressure and to better utilize livestock manures as a way to provide crop nutrients and build soil quality.
5. Use sensors and precision-farming data to help farmers use inputs more efficiently and adapt their diversified production systems to changing conditions in real time. Most of these technologies require access to a robust and highspeed internet system, which makes completion of a rural broadband network an essential goal.
6. Develop technologies that improve the labor experience on diversified farms. While economic profits are key to farm enterprise success, the viability of a farm household relies just as much on whether the farm can meet the lifestyle goals and needs of the farm family. Technological innovations that maximize the labor benefits (and minimize the burdens) will be as important as economic or production outcomes to the success of diversified farming operations.

Improve linkages between diversified farms and emerging markets

Success for diversified farms will rely on finding a thriving market for their products – particularly marketing opportunities that reward them for using diversified production practices. A growing number of technological innovations offer potential to make it easier for farmers to access these markets, and for food buyers to locate producers who use practices that they want to support. Some examples include:

1. Tools to track the performance of diversified farming systems. To access market premiums, buyers require confidence that the products they are paying for were produced using the methods they expect and generating the social and environmental outcomes they value, contributing to the health of agroecosystems in social and environmental as well as economic terms (Vadrevu et al. 2008). Recent innovations in environmental sensor technology provide real-time feedback about the agronomic and environmental performance of farming systems. Expanded access to affordable sensor and data networks are can improve the competitive position of small and medium-sized farms in the marketplace.

2. Improvements in the efficiency of certification processes. The paperwork and record keeping requirements associated with certifying that farm products meet the expectations of buyers can be a drain on scarce farm manager time and energy. New technologies and data systems that reduce the effort required to track key information (if scaled appropriately for small farms and businesses) could help reduce overhead and improve transparency in the food supply chain.

3. Tracking products through the food supply chain. Similarly, consumers in these new markets expect products they buy to come from farms using certain types of production practices, and this is commonly viewed as one of the benefits of a local food system. In an industry with so many small businesses, the challenges associated with tracking products throughout the entire supply chain can be daunting. New data management systems, in particular block chain technologies (see Appendix III), offer the potential to address these problems without placing undue burdens on producers, processors, and retailers.

4. Increasing opportunities for direct marketing. Many diversified farm operations can capture a larger share of the consumer dollar if they can sell directly to individuals and businesses. In the digital age, access to consumers often depends on having a robust and reliable presence on the internet. Innovations in rural broadband technology and support for small business commercial website software can help accelerate the growth of direct marketing opportunities for small and medium sized rural farms.

5. Expanded opportunities to market non-food benefits of diversified agricultural systems. While production of food, fiber, feed and fuel will always be the basis for an agricultural economy, there is growing recognition of the broader ecological and aesthetic benefits of diversified working agricultural landscapes. Efforts to develop and promote rural recreation and tourism, hunting and wildlife viewing, and other forms of agritourism can be important mechanisms to expand the impacts of farming on broader rural economic development. Technological innovations that help maximize these secondary industries include development of cropping and livestock management systems that maximize biodiversity and wildlife habitat, remote sensing technology to track landscape-scale land cover patterns, and new policies and institutions to help manage land use changes to maximize collective benefits without unduly constraining individual landowner choices. In the most direct example, carbon markets could provide new opportunity for farms and small businesses.

6. Capitalizing on the potential of food as medicine. Growing scientific evidence recognizing the connections between diet and health, and diversified farm production systems are well positioned to provide healthy and diverse foods that better meet the dietary needs of our population than the current food system delivers. Efforts to produce fresh foods that fulfill specific local prescriptions and direct sales from farms to hospital systems and other institutions would benefit from technology and innovations that reduce the overhead required to connect producers with consumers. There is also great interest in developing crops and other food products that are specifically designed to address particular health

challenges. With adequate technical support, diversified small producers would be well positioned to provide customized products for these emerging markets.

Expand opportunities for new businesses throughout a diversified food supply chain

While production agriculture sits at the core of any food system, it is important not to forget the critical role non-farm businesses play in providing inputs and information to farmers, and in processing, distributing, and retailing food to consumers. In fact, there are far more workers employed in the U.S. food system in these upstream and downstream sectors than there are working on actual farms. Although it may look different for diversified farms and horizontally integrated small businesses, the same association between farm production and many other associated supply chain businesses would be expected. As such, we also want to point to ways in which new technological innovations could provide opportunities for small businesses to thrive in the a diversified 21st century U.S. food system.

1. Innovative farm machinery designed for diversified producers. Diversified farms will require innovative new technologies to produce diverse crops and livestock at smaller scales. Small-scale manufacturing businesses would be well positioned to meet this new market demand. They can also play a role in providing niche parts (and many farm-based machine shops in Ohio currently do this even for global supply chains), specialized farming inputs, and value-added ingredients for diversified producers at local and regional scales.
2. Appropriate food manufacturing and processing technology for small- and mid-sized firms. Equipment that supports value added processing and manufacturing production across scales is feasible and under development.
3. Innovations in food safety monitoring and certification technologies offers the potential for small business entrepreneurs to help address potential threats to the safety of our food supply from a more decentralized and diversified network of producers. These innovations include new sensors and automated sampling technologies that are less labor intensive and more accurate than many current food safety monitoring systems. At the same time, it is critical to design monitoring programs and technologies that are accessible to and compatible with a distributed network of small-scale producers and food processors.
4. Logistics innovation could support greater energy efficiency in shorter-distance supply chains, with potential innovations including a wider range of transportation vehicles (the current system is very dependent on large trucks) and digital technology to optimize distribution systems.
5. Improve non-farm employment opportunities. Improved rural off-farm employment opportunities are critical to the well-being of small and medium-sized farm households because they provide a backstop that allows them to survive periods of adverse market and weather conditions. Technologies that support participation in the 'gig economy' in rural areas could provide livelihood options for producers and contribute to local economic development. Expanding programs that provide health insurance options for farm families would also reduce a source of stress for many diversified farm families that is responsible for many farm exits.

Broader considerations

While incentivizing technological innovation offers tremendous potential to support small and medium-sized businesses in a more diversified farm and food system, we believe it is important to reflect on the observation we made at the opening of our testimony: that context matters.

For decades, the dominant thrust of innovation and technical change in the U.S. farm and food sector has largely focused on specialized commodity production that tends to be vertically integrated in global supply chains. We do not believe that this will (or should) change in the coming years. However, because there is significant scale bias in the design and adoption of many new farm and food technologies, we are concerned that the trajectory of future technological change may not generate the opportunities for small businesses in rural economic development and improvements in farm household and farm worker quality of life that we all desire.

Fortunately, we know that public policy and targeted investments in research can help energize technological innovation and stimulate economic opportunities in areas where private sector investment is lacking.

With the rapid emergence of new marketing opportunities and growing scientific understanding of agroecological process, we believe we are at a crossroads where federal leadership in stimulating research and technological innovation around diversified farm and food systems could have a significant impact.

Examples of federal research programs that have made (and will continue to make) a critical difference include:

- USDA National Institute for Food and Agriculture competitive programs targeted at Small and Medium Sized Farms (A1601), Sustainable Agroecosystems: Health, Functions, Processes and Management (A1451), Inter-Disciplinary Engagement in Animal Systems (IDEAS; A1261), and Agricultural Microbiomes (A1402), as well as the major long-term research investments made in collaborative and interdisciplinary teams to study Sustainable Agricultural Systems (SAS).
- The USDA Specialty Crops Program – which supported development of digital tools to support a supply chain planning approach and that could also function as a clearinghouse for local and regional food system businesses (www.localfoodsystems.org)
- The USDA Organic Research and Education Initiative (OREI) and Organic Transitions Programs (ORG) that have supported collaborative research between farmers and scientists to test and innovate creative approaches to increasing diversification. Since organic farmers are prohibited from using many synthetic inputs, their production systems rely heavily on diversification as a strategy to address crop nutrient needs and prevent pest and disease damage. As such they serve as a natural laboratory for innovation around diversified farming practices.
- USDA-NRCS conservation programs that subsidize the costs of farmers seeking to diversify their crop rotations and deploy cover crops.

- USDA SBIR programs, that provide critical seed money to bring entrepreneurial ideas to commercial scale, and which we assume to be well known to the Committee.

Research universities can also play a critical role in doing the research and supporting technical innovations surrounding diversified farm and food systems. However, to be effective, we need to change traditional university disciplinary silos and training systems that produce specialized experts without a broader appreciation for the complexity of system dynamics.

There are promising examples of institutional transformation taking place at many land grant universities that should position them to be productive partners in this effort. For example, the Initiative for Food and AgriCultural Transformation (InFACT) at Ohio State is part of a broad effort to hire new faculty across several 'Discovery Themes.' These Discovery Themes all represent topics where interdisciplinary and applied expertise is required to solve major societal problems. In response to this challenge, Ohio State has hired over 150 new faculty members around these themes, with a particular focus on individuals who work at the boundaries between several disciplines. They are supporting these faculty to ensure they are rewarded for being innovative and entrepreneurial, and for collaborating with partners outside of the university, even when these activities deviate from traditional tenure and promotion review criteria. Approaches like the one being taken at Ohio State are the focus of a recent American Public and Land-Grant Universities report entitled "The Challenge of Change: Harnessing University Discovery, Engagement, and Learning to Achieve Food and Nutrition Security"[5].

Finally, technological 'fixes' alone will likely fall short in our goals to stimulate the development of a more diverse and robust food system (Reganold et al. 2011). A systems approach, from consumer demand across the entire supply chains to agricultural production practices, is needed to support healthier and more diversified rural economies. Much of the needed technology already exists and just needs to be recognized and applied. What is equally needed for this to happen are efforts to promote economic development models that are appropriately scaled and tailored for small and medium sized firms. This includes economic development approaches that support local and regional supply chain building, as opposed to the more typical approach of attracting one firm that is part of an existing global supply chain.

It can also involve creating new institutions to provide financial backing and support for creative innovation. As one example, InFACT is working with the Council of Development Finance Agencies to plan a first of its kind food system development finance agency, which would support both the public research needed to promote food and agricultural development, such as the supply chain and production innovations described above, and the financing for infrastructure that the evidence-based research supports.

Technology that supports the growth of diversified agricultural production systems can provide greater economic opportunity for more people along the entire supply chain. If well designed, it can support a range of scales of production from small and niche to

[5] https://www.aplu.org/projects-and-initiatives/international-programs/challenge-of-change/index.html

medium sized and diverse to large and specialized. Appropriate technology has the potential to improve rural livelihoods, build local and regional economies in which small businesses thrive, and help integrate these firms more effectively with global supply chains.

Technology that supports greater opportunity for more people and small businesses in rural communities could also alleviate other pressing needs, such as food security. Despite a bountiful supply of food, food insecurity remains a significant challenge in metropolitan regions that extend from the most rural to the most urban areas. In Ohio, diversified production systems have the potential to contribute improved diets and nutrition to a state population suffering from some of the highest rates of household food insecurity in the nation (ERS). Consistent with the specialization and simplification of agricultural economies, the dominant crops in Ohio are corn and soybeans grown for animal feed, not the foods that people need for improved food and nutritional security.

Our notes on the role of technology in improving agricultural economies are informed by and consistent with a recent report containing recommendations of agriculture and food system leaders in Ohio, entitled "Ohio Smart Agriculture: Solutions from the Land, a Call to Action for Ohio's Food System and Agricultural Economy" (Appendix IV). Farm community leaders, representing some of the smallest urban and rural Ohio farms to some of the largest crop and livestock farms in the State, were the most prevalent group represented on the steering committee that produced this call to action, and they were joined by leaders of environmental, food security, and policy sectors. We hope this consensus view from the heartland will be informative and inspirational to the work of your Committee and we greatly appreciate consideration of the future of our farming communities in your work.

References:

Boody, G., B. Vondracek, D.A. Andow, M. Krinke, J. Westra, J. Zimmerman, and P. Welle. 2005. Multifunctional Agriculture in the United States. *BioScience* 55 (1): 27–38. Doi: 10.1641/0006-3568(2005)055[0027:MAITUS]2.0.CO;2.

Bowman, M. and D. Zilberman. 2013. Economic factors affecting diversified farming systems. *Ecology and Society* 18(1):33. http://www.ecologyandsociety.org/vol18/iss1/art33/.

Davis, A. S., J.D. Hill, C.A. Chase, A.M. Johanns, and M. Liebman. 2012. Increasing cropping system diversity balances productivity, profitability and environmental health. *PLOS ONE* 7 (10): e47149. Doi: 10.1371/journal.pone.0047149.

Deutsch, L., M. Falkenmark, L. Gordon, J. Rockstrom, and C. Folke. 2010. Water-mediated ecological consequences of intensification and expansion of livestock production. pp. 97-110 in Steinfeld et al. (Eds), *Livestock in a Changing Landscape, Volume 1.* Washington, DC: Island Press.

Foley, J.A., N. Ramankutty, K.A. Brauman, E.S. Cassidy J.S. Gerber, M. Johnston, N.D. Mueller, C. O'Connell, D.K. Ray, P.C. West, C. Balzer, E.M. Bennett, S.R. Carpenter, J. Hill, C. Monfreda, S. Polasky, J. Rockstrom, J. Sheehan, S. Siebert, D Tilman & D. P. M. Zaks. 2011. Solutions for a cultivated planet. *Nature* 478: 337-342. doi:10.1038/nature10452.

Hatt, S., F. Boeraeve, S. Artru, M. Dufrêne, and F. Francis. 2018. Spatial diversification of agroecosystems to enhance biological control and other regulating services: An agroecological perspective." *Science of The Total Environment* 621 (April): 600–611. Doi: 10.1016/j.scitotenv.2017.11.296.

Hoy, C.W. 2015. Agroecosystem health, agroecosystem resilience, and food security. *Journal of Environmental Studies and Sciences* 5 (4): 623–35. Doi: 10.1007/s13412-015-0322-0.

Iles, A. and R. Marsh. 2012. Nurturing diversified farming systems in industrialized countries: how public policy can contribute. *Ecology and Society* 17(4):42. http://www.ecologyandsociety.org/vol17/iss4/art42/.

Kremen, C. and A. Miles. 2012. Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities and tradeoffs. *Ecology and Society* 17(4):40.

Lemaire, G., Franzluebbers, A., César, P., Carvalho, D.F., Dedieu, B., 2014. Integrated crop – livestock systems : Strategies to achieve synergy between agricultural production and environmental quality. *Agriculture, Ecosystems and the Environment* 190:4–8. Doi: 10.1016/j.agee.2013.08.009.

MacDonald, J.M., P. Korb, and R. Hoppe. 2013. *Farm Size and the Organization of U.S. Crop Farming.* ERR-152. U.S. Department of Agriculture, Economic Research Service. http://www.ers.usda.gov/publications/pub-details/?pubid=45110.

MacDonald, J.M. and W.D. McBride. 2009. *The Transformation of U.S. Livestock Agriculture: Scale, Efficiency, and Risks.* Economic Information Bulletin 43. Washington DC: USDA Economic Research Service.

Reganold, J.P., D. Jackson-Smith, S.S. Batie, R.R. Harwood, J.L. Kornegay, D. Bucks, C.B. Flora, J.C. Hanson, W.A. Jury, D. Meyer, A. Schumacher Jr., H. Sehmsdorf, C. Shennan, L.A. Thrupp, P. Willis. 2011. Transforming U.S. agriculture. *Science* Doi: 10.1126/science.l202462 .

Sulc, M. and B.F. Tracy. 2007. Integrated crop-livestock systems in the U.S. Corn Belt. *Agronomy Journal* 99:335-345.

Vadrevu, K.P., J. Cardina, F. Hitzhusen, I. Bayoh, R. Moore, J. Parker, B. Stinner, D. Stinner, and C. Hoy. 2008. "Case Study of an Integrated Framework for Quantifying Agroecosystem Health." *Ecosystems* 11 (2): 283–306. Doi: 10.1007/s10021-007-9122-z.

Appendices:

I. InFACT program overview
II. Hoy 2015 JESS article
III. NCAT report on Blockchain technology
IV. Ohio Smart Agriculture: Solutions from the Land