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FARMING IN THE 21ST CENTURY: THE IMPACTS OF AGRICULTURE TECHNOLOGY IN RURAL AMERICA

HEARING

BEFORE THE

SUBCOMMITTEE ON INNOVATION AND WORKFORCE DEVELOPMENT

OF THE

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FARMING IN THE 21ST CENTURY: THE IMPACTS OF AGRICULTURE TECHNOLOGY IN RURAL AMERICA

THURSDAY, JANUARY 9, 2020

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SMALL BUSINESS,
SUBCOMMITTEE ON INNOVATION AND WORKFORCE DEVELOPMENT,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:03 a.m., in Room 2360, Rayburn House Office Building, Hon. Jason Crow [chairman of the Subcommittee] presiding.

Present: Representatives Crow, Finkenauer, Kim, Davids, Veasey, Houlahan, Balderson, Chabot, Hern, Burchett, and Joyce.

Also Present: Representative Panetta.

Chairman CROW. Good morning. The Committee will come to order.

We thank everyone for joining us this morning to our first Small Business Committee hearing of 2020. And I want to especially thank the witnesses for taking the time to travel from across the country and take time away from their businesses in some instances to have this important discussion.

As is the case with these hearings, there will be members coming and going. There are overlapping hearings on other Committees, so you will see some folks come and go throughout and ask questions, so we just ask for your patience in bearing with that as well.

Farming and agriculture are at the heart of strong economies around the country. Investing in agriculture is crucial to ensure that our communities can thrive. Coming from Colorado, I understand the importance that farming and agriculture have on our state's way of life and economic well-being.

Nearly half of Colorado's 66 million acres are dedicated to over 30,000 farms and ranches, many of which are small, locally owned operations. Colorado is a leading producer of cattle, corn, wheat, and dairy, but Colorado's small farms are also raising everything from bison to ostriches and growing sunflowers, grapes, and mushrooms to name a few.

In the 21st century, technology and innovation are changing everyday life, reshaping how consumers shop, and how business is conducted. Modern farming is no different. Through advancements in robotics, sensors, artificial intelligence, GPS technology, and digital platforms, agriculture is undergoing a revolution and transitioning from the industrial age to the digital age. These inno-

vations, commonly known as agriculture technology, or ag-tech, provide an opportunity to help farmers increase yields and profitability while reducing waste and environmental impact.

Today's hearing will provide members with an opportunity to hear from innovators, farmers, and researchers about how ag-tech is helping farmers modernize their businesses and how entrepreneurship and innovation in ag-tech is changing our food and farming systems.

The increased use of ag-tech has the potential to address challenges our country and the world will face over the next century. Globally, the world's population is on track to exceed 9 billion in the next 30 years. According to the United Nations, this means our agricultural production will need to increase by 70 percent to meet the growing demand for food, fiber, and biofuels.

Meeting this global demand for food will be even more challenging in the face of climate change that is already impacting our food systems, water, and land. Changing temperatures reduce yields and increase pest pressures. Changes in participation patterns increasingly cause crop failure and production decline.

As a former Army Ranger, I have also seen how these threats, including scarce water resources and poor food security in other countries can have a profound impact on our own national security, readiness, and resiliency.

But the full potential of ag-tech to meet global food demands mitigate the negative impacts of climate change and create jobs in our rural communities will not be fully realized unless we fully support our farmers and innovators and the research that supports them.

Ag-tech can spur innovation and growth in rural parts of the country, but like many other sectors of the economy, agriculture is struggling to find and retain a skilled and stable workforce. To address this, I worked with my colleagues on both sides of the aisle to pass the Farm Workforce Modernization Act which will help create a reliable workforce for American agriculture. This legislation will help provide certainty for guest workers and for American farmers and ranchers, an important step in solving the labor challenge facing American farmers and ranchers.

There should also be robust funding of agriculture, research, and development at the USDA to support farmers in rural communities. I am proud that Colorado is a hub of ag-tech and innovation. Growing tech centers in the Denver and Boulder areas, funding opportunities through CoBank in my district, and a pipeline of talent from outstanding universities like Colorado State University and the University of Colorado systems have helped make Colorado the second largest ag-tech ecosystem in the country. As that pipeline develops the high-tech skills in food science, environmental engineering and precision agriculture, these specialists will lead the ag-tech industry forward.

Finally, it is crucial to mention the need for greater deployment of high-speed Internet in our rural communities. Outside of its importance in healthcare, education, and legal services, connectivity is the backbone of ag-tech. Broadband makes it possible for farmers to aggregate and analyze data in real-time while tracking commodity markets and operating digital technologies. Small busi-

nesses and farms across Colorado suffer daily from lack of access to high-speed broadband services due in large part to lack of investment. Reliable, affordable high-speed broadband is a necessity and why Congress must work to coordinate Federal resources and make investments in infrastructure projects.

Technology has become indispensable for all small businesses, and farmers and ranchers are no different. Small businesses play a vital role in providing products and services supporting America's digital farming revolution.

I look forward to hearing from our expert witnesses today on how farming is being impacted by technology and how R&D is impacting small business growth and entrepreneurship so that the U.S. can once again be the world leader in agricultural research and innovation.

And I would now like to yield to the Ranking Member, Mr. Balderson, for an opening statement.

Mr. BALDERSON. Good morning, everyone, and thank you, Mr. Chairman, Chairman Crow. I appreciate it. Happy New Year. And I look forward to a great 2020. I anticipate a great 2020 with another year of bipartisan camaraderie and innovation on Workforce Development Subcommittee.

Today's hearing will explore agricultural technology innovations that are modernizing our farms and revitalizing rural America. Having spent time working on a family farm myself, I understand the impact farmers have on their community and our Nation.

Agricultural technology, or ag-tech, is a broad term describing a diverse range of technologies, including bioscience, big data, analytics, automation and robotics, supply chain and logistics, and alternative business models such as hydroponics and meat alternatives. On farms, these technologies can increase productivity, reduce waste, and boost profits. On a larger scale, ag-tech entrepreneurship activities boosting rural revitalizing efforts by attracting startups, jobs, and investment dollars to agricultural regions. With the diversity of technologies involved, ag-tech attracts entrepreneurs and investors from various industries and geographies.

As we observe the astounding growth and impact of ag-tech ventures, we cannot lose focus on the primary stakeholders, our farmers. With uncertain markets and narrowing profit margins, farmers may be hesitant to take on additional risk that comes with new technologies. For example, an investment in precision agricultural systems include equipment purchases, installation charges, and precise precious time spent learning how to use and maintain these technologies. To be fully taken advantage of, the system must be compatible with preexisting machinery, Internet connectivity, and business model. To be worth farmers' investments, technologies must have a tangible impact on productivity and profit. As options rapidly increase, how do farmers determine what will work best for their specific business needs?

I would like to thank our witnesses for being here today and to talk about these experiences from ag-technologies and what resources are available to minimize the risk and maximize the benefits of investment. Thank you for being here today to represent this promising industry.

I yield back, Mr. Chairman.

Chairman CROW. Thank you, Mr. Balderson. And I agree with you on looking forward to 2020. We had some exciting wins and collaborations in 2019 and I look forward to continuing that in the next year.

The gentleman yields back.

And if Committee members have an opening statement prepared, we would ask that they be submitted for the record.

I would like to just take a minute to explain the timing rule. Each witness gets 5 minutes to testify and each member get 5 minutes for questioning. There is a lighting system in front of you to assist you. The green light will be on when you begin, and the yellow light will come on when you have 1 minute remaining. The red light will come on when you are out of time, and we ask that you stay within that timeframe to the best of your ability.

I would now like to introduce our witnesses. But before doing so, I am going to ask unanimous consent to allow Congressman Jimmy Panetta, who serves on the House Agriculture Committee to join this Subcommittee hearing.

Without objection, so ordered.

Welcome, Mr. Panetta.

Mr. PANETTA. Thank you.

Chairman CROW. Thank you for joining us today.

And I will actually yield to you to introduce our first witness.

Mr. PANETTA. Thank you, Mr. Chairman. I appreciate this opportunity to be here to speak about a very, very important issue. And thank you, Ranking Member Balderson. I appreciate both of your opening statements and agree with absolutely everything that both of you had to say. So thank you.

It is an absolute honor to be here. It is actually quite far away from where I come, not just in the Cannon Building but in California. I come from the Central Coast of California. And it is otherwise known as "the Salad Bowl of the World." Trust me, my fellow members on the Ag Committee get sick and tired of me saying that and they have heard me say it over and over. And now you get to hear me say it. But I say it with a lot of proud because there on the Central Coast of California, you name it, we grow it. We have hundreds and hundreds of specialty crops. There is a reason why we are not only "the Salad Bowl of the World," but we have "the Garlic Capital of the World." We have "the Artichoke Capital of the World." We have "the Berry Bowl of the world." We have specialty crops.

But as many of you know, specialty crops can be very difficult to harvest, especially crops take that human discernment when it comes to soft fruits and vegetables as to figuring out what is safe, what is ripe, what is ready to be picked, what is aesthetically pleasing to the consumer. Because as you know, most of the time those products, once they are picked, they go right into the cartons. Those cartons go right onto the shelves of the stores. And those cartons then go home with us and then those products go right into the mouths of our sons and daughters. And so it does take at this point a very skilled—you have to be very skilled in order to harvest this product.

Now, for a long time we have relied on humans to do that, especially on the Central Coast of California. That is why Jason, I com-

pletely agree with you, the Farmworker Modernization Act was a very, very important bill that I am proud to say has not only passed in a bipartisan basis in the House; it must be passed in the Senate and signed into law.

But in the meantime, the other avenue that we must go down is ag-tech, as you mentioned. But this type of technology for these types of crops, we are behind it. We are lagging. Now, do not get me wrong; I have been out in our fields there in Watsonville, and I have seen some pretty interesting things from some companies right over the hill from Silicon Valley, where I have seen machines take more pictures of a strawberry plant in one afternoon than all of the previous human history of taking photos of a strawberry plant. It is that type of technology that is needed. But more needs to be invested in this technology to do it.

And I think is why it is so, so important that we are having this type of conversation here in Washington, D.C., so that those types of investments in the fields, not just on the Central Coast but throughout this country, can benefit from the investment that is needed when it comes to ag-tech.

And so it is an absolute honor that I am here today with you, but also have the opportunity to introduce Mr. Kevin France. Kevin France is the chief executive officer of SWIIM Systems, a small business that provides on-farm agriculture water accounting. SWIIM has a satellite office in my district there on the Central Coast, and it partners with the Western Growers Association, which has one of its main offices in my district as well.

Now, under Mr. France's leadership, SWIIM has been recognized as a Top 25 Ag-Tech Company by Forbes Magazine. Mr. France, I thank you for being here, for your preparation, for your time, and all of us look forward to hearing what you have to say in regard to the investment that is needed and what has been done and what needs to be done when it comes to ag-tech. Thank you.

Thank you, Ranking Chairman, Ranking Member, Chairman, I yield back.

Chairman CROW. Thank you for being here, Mr. France, and Jimmy, you might have a lot of agricultural capitals of the world but I do not think you can claim the mushroom capital of the world because that distinction belongs to Ms. Houlahan sitting next to you. So I just wanted to be clear for the record.

Our second witness is Dr. David Potere. Dr. Potere is the head of GeoInnovation at Indigo Agriculture. He is a technology leader focused on building integrated applied science platforms using geospatial technology to tackle complex business challenges. For the past several years, he has focused on building a living map of the world's food supply. Using reliable maps, data, and metrics can help farmers grow crops that are more profitable and sustainable. Prior to joining Indigo, Dr. Potere was cofounder and CEO of Tellis Labs, which provided action agricultural intelligence across the food value chain using machine learning, remote sensing, and geospatial analysis. Dr. Potere has a Ph.D. in geodemography from Princeton University and served the country as a surface warfare officer in the U.S. Navy. Thank you for your service, Dr. Potere, to the country and for being here today.

Our third witness is Mr. Roberto Meza, a beginner farmer and cofounder of Emerald Gardens located in Bennett, Colorado. While a grad student at MIT in the Art, Culture, and Technology program, Roberto was inspired by student projects addressing food production in urban landscapes. His career quickly transitioned from the arts to agriculture with a focus on food access. After a hiatus working on farms and observing problems in our food systems, Roberto moved to Colorado with a childhood friend and started their own farm in 2017. Emerald Gardens grows, harvests, and distributes microgreens to restaurants, grocery stores, food pantries, and smaller retailers in Colorado's metro areas. They operate sustainably using geothermal and passive solar energy. Roberto is also the Chair of Membership and Outreach for Mile-High Farmers, the local chapter of the National Young Farmers Coalition and the Rocky Mountain Farmers Union. He is also a board member of the High Plains Food Co-op and is developing a model for Last Mile Distribution to help food co-ops and local producers gain access to markets. Thank you for taking time away from your business to be here today, Mr. Meza, and it is always good to see a fellow Coloradan in Washington, D.C.

I would now like to yield to our Ranking Member, Mr. Balderson, to introduce our final witness.

Mr. BALDERSON. Thank you, Mr. Chairman. I do want to acknowledge the Ranking Member of the Small Business Committee has joined us also, Ranking Member Chabot. Mr. Chabot, thank you for being here this morning.

I am sure a lot of you are looking and you see the witness list. Dr. Jackson-Smith and I have made an agreement. We are not going to do the O-h-i-o stuff. But we do want to acknowledge that though Ohio State is not in the National Championship, Joe Burrow is. That is where he got all his training, so Ohio State is still represented in the championship game coming up Monday evening. So I just want to make sure that everybody is well aware of that, and he lives from the southern portion of Ohio. So we are well represented.

Mr. CHABOT. Will the gentleman yield?

Mr. BALDERSON. Yes.

Mr. CHABOT. You mentioned Mr. Burrow. He may soon be a Cincinnati Bengal, too, which I happen to represent. We shall see.

Mr. BALDERSON. We shall see.

Our next witness—sorry, Doctor—Dr. Douglas Jackson-Smith, professor and assistant director of Ohio State University School of Environment and National Resources. He is here today as a representative of the university's initiative for food and agricultural transformation. Before joining Ohio State in 2016, Dr. Jackson-Smith served 15 years as a faculty member of the Department of Sociology, Social Work, and Anthropology at Utah State University. He has a bachelor's and master's degree in rural sociology, a master's degree in agricultural economics, and a Ph.D. in sociology. Trained as a rural sociologist, his research explores the dynamics of technology and structural change in agricultural and natural resource systems. He has helped lead $25 million worth of interdisciplinary science grant funding from USDA, NSF, and DOE. Dr. Jackson-Smith, we thank you for your research in this field and ap-

preciate you taking the time away from your work to be here with us today. Thank you.

I yield back, Chairman.

Chairman CROW. Thank you, Mr. Balderson.

In all due respect to the Ranking Member, Mr. Balderson, Dr. Jackson-Smith received his academic training from University of Wisconsin. So, go Badgers. Not to be outdone. Thank you very much.

Mr. France, you are now recognized for 5 minutes.

STATEMENTS OF KEVIN M. FRANCE, PRESIDENT AND CEO, SWIIM SYSTEM, LTD.; DR. DAVID POTERE, HEAD OF GEOINNOVATION, INDIGO AGRICULTURE; ROBERTO MEZA, CO-FOUNDER AND FARMER, EMERALD GARDENS; DR. DOUGLAS JACKSON-SMITH, PROFESSOR AND ASSISTANT DIRECTOR, SCHOOL OF ENVIRONMENT AND NATURAL RESOURCES, THE OHIO STATE UNIVERSITY

STATEMENT OF KEVIN M. FRANCE

Mr. FRANCE. Thank you, Mr. Chairman. Congressman, thank you very much, and other members of this Committee. I appreciate the opportunity to speak with you today on the impact of agricultural technology in rural America. And I appreciate this opportunity to share some of my experiences.

My name is Kevin France, and I am Chief Executive Officer of SWIIM System. My graduate and undergraduate degrees are in business administration, and my professional experience includes developing technologies through public partnerships that can be integrated into the private sector.

Prior to the "Internet of Things", also known as the IoT revolution, sensors were not generally connected to the Internet and as a result, data was gathered manually, normally by a grower, when time permitted in between growing. Now, sensors are being connected to the Internet and data is being made available in near-real-time. Growers need better access to this game-changing technology in order to sustain our agricultural economy in the face of ever-increasing water shortages.

SWIIM is an on-farm agricultural water accountant, twice recognized as a top 25 ag-tech company by Forbes Magazine, and we maintain a distribution agreement with Western Growers Association, one of the largest agricultural trade organizations in the Nation. Our clients are made up of growers of all sizes and shapes. We provide complete water use reporting, including applied and consumed water resources on a real-time basis by field and by crop.

Similar to the way your CPA provides a detailed statement of financial accounts—money in, money out, and from what source—we enable growers to quantify and protect their water allocations well into the future.

Our initial research was originally funded by private investment and underpinned by state water conservation grants. The technology was then developed over a 5-year period through an agreement with the USDA, Colorado State, and Utah State Universities. Our first issued patent was actually co-developed with the help directly alongside the USDA.

Depending on their location, a grower may have access to river water, access to groundwater. Some have access to both. Unlike other farming inputs, however, water is the only component to a farming operation that has no alternative source, and if not available, could put the farmer completely out of business.

By way of example, take the Colorado River—a prime surface water source for seven western states is over-appropriated by as much as 40 percent, leaving some farmers without water to grow the crops on which our Nation severely depends upon. Years of drought exacerbates this situation.

As another example, take California's recent passing of the Sustainable Groundwater Management Act to manage over-pumping of its aquifers. With these upcoming restrictions, at least 500,000 acres of farmland in the Central Valley of California will be without water most likely, which means no crops will be grown on those acres.

Our clients tell us they fear for their livelihoods and the legacy of their operations, many of which have been in their families for generations. Growers need access to updated technologies to fight the consequences of drought and lack of water availability that is widespread throughout the U.S.

The equipment we most often see in the field fails to provide the accurate water accounting needed today. We see roughly about one in five flow meters in the field are producing data that is off by as much as 25 percent and old-fashioned open canal measurements where they still use yardsticks to measure water levels being off by as much as 40 percent.

Consider what this means. Our experience shows us that many of the current funding sources available are geared toward research. These contributions are valuable, but the net sum result of many of these projects simply leads to more research without much private sector engagement, unfortunately. The USDA-NRCS has programs that are designed to help famers and irrigation districts implement technologies. They include EQIP and RCPP funding sources. These programs, although well-intentioned, are tough to plan around, as funding cycles do not track with grower needs and the application process is difficult to complete. Funds for these programs are managed and distributed generally on a regional basis making larger, more scalable projects that can benefit multiple regions more challenging to implement. We have seen this first-hand.

One promising example relates to a project that we are currently finalizing along the Colorado River in Arizona, with support from the Federal Government. The client is working with the Bureau of Indian Affairs and the Bureau of Reclamation (BuRec) to co-fund a SWIIM deployment in an area that will benefit significantly from this type of water use data. If this funding project could be expanded through a partnership with BIA and BuRec to multiple users along the Colorado River, then more meaningful scaling could be achieved.

To provide paradigm-shifting technologies and to facilitate the embracing of these types of technologies on a wider scale, funding sources must be flexible, and allow for approval on a project-wide basis across different regions, opposed to a region-by region basis as it is currently done.

Thank you for the opportunity to share this story with you today, and I look forward to answering your questions.

Chairman CROW. Thank you, Mr. France, for that testimony. And I would be remiss if I did not recognize that you are bringing your family here as well and it is my understanding it is at least your youngest daughter's first time in Washington. So welcome to our Nation's capital to the France family as well.

Mr. FRANCE. Youngest and oldest. Thank you, Mr. Chairman.

Chairman CROW. Right. Thank you.

Dr. Potere, you are now recognized for 5 minutes.

STATEMENT OF DAVID POTERE

Mr. POTERE. Thank you, Chairman Crow, other members of the Subcommittee. Thank you for the opportunity to testify in today's hearing.

You know, fundamentally, growing food has always been a venture of small businesses, and that is true here in the United States. Despite all that we hear about consolidation of farms, today in the U.S., no sector has a higher percentage of small business ventures than agriculture. And that is not only the farmers who are growing our food but the shippers and carriers that bring our food to market, the accountants and CPA, and agronomists and mechanics that help bring that crop out in the world. And, of course, small business is challenging. And no small business is more challenging than agriculture.

I come to you today as a technologist. I build technologies. I am not a farmer but I have been serving farmers for the last 5 years, building out a better system of agricultural intelligence using satellite and weather technology that is the result of hundreds of millions of dollars of government investment over the last many decades. And I am now proud to be a member of Indigo Agriculture, Inc., which is a company whose mission is to use technology to help farmers sustainably feed the planet.

There are many challenges that the farmers face today; we have seen 49 percent reduction in the profitability of farms since 2013. We are looking at a 400 percent increase in input costs for farmers over the last 40 years, most of that in the last 15. If you think about where that increase in input cost is going, it is not going to small businesses. Think about how challenging it is to market that grain out in the world. As an asset class, commodities futures is one of the most volatile asset classes on the planet, and farmers ever year have to figure out when and how to market their crop out into the world. It is hard to be small in the food system, and at Indigo, we believe that technology is a part of the solution to making farming a more valuable profession and by extension, making small business a more viable sector.

The two aspects of our business that I want to share most with you today are around bringing that crop out into the world via Indigo Marketplace, and learning how to grow a new kind of crop. Learning how to become a carbon farmer. We think this is one of the most hopeful things that we have heard of when it comes to the climate change story. Bringing farmers into the solution. It is true that farming represents 25 percent of carbon emissions but at Indigo, we believe that farming can be a definitive part of the solu-

tion for climate change because of the potential for agricultural soils to absorb carbon. It is really an old technology. It is called regenerative farming, and it basically means planting cover crops and letting what we all learned in eighth grade science take over. When it comes to photosynthesis, plants are really good at turning atmospheric carbon dioxide into soil carbon. We should let them do that and let them do that year-round by helping farmers move to a system where they plant crops during the winter, cover crops, that actually make the soil healthier, make the food healthier for human consumption, and actually create resilience for those farmers to better resist the changes of climate change, which if unmitigated look like they could create a 20 percent headwind when it comes to agricultural production in the country.

That carbon solution, it requires a marketplace, and Indigo Marketplace technology is designed to match buyers and sellers. And that is a real tough problem. I have sat at the farm gate with many, many farmers in my time at Indigo around harvest time trying to make that decision of where and when to sell their grain. They are not armed with the same technologies as the Big Ag companies that they are selling into. And we work to democratize the kind of market insights and intelligence that it takes to make smart, rational decisions at that key moment, including learning how to sell carbon.

One of the things that we wanted to make sure to mention today as we speak with all of you is an opportunity to support farmers in that chance to sell carbon. The thing we would like to observe is that for a decade now, due to changes in the Tax Code, oil and gas companies have had the opportunity to sequester atmospheric carbon as part of enhanced extraction. And the question we have for the Committee is if it makes sense at $50 a ton for the government to subsidize oil and gas to put carbon dioxide back into the ground, would it not make sense to allow farmers to do the same thing and to allow farmers to do that at lower cost per ton and do that in every rural community in America and allow them to become a part of the same solution that we know is so urgent for the planet?

So I will kind of leave you with that question. I look forward to answering your further questions.

Chairman CROW. Thank you, Dr. Potere.

Mr. Meza, you are recognized for 5 minutes.

STATEMENT OF ROBERTO MEZA

Mr. MEZA. Chairman Crow, Ranking Member Balderson, and members of the Subcommittee, thank you for the opportunity to testify today.

My name is Roberto Meza. I am a first-generation farmer and co-founder of Emerald Gardens, a farm located 15 miles east of Denver on 35 acres in Bennett, Colorado. My business partner and I operate a controlled environment, passive-solar greenhouse in which we cultivate herbs, edible flowers, and over 20 varieties of microgreens. Every week, we harvest more than 300 pounds of microgreens destined for restaurants, grocery stores, food pantries, public schools, farmers markets, and for direct delivery to consumers.

I am a member of Rocky Mountain Farmers Union (RMFU), which represents approximately 20,000 family farmers, ranchers and rural members across Colorado, New Mexico and Wyoming. I am also the Chair of Membership and Outreach of Mile-High Farmers, a co-chapter of Rocky Mountain Farmers Union and the National Young Farmers Coalition (NYFC).

My business partner and I are proud to be building our small farm with a focus on environmental stewardship, technology, innovation, and community engagement.

Microgreens are the primary crop of our farm and our labor of love. They have low input needs, have a quick turnaround time, can be grown year-round, and have a high nutrient density. It is through growing and incorporating microgreens into my diet that I experienced healing and renewal when I was struggling with personal health issues. Furthermore, they exhibit beautiful colors, have distinct flavor profiles, which make them highly sought after by chefs in restaurants and discerning consumers.

On our farm, we use innovative technologies that help us reduce our costs and be strong environmental stewards. Our greenhouse uses a passive-solar design that is both energy efficient, economically sensible, and environmentally friendly. It works by using clear polycarbonate material on the south side to let the light through, and insulated metal panels on the sides and the north wall to trap that heat. This allows us to charge our Ground to Air Heat Transfer System (GAHT), a design refined by Ceres Greenhouse Solutions, that is based on the principles of a climate battery. This allows us to channel that heat in the greenhouse through a series of tubes that run below the structure's foundation and allows us to reduce our reliance on auxiliary heating and cooling implements.

We grow vertically to maximize the use of our 3,000 square foot and use supplementary LED lighting to be energy efficient and cost-effective. Over the next few weeks, we will be installing 40 solar panels to power the lights and the fans in the greenhouse.

Also, as Coloradoans know very well, the state closely monitors water supply and use because of the arid climate. We use an automated recirculating water system to supply the roots only what they need while reducing evaporation.

Many people are still unfamiliar with microgreens. Social media is a critical tool we use to raise awareness about their nutritional benefits, as well as the important role they play in local food systems. By posting videos that show our farm practices and the technology we use in our production systems, it builds trust, transparency, and a deeper connection for consumers and their food source.

A major puzzle we have been working to solve is optimal distribution of our product. Emerald Gardens is a boot-strapped business, so unsurprising we have relied on some relatively low tech methods of distribution such as attending farmers markets. But we also have an online farm stand so customers can place orders from their smartphone.

For broader distribution, we have partnered with an innovative local grocery delivery startup, Bondadosa. Bondadosa allows us to deliver to all of our wholesale and retail markets through a single

weekly pick-up. We also looked to partner with Bondadosa to share data that helps us optimize their delivery routes. As technology advances, including agricultural technology, it is becoming increasingly important for today's farmers to have a college education. Indeed, it has become an asset on many farms as well as our own. A college education is out of reach financially for many and student loans are essential.

Unfortunately, student loan debt is one of several key factors preventing young and beginning farmers from getting or staying involved in agriculture. As a first generation and beginning farmer with my own student loan debt, I believe a Federal student loan debt forgiveness program is essential.

Looking ahead, we are excited by the opportunity to partner next year with a technology startup that will pilot new sensors in our facility. These sensors will generate data that will help us understand the microclimate in our greenhouse to increase the precision of our production methods. Support for technologies such as these, which can improve environmental and economic efficiencies are increasingly important within the context of our changing climate.

I want to close by saying that innovation is borne of struggle. While we face a myriad of challenges as small farmers and small business owners, we remain committed to a mission of feeding our communities, improving our farm and food systems, and remaining careful stewards of Colorado's natural environment. Technologies, both high-tech and low-tech, as well as grit and determination, are helping us get there.

Thank you for the opportunity to testify, and I look forward to your questions.

Chairman CROW. Thank you, Mr. Meza. And I know tomorrow is your distribution day. So I especially appreciate you flying out to do this today. It is always good to see you at the Stanley Marketplace.

Mr. MEZA. Thank you.

Chairman CROW. Dr. Jackson-Smith, you are now recognized for 5 minutes.

STATEMENT OF DOUGLAS JACKSON-SMITH

Mr. JACKSON-SMITH. Thank you. And I want to begin by thanking the Subcommittee for the opportunity to speak to this important issue. As your introduction pointed out, I am a professor of rural sociology and water security at the Ohio State University, and I have spent my career studying both the drivers and the implications of technological change for farmers, with a particular focus on small and mid-size farms in rural communities.

My comments today also reflect the contributions of a colleague, Dr. Casey Hoy, who is the Kellogg Endowed Chair of Agri-Ecosystem Management and the director of the initiative for Food and Agricultural Transformation (InFACT) that I can speak more about later, at Ohio State.

Many of the challenges faced by small businesses stem from structural disadvantages that they face when competing against large-scale specialized businesses that serve global commodity markets and benefit from economies of scale. With that said, there is reason for optimism for the future of small and medium-size farms,

agribusinesses, and food companies. Changes in consumer preferences, expanding markets for food products that offer social, economic, environmental, and health benefits, supportive public policies, and—most importantly for today's hearing—a whole raft of cutting-edge technological innovations provide a foundation for reinvigorating small businesses in rural America.

Specifically over 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 markets, and in response we are witnessing the resurgence of diversified farm and food supply chains in the U.S. This certainly includes farmers who incorporate cover crops and diverse crop rotations, reliance more on agro-ecosystem processes instead of synthetic inputs, and those who produce niche or specialty products.

It also includes small food supply chain businesses that are more nimble and better able to meet these emerging specialized needs of different types of customers. In our written testimony my colleague and I list many examples of innovations that could help support these diversified farm and food businesses, and for the sake of time I am just going to highlight a few in my oral comments.

First, there are innovations that improve the performance of diversified farms which we see as a foundation for this frontier. The diversified farming systems of the 21st century are not your grandfather's farm but rather improvements in scientific knowledge have opened new windows into the dynamics of agro-ecosystems and how diversification can be leveraged to improve farming. Some promising areas for innovation include support for farmer innovation. There are literally tens of thousands of farmers currently working to diversify their crop and livestock systems, and these farmers represent a reservoir of practical knowledge that you should start with and be a foundation for future discovery and innovation.

There are breeding and genetic engineering tools, both traditional and cutting-edge, that could be used to develop new crop and livestock varieties optimized for small scale and diversified production systems. And the use of sensors and precision farming data to help farmers use inputs more efficiently and adapt to conditions in real-time.

A second cluster of innovations might improve linkages between diversified farms and these emerging markets, and that would include tools to track the performance of diversified farms, innovations like the environmental sensors and tracking systems the previous speakers spoke to. Third, improving traceability. New data information systems, in particular block chain technology, could be harnessed to track products throughout a food supply chain without placing burdens on producers, processors, and retailers. And increased opportunities for direct marketing. In the digital age, connecting with consumers requires access and a reliable presence on the Internet, and the comments made earlier about the importance of rural broadband Internet, I think go no further mention.

Finally, there are innovations that expand opportunities for nonfarm businesses throughout this diversified system that we see. These might include innovative farm machinery companies, food processing technologies designed specifically to support diversified

production and small scale producers. It also includes food safety monitoring technology that could address potential threats to the food supply associated with a more distributed and diversified supply chain, including new sensors and automated sampling technologies that are less labor-intensive and more accurate than many current systems.

So big picture. While technological innovation can help small and medium-sized businesses thrive in a more diversified farm and food system, we are not working in a vacuum. For decades, the dominant thrust of technological change in the U.S. farm and food sector has focused successfully on large-scale specialized commodity production. I think without conscious public leadership in this space we are concerned that the future of technology may not generate the opportunities for small businesses and rural economic development that all of us desire. Fortunately, I think emerging markets, good public policy, and targeted investments in research and innovation and small business development can help energize the technologies we have talked about today and stimulate economic opportunities in areas where Federal leadership in stimulating research and innovation around diversified farm and food systems could have a significant impact.

And I thank you for the opportunity to address the Committee, and I look forward to your questions.

Chairman CROW. Thank you, Dr. Jackson-Smith.

I have appreciated everything that all four of you have shared with us today.

I will begin by recognizing myself for 5 minutes and start with Mr. Meza.

Mr. Meza, you have done something that not a lot of people are able to successfully able to do, and that is from kind of no background and experience in this area to jump in and start a small farming operation and to be able to survive your first few years. That is a very challenging statistically thing to do, and I would love for you to just share with us for a minute what advice you would share with other young folks that are looking at entering into the profession and doing this and your lessons learned, very briefly.

Mr. MEZA. Thank you, Mr. Crow.

My experience has definitely been challenging as you mentioned. I think one of the reasons why we have been successful is our involvement in our community, in our farmers union, working with extension offices, and also identifying appropriate technology and crops that are sought after in our community.

As you know, Denver is a blossoming culinary world but it also has an underdeveloped food system. So with those two factors in mind, we have targeted microgreens as a perfect crop to really address a lot of those factors. For us, it has been an opportunity to explore and research different models for how to create a niche for ourselves and how to create a viable business. With the support of our community and the solidarity with other farmers, it has allowed us to get to where we are today. I would say the backbone of our farm aside from technology is also the relationships and partnerships that we have established. So I would definitely advise

beginning farmers to collaborate, especially with their local community.

Chairman CROW. And I know the last time we had a roundtable together at the Rocky Mountain Farmers Union there was some discussion about what you mentioned on the burgeoning restaurant market. You know, we have added almost 50 percent population, almost 2 million more Coloradoans than the last 2 decades, which has led to a boom in the restaurant industry. But one of the biggest challenges is getting fresh produce to those restaurants in a timely way without them sitting on the shelf and having the spoilage. And I know some folks in the union are experimenting with online platforms to do that where a restaurant can order something up in real-time and get it within hours. Have you had experience with that, and are those platforms you think valuable?

Mr. MEZA. Definitely. These platforms allow us to have a really strong relationship and communication avenues with our markets and our buyers. Growing microgreens allow us to generate enough product every week to cover the immediate needs of chefs in restaurants. So we have been able to capitalize on the benefits of microgreens in order to satisfy the needs of our blossoming culinary enterprises.

Chairman CROW. And is there a role in your view for this Committee in helping young folks with the startup costs or the barriers on those platforms? Because, I mean, one of the things I love about this is you cannot outsource fresh produce; right? I mean, it has to be grown locally and produced locally and sent to local restaurants. So I think it is at great opportunity for us. But what are those barriers that you think folks like us sitting up here could help reduce?

Mr. MEZA. Absolutely. I think, you know, one of the challenges was accessing capital. When my business partner and I decided to start a farm in Colorado, we did not exactly know how to approach it. We did not know what products to grow, and we also wanted to be mindful of food waste. So for us it was an opportunity to research what the local menu is in our context. Microgreens became that crop that we focused on. And because of their ease of production and low input needs, we were able to bootstrap our operation in a very small, 150 square foot greenhouse that was adjacent to my initial property that I was renting in Colorado. And through that it allowed us to really connect with the markets that were emerging, especially through farmers markets.

Now that we have scaled to our commercial phase, we have realized that much more infrastructure and input needs have been required by our business model to be viable. So access to capital has been quite a challenge but we are bootstrapping it as we go along. This allows us to really understand the scale that is needed to address a lot of these factors and make our business viable.

Like I had mentioned before, student loans have been a factor in our ability to address the infrastructure needs of our business but we are optimistic and we are determined to innovate new models for helping younger farmers, especially since a lot of our aging farming population is experiencing this moment of transition. So we are trying to engage, inspire, and motivate the next generation of agriculturalists.

Chairman CROW. Thank you, Mr. Meza.

And I do have some questions for the other witnesses but I do want to spread it around a little bit before I loop back to all of you for a second round.

So my time has expired, and Mr. Balderson is now recognized for 5 minutes.

Mr. BALDERSON. Thank you, Chairman Crow.

I will start off with Dr. Jackson-Smith.

Doctor, according to a recent article in the Minnesota Times—excuse me, Minnesota Star Tribune—tractors built in 1980 or earlier are in high demand because the price to buy and maintain them is significantly lower than new high-tech tractors. Can you give us a brief interpretation of this trend?

Mr. JACKSON-SMITH. Certainly. And I can say I just retired my 1985 Toyota Corolla, which rusted out before the engine ever went, so I bond with those farmers. I farmed for 25 years, and when I farmed I understood the value of this kind of tier of technology.

My explanation for that ties into the fact that farmers at this small and mid-size tier have limited resources and a lot of cutting edge technology, especially when it first rolls out is beyond their reach or designed for scales that initially might exceed their capacity to take advantage of it, whereas technology from the '70s and '80s, certainly tractor technology, can do the job without having to be very expensive and difficult to acquire and maintain.

Farmers also farm for more than economic reasons. The quality of the labor experience, their ability to achieve independence is critical to farmers that I work with. And being able to work on your own tractor was why I kept that Toyota Corolla. I could fix a car that had a carburetor. I cannot fix my Toyota Prius. In fact, I am scared to touch the Toyota Prius engine.

So it is a very interesting observation but it does reflect, I think, both the lack of development of appropriate technology perhaps in the mainstream machinery industry historically and therefore, old tractors having a niche, but also an opportunity for manufacturers to get into that space and find ways to produce technology that is really targeted and suited to that kind of clientele. And there are manufacturers I think who are wising up to that.

Mr. BALDERSON. Yes, I agree. Thank you very much.

This next question I have is for the whole panel and you all can jump in however you may.

According to the Innovate Ohio statewide broadband strategy, 300,000 households in Ohio, representing approximately 1 million Ohioans lack broadband Internet access. As a member of the Small Business and Transportation Infrastructure Committees, I advocate for rural communities, including those in my district that suffer from crumbling infrastructure and inadequate Internet access. How does broadband access impact technology adoption for rural farmers?

Mr. POTERE. Ranking Member Balderson, I can make a comment from the prospective of Indigo Ag. We have had to build mobile technologies for farmers to validate the work they are doing on farm in order for buyers to pay a premium. We are trying to decommoditize grain agriculture. And that means we have to send agronomists and farmers themselves into the field to take notes on

what is happening. The lack of broadband access has required us as a technology company to build all of our apps resilient to a lack of Internet connectivity. The development costs of that and the missed opportunity around a two-way street of data flows for the farmer are just really mindboggling.

It is really interesting from a software developer perspective, we bring developers from all over the world to Indigo. They were shocked to deal with that engineering challenge because they are so trained on solving urban problems, it was a real moment to realize that the lack of bandwidth was going to mean developing against total blackout from a bandwidth perspective.

Mr. BALDERSON. Thank you. That is a good answer.

Sir?

Mr. FRANCE. If I may, I would like to second that. Our entire network has been developed based upon a cellular and satellite uplink because of the fact that in many of the regions we are in, there is not sustainable broadband. So we do use broadband where we can because there is a cost benefit to doing so. But it is a secondary backup. I mean, some of these areas, they are in the middle of the desert. You know, we are in areas where it gets to 130 degrees as a high, and then, of course, in areas of Colorado it is below zero. So that shift in climate over the year puts you in a position where not only do you have to have solid equipment that can sustain itself but also the connectivity to get to the web is still not there.

Mr. BALDERSON. Okay.

Mr. Meza?

Mr. MEZA. We have been lucky in our context in rural Bennett that we have incredible fiber-optic connections. It is an essential part of our business model because we are able to create a niche for ourselves and a market for ourselves through the use of communication of platforms by educating consumers about our product and connecting them with their food source. That is pretty much how we have been able to create this business for ourselves. And we also need this technology to utilize the sensor technology that we are using to mitigate any energy waste that we may encounter in our production methods.

Mr. BALDERSON. Thank you very much.

Mr. Chairman, I yield back.

Chairman CROW. Thank you, Mr. Balderson. The gentleman yields back.

The gentlelady from Kansas is now recognized for 5 minutes.

Ms. DAVIDS. Thank you, Chairman. And thank you for holding this hearing. Thank you to all the folks who came out here to testify on what I think is a really amazing opportunity for us on the Small Business Committee to be talking about issues that really touch on rural, urban, and suburban points of contact here.

I represent the 3rd District in Kanas, which is home to Garmin. So we have got a lot of the precision agriculture technology. You know, it is very important to the district I represent, but also, in my state there is really, I would consider there to be a big push toward the sustainable agriculture that you all have been talking about today. Johns County Community College has a sustainable agriculture program that I had the opportunity to go and visit. And

one of the things they brought up is how hard it can be for people to get into some of the types of farming that you have been talking about, the smaller farms, getting into some of the crops that people are less familiar with.

So I guess the question for anyone on the panel who wants to help enlighten us is how can we as the Small Business Committee or Congress help support that pipeline? And also, the technologies that I think—I am particularly excited about the carbon sequestration piece, but I would love to hear from you about how we can really impellent or make the programs that we have existing better for you all.

Mr. POTERE. Congresswoman Davids, I appreciate the question, and I will maybe address in particular the carbon opportunity.

Something we wrestle with is if this is such a win-win, you know, coming to a regenerative system means you can use less inputs, farm more profitably, make more healthy food and be paid for it, why have we not seen the transition; right? I mean, farmers are entrepreneurs. If it was that compelling, why are we seeing only 2 and 3 and 4 percent of all American farmers doing those things? And we think the barrier in large part is risk and know-how. So it is risky to change the model. And the model of conventional farming is well understood. And so anything that stretches conventional farming introduces risk. And so I would suggest that anything that Congress can do to create incentives around overcoming that first barrier is a game changer; once folks have been doing this for 2 and 3 years, it is actually a more profitable farm. But it is overcoming that initiation obstacle that seems to be a big part of the blocker.

Mr. FRANCE. If I may add to that. So SWIIM, we are in three states, and we have a staff of 30-something. So we are a small business as well. We have applied for state and Federal funding. Been successful in some cases. Failed in others. We find ourselves helping our growers may be 30 percent of the time use some funding mechanism to help integrate this type of technology, whether it is SWIIM-based technology or otherwise, some level of technology.

The other thing that we find as a barrier is the fact that these growers tell us over and over that they just want to grow. They are not in a position where they want to fill out paperwork. They are not in a position where they want to wait for funding. Many of the programs, at least the ones that we are involved in that are available create a disincentive to pre-deploy these types of technologies. Again, whether it is SWIIM or any other technology where one could apply for funding, the grower wants to get in on it now. If they do pre-fund, the available funding packages will not allow them to be reimbursed. So they cannot. And I am speaking specifically to EQIP. I am sure there are others. We have had growers just say flat out, I am tired of waiting. I want to get this water conservation technology in place. To heck with it, I am just going to deploy it myself. Over and over. We have actually helped our clients apply multiple times. And almost every single one of them have just moved forward and done it themselves. So a revamp of the process, maybe thinking outside of the box. You know, we have had growers say if we could just do one master application for all

of our fields in this one region we would do it in about 5 seconds. But one form for every single field? It is the same reason they do not want to monitor their water. They want to leave that to a professional. The same reason that we found pushback on these types of programs.

Thank you.

Ms. DAVIDS. Thank you. And my time is coming to an end here. I appreciate the tangible suggestions that you have. And I will reach out to the folks who did not get to answer this question to see what you have to say about it.

Thank you so much, and I yield back.

Chairman CROW. Thank you. The gentlelady yields back.

The gentleman from Tennessee, Mr. Burchett is recognized for 5 minutes.

Mr. BURCHETT. Thank you, Mr. Chairman. I appreciate the opportunity to be here, and I appreciate you all being here.

I have been involved in I guess an organic business. I have had a little composting, mulching business for a long time and I know, I guess, the learning curve I had to experience but also with regulations, they just make them up as they go. And so I am excited to see you all doing what you are doing.

I have a couple of questions. This is for the full panel.

How do American consumers affect ag-tech industry dynamics? And are they driving the expansion of this industry or are they continuing to learn how it works?

Mr. MEZA. Thank you, Mr. Burchett.

Mr. BURCHETT. You can call me Tim. We are good. I would appreciate it.

Mr. MEZA. In Colorado there is a really strong local food movement, and consumers are increasingly demanding products that are available locally, not only to receive the freshest and most high-quality ingredients, but also to limit the food miles that food has to travel to get to their plates. So we have been able to address that by the kind of crop that we grow. And not only that, but I think there is also this greater awareness of the participation we all have in establishing a sustainable local food system. It is really the ecosystem that we all partake in. Farmers, consumers, everybody that is involved in food. So it really is a driving force because we grow for the consumer. That is our primary goal. And for me it is really important to not only think of it in terms of a transaction but a reciprocal relationship; right? We see it as we take care of the plants so that they can take care of us, and then we can take care of the community. And that relationship has been the, I would say, intangible infrastructure that supports our entire business.

Mr. BURCHETT. I was glad to hear you say that. I am an organic gardener and I grow tomatoes and squash and green beans. And we have got blueberries and blackberries and raspberries. And it is all sort of conglomerated. And I remember when I started in my backyard it was covered in all kinds of stuff. And my neighbor, oddly enough, who was not in my political party, but told me I needed to spray it down with some chemicals. You know? And I hesitated. I was mayor of the county but I lived in the city, kind of confusing, but I adopted two goats and they were wonderful.

Even the neighbors ended up liking them, so I always thought I was going to get in trouble with the goat police if there were any but they were awesome. A lot of fond memories. They were Ray and Lucy. I named them after some friends of mine. I appreciate that. It is true. You can look it up. You can look it up. Neighborhood kids would come by. They would say, "Mayor, can we get a picture made with your goats?" And I would say, "Sure. Come on back."

They are great, man. They were just like a member of the family. I remember one time we were eating breakfast, my little girl Isabelle, I heard this chomping in the background. And I looked over and me and her mama saw that daggone goat had eaten the screen. And they do eat anything. I mean, anything. That is no lie. Had eaten that screen and she was feeding it Cinnamon Life through the kitchen window. But, you know, I love my girl so it could have come right in the kitchen for all I care. Mama would not have liked that but it was all right with me.

But anyway, back to my questions. That is good for ratings on C-SPAN by the way. They love that stuff.

What motivates or discourages small family farmers when they are considering new technologies? You know, when I was in my deal, I mean, I was strict on the environmental issues and it seemed like our universities, they did not like the organic aspect. And I found out later that a lot of the funding comes from some of the big boys who I taunt regularly on my Twitter page about, you kwon, my organic berries and stuff. And which I am sure it brings them to their knees. But the truth is that they get a lot of funding, these universities do from that, and so they sort of discourage the environmental thing. I know one of you all said you grew microgreens and other things, so I was kind of curious how that all played in.

You all just kind of jump in wherever you want to. Or just shake your head in disbelief.

Mr. JACKSON-SMITH. Since you pointed out universities, let me just jump in on this one. And I think the world has changed. Compared to 30 years ago, unversities are now very much focused, as is agriculture, on this sort of emerging, consumer-driven market. There was skepticism when I started my career about whether organics was the real deal and whether there is real science behind organic farming. It is now a $50-60 billion industry. And so that has woken up a lot of researchers to the possibilities of being in that space and helping to optimize those systems in the same way we have optimized conventional agricultural systems.

And I think for farmers, the area of diversification and regenerative agriculture is going to be the next frontier. It is complex. It is going to require a lot of support and targeted work but I think if I were to be self-serving, universities are going to play a role in helping solve and figure out some of those fundamental science dynamics of those systems that entrepreneurs and innovators will be able to develop into new technologies that can help farmers adopt.

Mr. BURCHETT. All right. I see I have run over my time once again but I really appreciate you all being here. Thank you in all sincerity. I dig entrepreneurs and we have got to encourage that.

We have got to encourage the university and through all these emerging new markets it is very encouraging.

Sorry, Mr. Chairman, I yield back none of my time.

Chairman CROW. Thank you, Mr. Burchett. I think everyone is disappointed that your time is expired, including me. Always one of my favorite——

Mr. BURCHETT. I know the viewers are.

Chairman CROW.—some of my favorite 5 minutes of all the Committee hearings. So I appreciate it very much. But I am sure you will go viral so, you know, we can watch it later.

The gentleman's time has expired.

The gentleman from Oklahoma, Mr. Hern, is recognized for 5 minutes.

Mr. HERN. Thank you, Mr. Chairman. I have no goat stories, but I did grow up on farms.

I thank the Ranking Member as well, and thank you all for being here today.

As a small business owner for almost 35 years now and job creator and all kinds of farming and ranching over the years, but I am also an engineer so I really appreciate technology and what it does to make our lives better, or confuse us, one or the other a lot of times. It has allowed for a lot of increased deficiencies and you have related to that in your testimony. And it is also, I am very familiar with IOT and what it has done for changing America, the legacy equipment we have out there.

You know, because small businesses start as numerous innovations and agricultural technologies to help aid American farmers, specifically these innovations have helped farmers to identify problematic factors impacting their crop productions, how to become more efficient, and you know, there has been a lot of conversation about more sustainable food production, the creation of a stronger resistance to environmental factors which is huge, to create more yield. To continue this success it is essential that we as elected officials are fostering growth for startups and small businesses rather than creating more barriers. One of the things, if you know the history of this Committee, it is a really bipartisan Committee that really works on trying to cut through all the politics of what is out there to really get things into the hands, ideas, and remove barriers for our entrepreneurs to go out and create a lot of jobs.

Unfortunately, a lot of times when we try, the government tries to get in the way, and I know a lot of times when you come here you are asking for the government to get involved, and we can also be the worst nightmare because everybody has a wonderful idea that tends to stifle growth and innovation. And one of these examples of the barriers stems from a 2011 study you may be familiar with which found that due to regulations, bringing a new plant biotech variety to market costs an average of $136 million and more than 13 years to complete. In an effort to reduce these burdens, both Obama and Trump administrations have called for reforming our agricultural biotech rules to reduce cost, improve efficiency, and reflect decades of safe use. That said, there is more that we can do to improve our regulatory environment. This is something I would like to ask each of you about.

So the question is in our 2-1/2 minutes, and we will just start right here and just kind of move down if you do not mind, do you all have thoughts and recommendations, specific or general, on ways we can improve the regulatory climate, remove unnecessary market barriers, or allow for better small business participation in this critical sector?

Mr. FRANCE. Sir, I would write a book on that if I could figure that out. It would probably be a best seller would be my guess.

But in all seriousness, as far as regulation goes, we have spent a lot of time in our particular area looking for ways to take already established programs and make them work for our clientele. So we are talking EQIP, RCPP funding through a third-party source, directly going to BuRec or BIA. I struggle with asking the government to come up with another program. I would suggest looking at the programs we have and giving more leeway to those that already have the ability to kind of look outside the box. For example, a lot of the USDA funding that is issued on a regional basis, you know, it is issued to regional offices if you will and they place it. If, for example, you found a project that spanned regions giving one person authority to fund all of those under the same terms and conditions, maybe flexing within the system that is in place would be my advice because I am not sure you would necessarily want to go in and try to create a brand new program. That is just my view.

Mr. HERN. Dr. Potere?

Mr. POTERE. We certainly feel the effects that you are describing. It is one of the reasons why we have pursued microbial technology, naturally occurring microbes that are in nature, amplifying those is one way. One of the reasons that is an attractive avenue for yield improvements is because of the barriers that you were talking about. So this is an example of the private sector reacting to those barriers.

And I would say also that the system of conventional farming is something that needs to change. And that is also not a regulatory-constrained avenue. So in our case, I think while we do face some of the constraints of regulatory approval for those microbes that we are developing, we found two promising ways kind of around that. So certainly verifying what you are saying around the challenges that it creates.

Mr. HERN. Thank you, Mr. Chairman. I yield back.

Chairman CROW. I will extend 2 minutes. I would actually like to hear the other two witnesses answer your question.

Mr. HERN. Thank you.

Chairman CROW. Yep.

Mr. HERN. Mr. Meza?

Mr. MEZA. Yeah, I think, you know, the first thing we need to do is go to farming communities and ask them what ideas they have. I think too often we as experts think that we have a program that is complete and that will remove and allow further development. But, you know, contexts are different everywhere. And so the only one that can really speak to those contexts are the farmers themselves. I think it is really important to take into account the specificities of each farmer and what they need and how they see the whole matrix of things working.

Another thing that I think would help is, you know, we all know that Big Ag has been subsidized. So we should be able to channel some of the funding into regenerative agriculture, new innovative models for producing food. And hopefully, we can come up with a nice brainstorming session that will yield some innovative models.

Mr. HERN. Thank you.

Mr. JACKSON-SMITH. It is a fantastic question. You stumbled into an area about which I know too much so I will be talking for the next 45 minutes, like any good professor.

No, actually, I have worked for quite a while on ag-technology. I started out when Bovine somatatropin (or bovine growth hormone) was a cutting-edge technology in the dairy industry in Wisconsin. And it was and still is a controversial and contested technology. And it was the opening salvo in an ongoing saga of genetic engineering being a political football or at least a very contested issue. And I think our regulatory system reflects that. I do not know anyone who thinks our current regulatory system on genetic engineering makes any sense. It is kind of like no one really likes our immigration system. But to find our way forward with genetic engineering regulation requires finding some middle ground, finding some balance, and coming up with a system that incentivizes careful scrutiny in places where it is necessary and recognizes that many of the barriers that have been put in place right now are preventing us from deploying technology for purposes that I think all of us would celebrate.

There are plenty of examples. We talk some about it in our longer written testimony, for example, innovations in cover crops that allow cover crops to succeed. They are a great idea but I know most farmers try them and find that it is more complicated than they were told. And that is because we have not had the ability to engineer and develop and breed cover crops that suite the diversity of climates and production systems farmers use. Biotechnology and genetic engineering could be a tool if we were able to confidently deploy that as part of our portfolio.

But I recognize, and I am sympathetic that the ways in which it has been deployed to date have not always percolated down into benefits for consumers or small businesses. And so the skepticism and concerns about biotechnology are real. But I think you are touching on an area where there is a bottleneck and a bottleneck that somehow we are going to have to see our way through in the future.

Mr. HERN. Thank you.

Mr. Chairman, thank you.

Chairman CROW. Thank you, Mr. Hern. The gentleman yields back.

The gentleman from Pennsylvania, Dr. Joyce, is recognized for 5 minutes.

Mr. JOYCE. I thank the Chairman for yielding and for the opportunity to discuss the opportunities that ag technology can bring to rural America.

First, I would like to take a moment to highlight a farm in my congressional district which has been incredibly successful in utilizing technology to improve their operations. Jan and Dan Turner own and operate Ewe Lamb Right Farm, an 80-acre farm in

Shippensburg, Pennsylvania, where they primarily raise hair sheep and lambs. Several years ago, Dan and Jan entirely relied on a system of spreadsheets and post-it notes to record the growth and any medication, vaccination, trimmings, other details relevant to managing their flock. The process to collect this data was tedious and it required them to access the sheep one by one, flip through pages of spreadsheets to find the corresponding records, and then input the updated relevant information into the spreadsheets.

To improve this process, the very innovative Turners joined the National Sheep Improvement Program and purchased a system which consisted of ear tags with an RFID chip and a handheld chip reader, as well as a Bluetooth enabled scale that works with the chip reader. This technology has allowed them to collect more data and do it in a fraction of the time. They have seen a remarkable 4-to-1 time reduction in the barn and a stunning 12-to-1 reduction in labor on data entry. More importantly, the Turners not only save time but the additional data enables them to improve quality of care to the flock and decreases the stress on the animals and the shepherds. In the words of the Turners, and I quote, "It is like having a farmhand who has X-ray vision and almost perfect memory." We can all agree that technology of this magnitude can be revolutionary for small and medium operations.

However, as noted by your testimony here today, major hurdles continue to develop and impede the deploying of those technologies. And this technology relies in a large part to broadband access. One of my top priorities since coming to Congress has been to increase and expand rural broadband deployment.

Dr. Jackson-Smith, you certainly have a broad expertise in this. Can you further elaborate on how a lack of reliable broadband limits opportunities available to small and medium farms that are looking to diversify, to modernize, and to improve their operations?

Mr. JACKSON-SMITH. I can. And I can speak about the goats that I used to raise. Not really. But the fact is that I used to live on a farm where we did raise goats and sheep, and we had dial-up Internet. And it sensitized me to the realities of what life in rural American is like for farming and being able to access cutting-edge technology.

For most developers of technology these days, they have very little exposure to agriculture, very little personal experience with the realities of what the working environment is like, the complexities of juggling all the demands of that task. Many come from urban areas. And so some of the comments made earlier about how surprised people are who have been working in tech development for 20 years, when they take on a rural project or an ag project, the realities of what Internet access is like. It is a huge issue. It is a tremendous barrier to being able to deploy things.

One of the strategies I think that we should explore more is to be able to get more entrepreneurs and innovators, and this speaks to workforce development, out on farms, out in rural communities before technology is hardened and developed to get an appreciation for what the clientele are like and where they have needs and where there are opportunities. I think it is a vastly under resourced place for us to spend resources and effort that would lead to things we could not imagine. We need a designed system. I raise

sheep. A designed system for a small scale sheep producer that fits with my budget, makes my life easier, and allows me to be more successful is exactly where we ought to be at.

Mr. JOYCE. Thank you, sir.

Thank you, Mr. Chair, and I yield back.

Chairman CROW. Thank you, Dr. Joyce. The gentleman yields back.

The gentleman from Texas, Mr. Veasey is recognized for 5 minutes.

Mr. VEASEY. Thank you very much.

I wanted to ask some questions for Mr. Jackson-Smith. I know that information that can help farmers make these decisions surrounding input and best management practices are very critical, obviously, to be able to maximize yields. As the digital technology and tools become more available, how do you think this is going to change farmers' behaviors as it relates to conservation?

Mr. JACKSON-SMITH. I think conservation is where we are going to see some of the major opportunities in terms of technology-driven, data-driven, information-driven decision-making. It requires the emergence of markets and incentives for conservation that allow farmers to get returns for those kinds of investments which often benefit society a lot more than they will benefit the individual operator. I think my comment earlier speaks to the fact that if not appropriately tailored to the needs of rural and small and medium-size operations, a lot of technology might not give us the benefits that we would like to think they can achieve. And so I think that is where there is a role for all innovation is going to come from the private sector. There is a critical role for small, and all businesses to innovate. But for the Federal Government or governments in general to build the infrastructure that creates the template in the 21st century for success, and rural broadband Internet is one of those key infrastructure investments that will never make sense to a Verizon Wireless company because there are not enough customers per mile but make tremendous sense in terms of us being prepared to be a key player and small and rural communities being a key player in the future.

But also, trying to train and develop a workforce that is capable of being sensitive to the needs of agriculture. I spoke in my oral comments about getting farmers more involved in research. And I went by it quickly, but I have come to the opinion that conservation innovation is going to go a whole lot faster if farmers are there at the very beginning of the process to help design solutions than if we work from the outside and innovate and then try to sell things to farmers. And so I think supporting programs that embed farmers with universities, I do that every day in my work, but also embed entrepreneurs in businesses to a greater extent in farming and rural communities will be some of the hidden ways we can really accelerate innovation in that space.

Mr. JOYCE. Do you think that innovation of the space is embraced by people in agriculture, or is it something that has to be sort of gradually, you know, sold to them? Or is it something that people are very open to? Or is it more of a hard sale?

Mr. JACKSON-SMITH. So I am a social scientist. I get the phone call from my technology-oriented colleagues who say we have

invented something. Farmers do not use it. You come along, wave your magic sociology wand, and tell us how we can better get people to do that.

I have learned to turn that question back and say, well, I have always found that things that work are pretty easy to convince people to use. If you have designed something that really solves a farmer's problems or fits with the kind of context they are making decisions, it is a whole lot easier to get to that adoption.

It is simple think that farmers do or do not want to do conservation but it is actually a lot more complicated. I have rarely met farmers who do not want to do conservation. Ubiquitously, people are very sensitive about their environmental footprint. They want to be good stewards. They want to leave the land in better shape than they found it. That is what agriculturalists are like.

When farmers are not doing conservation, it is usually for reasons that make sense. There are costs that exceed anything they can afford without returns that compensate for that. Or technologies that sound better than they might actually operate, like in the cover crop arena. We need to do a lot more to make cover crops be something. And when we design solutions I think in partnership with farmers, we are going to find that the end of convincing people, of telling people and educating them is no longer going to be the barrier. It is really something that tends to unfold on its own.

Mr. JOYCE. Thank you.

I yield back.

Chairman CROW. Thank you. The gentleman yields back.

The gentlelady from Iowa, Ms. Finkenauer, is recognized for 5 minutes.

Ms. FINKENAUER. Thank you, Mr. Chair. And thank you guys all so much for being here today. I know some of you have traveled pretty far to be here and it means a lot. And as the Chair said, I am a congresswoman from Iowa. I represent Iowa's 1st Congressional District. It is 20 counties in northeast Iowa. We touch Illinois, Wisconsin, up to Minnesota, and innovation and agriculture is huge for us. And doing it right and making sure that our folks in Iowa and to have access to the innovation is one of our top priorities, but also something that we struggle with because of our lack of access to broadband, which I know you guys have touched on quite a bit today. But I think it is just important to keep hammering this home why this is so important.

You see, in my district, it was about 3 months or so ago, I had FCC Commissioner Jessica Rosenworcel, or Rosenworcel up to Iowa One. We went to a farm in Dyersville, showed her some of the new equipment that was out there in regard to precision ag. But then also as we were sitting there and, you know, she was talking to some of the young farmers in the area as well. One of the guys came with his dad who I think he just got out of ISU and he is trying to show her on his iPad the operation they have. They are pork producers. For their feeding operation. And as he is pulling out the iPad to show her, the thing will not load. And it was just a perfect example about why we have an issue when it comes to folks having access to the innovation that is already here. But also what that means in the long run as well about what we are going to be missing out on if we do not get this right sooner than later

when it comes to broadband and making sure that our farmers have reliable connectivity and fast connectivity.

And I know, Mr. Potere, I know you spoke about this, you know, doing some innovative work on trying to create apps or different things that would make it so that if you had low connectivity it would still work. And I think that is great. But what I would like to know is what are we missing out on right now because we do not have the high-speed connectivity reliably throughout the country? And what would that actually mean for innovation if we had that so you could focus your work on apps and other things that could do even more versus on trying to bring them down to where they work on low connectivity?

Mr. POTERE. Congressman Finkenauer, I think I am going to highlight three examples of the things we are missing out on.

What we have today is essentially a one-way street where we build apps that are resilient so we can log a bunch of data, and then once you get to a broadband area, dump it back out into Indigo servers. And so that means it is a one-way street. And so we are not able to provide agronomic decision support to the farmer the way we could so that they are getting drone imagery in near-real time of critical moments in that crop's lifecycle. So there is a disadvantage around the farmer decision-making. They are missing out on intelligence they should have.

There are also consumers who are missing out. Consumer preferences are such that, as Dr. Jackson was saying, they are changing. And consumers are increasingly ready to pay for decommoditized agriculture. At Indigo, we have done deals with companies like Anheuser-Busch, sourcing sustainably grown, low water, rice, but you have to verify that the farmers are doing what they are saying. And if there is no connectivity, if you are in a black zone, you cannot do that.

And I would say the last example is those experiments that Dr. Jackson-Smith was talking about involving farmers. Every day, there are millions of experiments as farmers decide what to plant and when to plant it. If we are not watching, we cannot allow them to participate in this experiment. In Indigo, we fight that by trying to instrument as many of those fields as possible and watching them from space. But that is a half measure. You know, the reality of prevalent broadband would be that all three of those things I think get a lot better and just accelerate us.

Ms. FINKENAUER. Well, thank you so much. And again, I appreciate you all taking the time to be here today. This is such an important topic.

And thank you, Mr. Chair, for holding this hearing.

And with that I yield back.

Chairman CROW. Thank you. The gentlelady yields back.

I would now like to recognize the gentleman from New Jersey, Mr. Kim, who is also the Chairman of the Subcommittee on Economic Growth, Tax, and Capital Access, a relevant Subcommittee for this discussion as well, for 5 minutes.

Mr. KIM. Thanks, Chairman.

I just wanted to dive into a few things. You know, this is critically important to my district. We have nearly 1,000 farms in the New Jersey 3rd Congressional District. You know, making farming

more efficient and profitable in industries, something I care deeply about, the technological advances that you join us to speak about certainly sound really promising here. And I am trying to think about how best this can be implemented.

I guess my question is, you know, Dr. Potere, I would like to start with you. I guess my initial questions are, what can be done to help farmers successfully transition into more technologically driven farming practices? And as we know that with the advent of technology into different industries that we have seen in other sectors, you know, sometimes that transition is difficult both in terms of taking on the resources, being trained up, things of that nature. So what can we do to decrease the burden upon farmers to integrate this type of technology into their lives and their work?

Mr. POTERE. Congressman Kim, I appreciate the question.

You know, we should realize that we are incenting farmer behavior with billions of dollars of tax and other kinds of subsidy. And the question is how could we direct some of what is already out in play towards more of these sustainable beneficial ag practices?

I mentioned just one example I will spend a moment with you on which is this carbon tax concept. For us, the question is we have decided a decade ago that it makes sense to incent oil and gas companies to sequester carbon dioxide as part of enhanced extraction techniques. It costs of $50 a ton to do that. We think that for a fraction of that cost, farmers can put the same amount of carbon dioxide into the living, agricultural soil.

So the question is, would it not make sense, should we really care where those carbon that is being pulled out of the atmosphere is going? We have done some math and it is why we have created what is called the Terraton Initiative. It is a challenge to sequester a trillion tons of carbon dioxide equivalent into agricultural soils all over the world. That is all of the carbon dioxide that has been emitted net since the beginning of the Industrial Revolution. So literally, farming has the potential to be a solution to the climate problem.

We have farmers on all of that land and, you know, Dr. Jackson-Smith is right. Cover crops and regenerative agriculture, it is not easy. It is going to take technology to help those farmers understand a new sort of a digital playbook of how to do this well. But the reward, if the government can help incentivize that kind of behavior, is really hopeful. It is putting the farmer as the hero in the climate challenge. And we think it is time to start to put incentives in place to make that happen.

Mr. KIM. I appreciate your answer there.

Dr. Jackson-Smith, I just have a question for you.

I really enjoyed in your presentation just kind of the breakdown of how to look at this in terms of what technology can do on this front. And I would like to just delve in a little deeper. In my district, you know, our district got crushed by Superstorm Sand. In New Jersey we have a lot of temperature flux as we see the challenges that are arising with climate change and extreme weather. This is a real problem for farming in our district. We know cranberries and blueberries are particularly sensitive to that kind of change in temperatures, and flooding is something that is just get-

ting worse and worse. It is not just about when storms come. It is really a daily occurrence in many places.

So I guess my question to you is, how can technology help lessen some of these harmful effects, the impacts of such events, as well as increase the resiliency of when we were looking at farming?

Mr. JACKSON-SMITH. So I think one, easy, big picture answer lies in the concept of diversifying our production systems. So to the extent that we look more towards agroecosystem based solutions, we are going to need farmers and farming systems that produce a wider range of crops, that have soil building practices that give them resilience in the face of extreme weather events that we know is possible. And we are going to have to develop the technologies in the markets that allow that to be a viable and expanding and exciting opportunity. And so I think it is that combination of putting the package together to take us to that next generation of agriculture that is going to show up as a more robust and resilient agricultural community in your district. To the extent that we can help those farmers make that transition in ways that make sense to them we will succeed.

Mr. KIM. Yeah, well, look, these are all things that we will have to work together to do.

Chairman, I yield back.

Chairman CROW. The gentleman yields back. Thank you very much.

We want to thank all the witnesses for taking time out of their schedules to be with us today on this really important topic, and there was really fantastic testimony on the issues that we all look forward to working on and trying to find ways to help the industry.

As we have heard today, small businesses are at the forefront of the ag-tech revolution as both producers of exciting new technology and as farmer and rancher users become more efficient and sustainable over time helping that transition to occur.

In the 20th century, the United States public investment in agriculture, research, and development was a driving force behind innovation and increased efficiency. Yet, U.S. public investment in agriculture, research, and development has decreased steadily since 2002, being surpassed by China actually in 2008.

So I am going to thank our witnesses for being here today to share the challenges and opportunities to help reverse that trend and make really smart and wise investments. I think we all view our role here and there is great collaboration. And this Committee is trying to find ways to reduce barriers and to help spur innovation in the private sector, the public sector, and at research institutions and universities as well. There is tremendous work going on. I think we all recognize that and we want to be helpful in reducing the hurdles and barriers so that that can continue.

So I would like to ask unanimous consent that members have 5 legislative days to submit statements and supporting materials for the record.

Without objection, so ordered.

And if there is no further business to come before the Committee, we are adjourned. Thank you.

[Whereupon, at 11:36 a.m., the subcommittee was adjourned.]

APPENDIX

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Testimony of Kevin France, Chief Executive Officer
on behalf of SWIIM System, Ltd.

Farming in the 21st Century: The Impacts of Agriculture Technology in Rural America

Before the House Committee on Small Business
Subcommittee on Innovation and Workforce Development Hearing

January 9, 2020

Thank you, Madam Chairwoman and other members of this committee. I appreciate the opportunity to speak on the impact of agricultural technology in rural America and I appreciate the opportunity to share some of my experiences.

Background

My name is Kevin France, and I am Chief Executive Officer of SWIIM System. I have significant experience related to agricultural-based ventures, specifically with regard to water rights policy. My graduate and undergraduate degrees are in business administration and my professional experience includes developing technologies through public partnerships that can be integrated into the private sector.

SWIIM is an on-farm agricultural water accountant – twice recognized as a Top 25 ag-tech company by Forbes Magazine. We maintain a distribution agreement with Western Growers Association; one of the largest agricultural trade organizations in the nation. This agreement ultimately led to a ground-breaking investment by Western Growers in SWIIM. Part of the reason for this investment is they believe that one of the keys to the sustainability of agriculture lies with growers being able to quantify and protect their water allocations into the future.

Our clients are made up of growers of all sizes – individual farmers to corporations, as well as irrigation districts. We provide complete water use reporting, including applied and consumed water resources, on a real-time basis, by field and by crop. Similar to the way your CPA provides a detailed statement of financial accounts – money in, money out, as well as from what source. We enable growers to quantify and protect their water allocations into the future.

Agricultural Technology Impacts

There are a variety of technologies available in the marketplace that tracks water flow, soil moisture, crop water use, plant health and other important data points. In addition to field-level data, some companies focus on regional or remotely-gathered data, including climatic (weather stations), satellite imagery or aerial sensors and drones.

Prior to the "Internet of Things" (IoT) revolution, sensors were not generally connected to the internet and as a result, data was gathered manually, normally by the grower, when time permitted. Now, sensors are being connected to the internet and data is being made available in near-real-time. Growers need better access to this game changing technology in order to sustain our agricultural economy in the face of ever increasing water shortages.

Typically, agricultural technology companies work with two different types of clients. The first type gathers some level of field data and is always looking for new tools to provide better data as it relates to their operations. The second type of client is not as fortunate. They are dissatisfied with their data or are not tracking any data at all. They may be frustrated with their farm's efficiency; concerned that new regulations will reduce their ability to remain profitable; and upset because they do not have the right tools to plan and manage their operation.

With the reduced cost of sensors and the wider overall availability of data, growers are now able to benefit from analytics and do not need to entirely rely on how they "feel" about a specific crop or field. SWIIM provides a higher level of data analytics than has been previously available.

Background

Our initial research that led to SWIIM's development was originally funded by private investment and underpinned by state water conservation grants. The technology was then developed over a five-year period through an agreement with the US Department of Agriculture, Colorado State University and Utah State University. Our first issued patent was co-developed directly alongside the USDA. Since then, three patents have been issued in total. The research included accurate in-field tests, alongside the development of an algorithm, that underpin our technology.

We utilized a *Cooperative Research and Development Agreement*, more commonly known as a "CRADA," whereby we paid the federal government to develop the algorithm and process used to calculate water application and consumption, which results in an accurate water use statement. These are the same types of agreements used by the Department of Defense to develop technologies with the private sector.

SWIIM automatically takes water delivery data from a grower's field and compares water consumption as it is occurring in real time, simultaneously, through a combination of connected equipment, regional weather data and satellite overlay. This data is transmitted securely to the cloud and is seamlessly "meshed together," to provide an auditable trail of data. This can be used to create a baseline, as the grower looks to improve his or her overall water use efficiency. The system also provides easy-to-read graphs and map overlays within its online platform accessible from any device – tablet, computer or smartphone. We are able to deploy the technology on already-installed, compatible equipment; or if needed, we install new equipment.

In addition to audited reports that have been used to settle water disputes, we have a full time quality assurance department that is monitoring equipment and data sources each day looking for irregularities related to instrument problems and other factors.

Water Allocations

Depending on their location, a grower may have access to surface water sources (i.e., river water), or access to groundwater sources via pumps. Some growers will have access to one or both sources for irrigation, while others will lose access to their entire water portfolio, with little if any notice. If this occurs, significant impacts can include an entire loss of the operation.

Unlike other inputs to a farm, whether it is seed, fertilizer or labor, water is the only input to a farming operation that has no alternative source, and if not available, could put the farmer completely out of business.

Restrictions on Use

By way of example, the Colorado River – a prime surface water source for 7 western states is over-appropriated by as much as 40 percent[1], leaving some farmers without water to grow the crops on which our nation depends. Years of drought exacerbates this situation.

As another example, take California's recent passing of the Sustainable Groundwater Management Act to manage over-pumping of its aquifers. With these upcoming restrictions, at least 500,000 acres[2] of farmland in the Central Valley of California will be without water – which means no crops will be grown.

Our clients tell us they fear for their livelihoods and the legacy of their operations, many of which have been in their families for generations. Growers need access to updated

[1] *On the Water-Starved Colorado River, Drought Is the New Normal*, by Jim Robbins, Yale Environment 360, Published by the Yale School of Forestry & Environmental Studies

[2] *Water and the Future of the San Joaquin Valley*, Public Policy Institute of California (PPIC), Eilen Hanak, et al. https://www.ppic.org/publication/water-and-the-future-of-the-san-joaquin-valley/

technologies to fight the consequences of drought and lack of water availability that is widespread throughout the US.

Current Solutions

The equipment we most often see in the field fails to provide the accurate water accounting needed today. Flow meters in the field are producing data that may be off by as much as 25% and old-fashioned open canal measurements off by as much as 40%.

Think for a moment what that range of potential error could mean on a system-wide basis on the Colorado River or for a groundwater basin. Regardless of the measurement method used, tracking accurate water use in all of our sensitive agricultural regions is critical. It is all about the quality of data; therefore we should all look at ways for growers to access tools to better track their water allocations.

Available Funding From State & Federal Sources

Our experience has shown us that many of the current funding sources are geared toward research. These contributions are valuable, but the net sum result of many of these projects simply leads to more research without much private sector engagement.

The USDA-Natural Resource Conservation Service (NRCS) has programs that are designed to help famers and irrigation districts implement technologies. They include the Environmental Quality Incentives Program, commonly known as EQIP, and the Regional Conservation Partnership Program, commonly known as RCPP. These programs, although well intentioned, are tough to plan around, as funding cycles do not track with grower needs and the application process is difficult to complete. Funds for these programs are managed and distributed on a regional basis making larger, more scalable projects that can benefit multiple regions more challenging to implement.

One promising example relates to a project we are currently finalizing along the Colorado River in Arizona, with support from the federal government. The client is working with the Bureau of Indian Affairs (BIA) and the Bureau of Reclamation (BuRec) to co-fund a SWIIM deployment in an area that will benefit significantly from water use data and will assist in quantifying a good portion of the Colorado River allocation in that respective region. The process includes collaboration with the private sector, alongside the federal government. If this funding project could be expanded, through a partnership between BIA and BuRec, to multiple users along the Colorado River, then more meaningful scaling could be achieved.

Alternative Solutions

To provide paradigm-shifting technologies on a wider scale, funding sources must be flexible, and allow for approval on a project-wide basis across different regions, opposed to a region-by region basis as it is currently done. Traditional funding packages as offered primarily through the USDA are managed by each regional office. This does not allow private companies to span projects in multiple regions very efficiently. We should provide more latitude to federal agencies that are best suited to distribute funds outside of the traditional programs that are currently available.

Thank you for the opportunity to share this story today and more importantly, thank you for addressing the needs of our growers – our food supply is at stake.

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United States House Small Business Subcommittee on Innovation and Workforce Development

Farming in the 21st Century: The Impacts of Agriculture Technology in Rural America

Testimony submitted by

Mr. David Potere, PhD, Head of GeoInnovation

Indigo Agriculture, Inc.

January 9th, 2020

Chairman Crow, Ranking Member Balderson, and Members of the Subcommittee:

Thank you for the opportunity to submit testimony for the hearing on "Farming in the 21st Century: The Impacts of Agriculture Technology in Rural America." This Committee's leadership on this important topic is key because agriculture has the highest fraction of small business employment of any single sector in the US economy[1], while at the same time, agriculture has the most opportunity at hand in closing longstanding technology gaps[2]. Getting the right technology investments into this sector now has the potential to be transformative in Rural America and beyond.

At **Indigo Agriculture**, Inc. ("Indigo"), our mission is to harness nature to help farmers sustainably feed the planet. We offer a systems approach to agriculture that includes regenerative agronomic services, satellite-powered digital tools, and beneficial plant microbes all aimed at helping farmers grow high quality, sustainable harvests while reducing input costs. **Indigo Marketplace**™ is a supply chain solution for connecting those growers with buyers and food companies across America who are willing to pay premiums for healthier, more sustainable crops. Bringing crops to market efficiently is a challenge, especially for a small business. We use modern agronomy, finance, and logistics services, including **Indigo Transport**™, to give the grower the same market insights and sophisticated tools that have until now only been available to much larger enterprises. And most recently, with **Indigo Carbon**™, we're redefining what a harvest means to include the massive carbon sequestration potential inherent in our soils. Agricultural soils are the most hopeful solution we know of in the climate change challenge, which is why we have created the **Terraton Initiative**™[3], an ambitious program for sequestering a trillion tons of atmospheric carbon dioxide into the world's agricultural lands.

Last year, *CNBC* ranked Indigo as the most innovative company in the world, making us the first agriculture company to be awarded the top spot on the CNBC Disruptor 50 list.[4] Founded in 2014, Indigo's global headquarters are in Boston, with our North American commercial operations in Memphis and research facilities in Research Triangle Park, NC. We also operate in Argentina, Brazil, India, and Europe.

[1] "2018 Small Business Profiles US," US Small Business Administration, https://www.sba.gov/sites/default/files/advocacy/2018-Small-Business-Profiles-US.pdf.

[2] "Digital America: A tale of the haves and the have mores", McKinsey Global Institute, Dec 2015. www.mckinsey.com.

[3] Terraton Initiative https://terraton.indigoag.com/.

[4] "Meet the 2019 CNBC Disruptor 50 Companies." *CNBC*, 15 May 2019. https://www.cnbc.com/2019/05/15/meet-the-2019-cnbc-disruptor-50-companies.html. *See also* https://www.indigoag.com/pages/news/indigo-ag-ranked-top-cnbc-disruptor.

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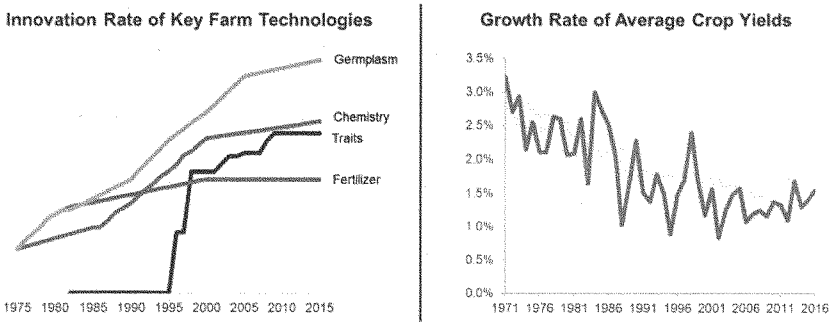
1. **Agriculture Technology Supports Crop Production**

Indigo's business was built to serve small and mid-sized businesses in the ag sector – from crop production to crop marketing. On the production side, we believe farmers have been underserved when it comes to obtaining independent advice on how to profitably grow crops. Often, advice comes from salespeople focused on optimizing maximum yield. For many farmers, the strategy has simply been to harvest and ship as much grain as their farm can produce. However, getting as much grain off the field may not always be the most profitable strategy for a farmer.

Over the last fifty years, U.S. agricultural productivity has been driven primarily by the increased use of four inputs: synthetic fertilizer, agricultural chemicals, plant breeding and hybridization, and, more recently, genetically modified traits (GMOs). Innovation in those four technologies has begun to plateau over the past fifteen years. Since around 2000, there has been no significant innovation in fertilizer technology and only one new class of agricultural chemicals. GMO traits first introduced in the 1990s have driven only incremental benefits, and traditional plant breeding has been more impactful, largely in corn.



Despite this plateau in innovation, however, there has been a dramatic increase in the costs to the farmers of these inputs – about a four hundred percent increase over the same forty-year timeline. Most of this increase has happened over the past fifteen years and has been driven primarily by the costs of seeds and fertilizer. It is important to note that while costs have increased significantly, yields have increased only slightly. Not surprisingly, the result of this is that farmer margins are at unsustainably low levels. Farm profitability, specifically net farm income, is down by forty-nine percent since 2013.[5]

[5] "Highlights From the March 2019 Farm Income Forecast," *USDA Economic Research Service*, 7 March 2019. https://www.ers.usda.gov/topics/farm-economy/farm-sector-income-finances/highlights-from-the-farm-income-forecast/.

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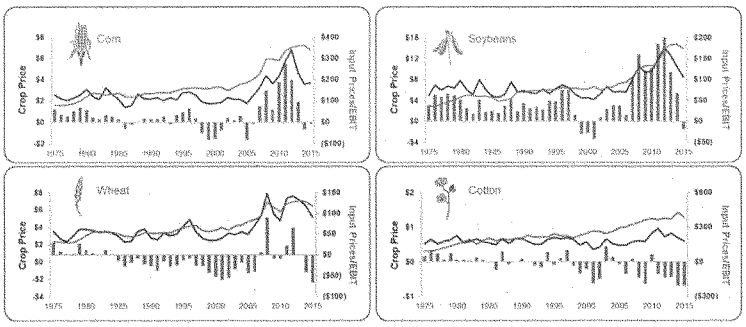
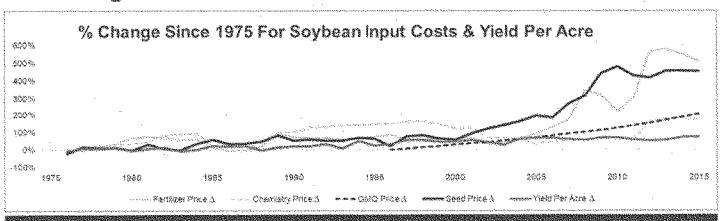
Farm Margins Are at Unsustainably Low Levels

Columns = Farm Profit
Gray Line = Input Prices
Blue Line = Commodity Price



In the charts above we see the largest four crops in the United States. In each of those crops, we have graphed the input price (grey), the commodity price (blue), and farmer profitability (or lack thereof, in red). There are a few remarkable takeaways. Historically, profitability rose and fell with commodity price. Recently, we have seen spikes in commodity price, where both profitability and input prices soared. While commodity prices have since come down, input prices remain at historically high levels. This is why, despite the agricultural innovations of the last forty years, farmers today are not necessarily economically better off than they were in 1975.

Input Companies Continue Capturing an Increasing Share of Farm Value Despite Plateauing Innovation in their Core Technologies



Input prices have increased more than 400% over the past 40 years compared to an only 70% increase in yields during the same period

With consolidation among suppliers, money is flowing from farmers to input providers. Indigo is focused on reversing that flow of money — putting it back into farmers' pockets and reinvested in their local communities. If we are successful, we improve the economics of farming substantially, giving farmers increased

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market power, premiums at harvest, and data-based agronomic information. The agriculture industry needs to be economically attractive, supporting small actors throughout the supply chain in order to sustain and expand our small businesses across rural America.

2. Agriculture Technology and Satellites Support Crop Marketing

Indigo also helps farmers get paid more for what they are growing. When it comes to crop marketing, farmers consider how and where to sell grain by using a range of legacy tools, including personal networks, fax machines, or even driving to elevators to assess current prices. Indigo is focused on bringing transparency in this process. We believe the profit opportunities of the future for farmers will come from additional quality and traceability, while providing healthy food, becoming carbon positive, and conserving natural resources. By connecting buyers and sellers of grain through Indigo Marketplace™,[6] growers receive premium prices for producing high quality crops more sustainably, and buyers source grain with a range of characteristics to meet consumer preferences for quality and sustainability. Helping farmers create specialty products in a commodity system is how this platform connects buyers – from leading consumer facing brands to processors – with sellers, who largely run small businesses and may not find these markets on their own. Indigo Marketplace™ presents the opportunities for farmers to differentiate high-value products and earn more for them.

Indigo Transport™, incorporated within Indigo Marketplace™, is an agricultural transportation platform connecting carriers to a network of growers and dry bulk commodity shippers across the United States. The platform uses digital tools to help farmers access bids within an expanded region and assess net costs of moving grain. Not only can individual farmers increase profitability through efficiency gains in transporting grain, many independent carriers who may struggle with the scale and logistical challenges of finding new loads are exposed to new hauling opportunities. Indigo Transport™ enhances the ability of carriers to diversify their portfolio, so they have full occupancy roundtrip, providing them with the tools to operate with the efficiency and scale of a large carrier fleet. This agility and efficiency is enabled by Indigo's proprietary technology, similar to that used in other industries, such as Uber™. On the buy-side, small elevators and co-ops rely on full occupancy to get paid; an error in bookings is expensive. Allowing smaller businesses to draw on a larger community of growers is beneficial to keeping small businesses thriving in Rural America.

Indigo also uses algorithms to help farmers identify the best times to sell their grain. This type of technology provides smaller growers with access to information on the cash grain economy, previously only accessible to large enterprises. In collaborating with small businesses, Indigo works with startups to help them reach scale through partnerships. In fact, my seed stage startup, TellusLabs, is an example. I cofounded Tellus in 2016 to bring more transparency into the food system via NASA satellite imagery, and in 2018 we joined Indigo. Now through the **Indigo Atlas™** technology, we provide crop reports, satellite imagery and expert commentary to all of the growers, buyers, and shippers – most of them small businesses – who work with Indigo. Plants are their own best weather stations, and thanks to decades of US leadership in spaceborne satellite technology, we can listen to what they have to say about the condition of our crops. Atlas is a "Google Maps™" for the food system and for rural America. Our crop production forecasts level the playing field for US farmers, giving them early, accurate, and detailed grain marketing intelligence. All of this is made possible by continued free access to NASA, NOAA and USGS data assets. At Indigo we are democratizing access to actionable insights from that public data, translating raw pixels into the sort of advice and early warning that can make a difference for US farmers. Last winter's bomb cyclone is a good example, where we translated thousands of raw NASA images into a flood map that identified the grain storage bins and farms most impacted by flooding.

[6] Indigo Marketplace™ https://www.indigoag.com/indigo-marketplace.

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3. Agricultural Technology Supports Sustainability and Carbon Sequestration

Agriculture offers the most hopeful opportunity for addressing climate change. It is Indigo's firm belief that the world's 12 billion acres of farmland and pastureland offer the most immediate, scalable, and affordable opportunity to remove carbon dioxide from our atmosphere.

This past summer, Indigo launched the Terraton Initiative, a global effort to remove one trillion tons of atmospheric carbon dioxide and store it within agricultural soils.[7] Agricultural technology now makes it possible to pay farmers for carbon sequestration. This matters since atmospheric carbon dioxide has risen fifty percent above pre-industrial levels, putting us on-track for severe climate change. Agriculture generates twenty-eight percent of global greenhouse gas emissions, and farm productivity is expected to worsen by nine to sixteen percent on average as the planet grows warmer.[8] Experts project that climate change will further lower farm productivity. As long as farmers are producing commodities, farmers will lack financial incentives to adopt technologies and practices that shift these dynamics and improve sustainability and quality. Paying farmers for carbon sequestration is a way to harness a scalable and affordable solution to address climate change—starting today.

Incentivizing drawdown through agricultural soils will require partnerships with government to maximize this potential. There is fortunately a bipartisan roadmap for how to achieve these key principles through policy tools. As originally enacted in the Energy Improvement and Extension Act of 2008 and substantially modified by the Bipartisan Budget Act of 2018, section 45Q provides a tax incentive for carbon sequestration by a qualified facility, used by such a taxpayer as a tertiary injectant in a qualified enhanced oil or natural gas recovery project. The new law raises the tax credit linearly from $22.66 (the inflation-adjusted amount) to $50 per ton over the period from 2017 until calendar year 2026 for CO2 captured and permanently stored, and from $12.83 to $35 per ton over the same period for CO2 captured and used as a tertiary injectant. Starting with calendar year 2027, the tax credit would be indexed to inflation.

Throughout its history, section 45Q has enjoyed broad bipartisan support. In the run-up to 45Q's eventual expansion in 2018, stand-alone bills expanding the provision had 50 cosponsors in the House and 24 cosponsors in the Senate. Unfortunately, section 45Q was designed for industrial and energy facilities and is generally unusable for farmers today. But, if there is broad bipartisan support for federal policy that incentivizes corporate industrial and energy producers to sequester carbon, why can't that same support be there when farmers try and do the same?

At Indigo, we question everything because we think it's time for our food system to change. If farmers were to be paid for meeting market demands uniquely, for ecosystem services, or for additional benefits such as more nutritious crops, then soil health and food production could be enhanced together. Doing so will create more opportunities for small and mid-sized businesses across Rural America and just might help revitalize the rural economy in the process. It's a solution whose time has come. Thank you for the opportunity to present these remarks.

[7] Terraton Initiative https://terraton.indigoag.com/.
[8] Sources: WWF, FAO, Water Resources Research, Washington Post, American Geophysical Union, WRI

TESTIMONY OF ROBERTO MEZA

Submitted to the U.S. House of Representatives, Committee on Small Business
Subcommittee on Innovation and Workforce Development

"Farming in the 21st Century: The Impacts of Agriculture Technology in Rural America"

January 9, 2020

2361 Rayburn House Office Building
Washington, D.C.

Chairman Crow, Ranking Member Balderson, and members of the subcommittee, thank you for the opportunity to testify today.

My name is Roberto Meza. I am a first-generation farmer and co-founder of Emerald Gardens[1], a farm located on 35 acres 15 miles east of Denver in Bennett, Colorado. My business partner and I are piloting an industrial hemp operation and also operate a controlled environment, passive-solar greenhouse in which we cultivate herbs, edible flowers, and over 20 varieties of microgreens. Every week, we harvest more than 300 pounds of microgreens destined for restaurants, grocery stores, other farms' food share programs, food pantries, public schools, and for direct delivery to consumers.

I am a member of Rocky Mountain Farmers Union (RMFU), which represents approximately 20,000 family farmers, ranchers and rural members across Colorado, New Mexico and Wyoming. I am also the Chair of Membership and Outreach of Mile-High Farmers, a co-chapter of Rocky Mountain Farmers Union and the National Young Farmers Coalition (NYFC).

My business partner and I are proud to be growing our small farm business in Colorado with a focus on environmental stewardship, technology, innovation, and community engagement.

Technology, Innovation, and Environmental Stewardship

Microgreens are the primary crop in our farm operation, and they have numerous advantages. They have the potential to be very profitable because they can be grown quickly, have relatively low input needs, and can be grown year-round. Some varieties like cilantro, green basil, and arugula have been shown to contain up to 40 times the nutrient density compared to their mature counterparts, which makes them appealing to increasingly health conscious consumers.[2] Furthermore, they exhibit beautiful colors, ranging from pink to purple, red to green, and have very distinct flavor profiles. These characteristics make them highly sought-after by chefs, grocery stores, and a growing number of discerning consumers.

We are able to grow year-round because of our greenhouse's passive-solar design. This structure is both energy and economically efficient, and environmentally friendly. It works by using clear polycarbonate on the south-facing side of the structure, which lets in the sun's rays and generates heat; insulation on the three other sides help trap that heat. The heat charges

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[1] https://www.emeraldgardens.farm/

[2] Xiao Z, Lester GE, Luo Y, Wang Q. Assessment of vitamin and carotenoid concentrations of emerging food products: edible microgreens. J Agric Food Chem (2012) 60:7644. https://www.ncbi.nlm.nih.gov/pubmed/22812633

our Ground to Air Heat Transfer System (GAHT), a technology refined by Ceres Greenhouse Solutions, and is based on the principles of a climate battery -- a design that distributes heat through a series of tubes that run below the structure's foundation. This approach sometimes requires the use of supplementary heaters and an evaporative cooling wall, but our climate battery system helps us significantly reduce our reliance on those sources.

Another important technology we use is a 5-tier shelving system with LED lights on the bottom shelves to supplement light during the short days in winter. Growing vertically increases the growing capacity of our 3,000 square foot greenhouse and LED lighting is incredibly energy efficient and cost-effective over the long term. Over the next few weeks we will be installing 40 solar panels to power the lights and fans in the greenhouse.

As Coloradoans know very well, the state closely monitors water supply and use because of the arid climate. Ever conscious of water scarcity, we use an automatic recirculating system that delivers water to our vertical hydroponic growing system for about 2-4 minutes each day, so the roots get only what they need, allowing water to drain back to our main tank through gravity. This reduces evaporation, maintains consistency, and significantly reduces our water use.

Community Engagement and our Local Food System

We believe it is important to participate in strengthening our local communities. Thus, community engagement is a focal point of our business. There are many ways we engage in our local community, including hosting workshops, educating consumers on the importance of eating local food, and the nutritional value of microgreens through in-store demos at our grocery stores. Additionally, we periodically engage in panels and discussions relating to local food systems and food access initiatives, and also helped bring microgreens into food pantries through the Food Pantry Assistance Grant, which incentivizes pantries and food banks to purchase local farm products.

A ubiquitous and essential technology we have come to rely upon to grow our business, build our brand, and reach our community is social media. Our Facebook, Instagram, and Twitter engagement helps us build trust with our customers and community. We have found that by showing people how their food is grown, they form a deeper connection with their food source. Thus, social media supports us in our goal to strengthen our local and regional food system.

This community engagement goes hand-in-hand with our mission to grow food using sustainable and regenerative agriculture principles. These principles are key to protecting the

environment, but also improving the quality of life of farmers and enhancing the communities in which farmers and their customers live.

Challenges and Opportunities

We face many challenges as small business owners. A major puzzle we have been working to solve is optimal distribution of our product. Emerald Gardens is a bootstrapped business, so unsurprisingly we have relied on some relatively low-tech methods of distribution, such as attending farmers markets. But we also have an online "farm stand" so customers can order directly from us for delivery.

For broader distribution, our current solution is a partnership with an innovative local grocery delivery startup, Bondadosa. Bondadosa is a good fit for us because it allows us to deliver to all of our wholesale and retail clients through a single weekly pick-up. We also looked to partner with Bondadosa because of their focus on decreasing food inequality in the state of Colorado by providing free delivery services to underserved communities, offering food items at wholesale prices, and accepting payment through the Supplemental Nutrition Assistance Program (SNAP). Emerald Gardens helps Bondadosa by actively seeking customers at points along their delivery routes that will help them maximize use of their delivery trucks. As we continue to scale our business, we plan to seek the opportunity to work with larger distributors as well.

Another challenge we have faced is accessing the capital we need to build our business. As technology advances, including agricultural technology, it has become increasingly important for today's farmers to have bachelor's degrees and graduate educations. Indeed, it is becoming an asset on farms of all types, including our farm. A college education is out of reach for many financially, and student loans are essential. Moreover, the farming population is aging and increasingly children who grew up on farms are not returning. My student loan debt has at times proven a barrier to additional investment in my business, including additional adoption of new technologies. For all of these reasons, and as a first-generation, beginning farmer, I believe a federal student loan debt forgiveness program is essential.

We have benefited from investment in fiber optic in the area where our farm is located and thus have reliable access to high-speed broadband, which is essential for our business. We support continued efforts to ensure competitively priced, high-speed broadband and wireless connectivity for rural America and further development of the fiber optic and cell tower networks in places with no or insufficient coverage.

Emerald Gardens continues to strive to make our business more sustainable and to improve our growing systems. Thus, we are excited by the opportunity to partner in the year ahead with a company that will be piloting new sensors in our facility that will monitor and collect data on environmental conditions. We are hopeful that the data generated by these sensors will allow us to achieve increased precision in delivering optimal water and nutrients to our crops. Support for technologies such as these, which can improve environmental and economic efficiencies for small businesses, are increasingly important for farm businesses in the face of volatile weather and a changing climate.

Conclusion

I want to close by saying that innovation is born of struggle. While we face a myriad of challenges as small farmers and small business owners, we remain committed to a mission of feeding our communities while remaining careful stewards of Colorado's natural environment. Innovative technologies, both high-tech and low-tech, are helping us get there. We are problem solvers who have used grit, determination, and technological savvy to create a market for our products and to work toward building a viable business that we hope can be a part of changing our food system for the better.

We believe in taking a comprehensive approach to our farming operation by engaging in policy conversations and development. That is why we actively participate in food policy councils, food cooperatives, food access initiatives, and why we are members of the National Farmers Union, Rocky Mountain Farmers Union, and Mile-High Farmers. This is also why we're so glad to have the opportunity to talk to you today.

Thank you for the opportunity to testify. I look forward to your questions.

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.

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[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.

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Appendices:

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

Agroecosystem health, agroecosystem resilience, and food security

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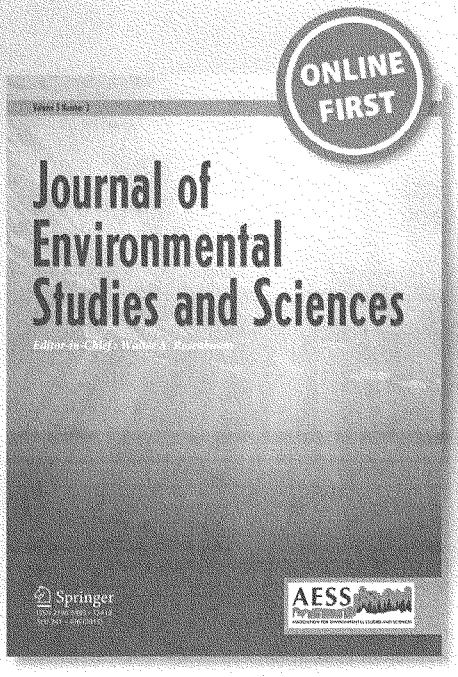

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Agroecosystem health, agroecosystem resilience, and food security

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Abstract This paper lays out the relationships between three mutually reinforcing concepts associated with agroecosystems: (1) agroecosystem health, the extent to which an agroecosystem can meet human needs for all of its residents over time; (2) resilience, the capacity of a system to adapt, reorganize, and maintain key functions in the face of turbulent and unpredictable change in its environment; (3) food security, sufficient quantity and quality of food for everyone at all times. Agroecosystem health has been defined by a number of properties including the following: stability, sustainability, equitability, productivity, and autonomy, each in the context of specific spatial and temporal scales. Indicators that characterize biophysical and social conditions including soil health, biodiversity, topography, farm economics, land economics, and social organization can be combined using analytical hierarchy process to map agroecosystem health across a landscape. The resulting map may provide incentive and guidance for improving the conditions underlying agroecosystem health. Resilience and agroecosystem health overlap largely because both rely on diversity, in biological and physical as well as human cultural, social, and economic terms. The Agroecosystems Management Program at The Ohio State University has approached research and outreach to improve agroecosystem health, resilience, and food security by encouraging self-organizing social networks for economic development around local and regional agricultural supply chains, encouraging farm enterprise diversity at a wider range of farming scales, and conducting research to monitor and estimate the benefits of such diversification. Social media tools have been explored for connecting entrepreneurs at the planning stage, with the ultimate goal of improving the economic support for more diversified enterprises in agroecosystems. Although challenging, such adaptive management experiments may create and encourage new opportunities for managing agroecosystem health, and with it, resilient food production and security.

Keywords Biodiversity · Crop diversity · Enterprise diversity · Entrepreneurship · Self-organization · Sustainable agriculture

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Introduction

In this paper, I will first discuss a framework for agroecosystem health and then describe conceptually the role of healthy agroecosystems in sustainable and resilient food security. The goal is not to review the literature on these topics or present an evidence-based study but rather to describe a conceptual model, a complex hypothesis, that is shaping research and outreach in the Agroecosystems Management Program (AMP) at The Ohio State University (OSU). The program began with a group of faculty who were willing to consider agriculture holistically. Rather than focusing on a list of production problems and solving them individually and sequentially, as is often the case in colleges of agriculture, we consider the entire list to be properties that emerge from agroecosystems, consisting of both people and the land interacting at landscape scales, for example entire watersheds. Our focus became what could be changed about the structure and function of the system as a whole so that new properties emerge, with simultaneous gains in social, economic, and

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environmental considerations as the objective. That holistic thinking led to consideration of how both social and biological diversity are important in agroecosystem health and resilience and is behind our adaptive management experiments to foster healthy and resilient agroecosystems, with food security as a key function. Because the story represents that of the many faculty and non-academic partners that comprise AMP, I will use the first person plural for most of the remainder of this paper and describe some of the challenges and opportunities in increasing agroecosystem health and food security that have been revealed in our research and outreach, but I accept full responsibility for what follows as my interpretation and representation of the work and ideas behind it.

Resilience is a property that includes stability in the face of small disturbances but more importantly describes the capacity of a system to reorganize and maintain key functions when the environment changes to an entirely new state (Levin 1998; Gunderson and Holling 2002; Biggs et al. 2012). Discussions of resilience in agriculture are typified by the insurance hypothesis, in which diversity results in redundancy and preservation of functions after environmental perturbation (e.g., Lin 2011). People have adapted agriculture and food production to the current range of environmental and social conditions in various ways. However, climate change predictions include profound environmental changes that may leave our current farming systems poorly adapted to a new and very different set of conditions. Such changes could be profound enough that they may result in an entirely different form and very different required functions in agricultural ecosystems, in both socioeconomic and biophysical terms, to achieve agroecosystem health and food security. Therefore, we will discuss increasing diversity in agroecosystems as a means of maintaining current ecosystem services and, along with self-organization, as a means of increasing the capacity of agroecosystems to adapt to climatic patterns that are expected to change in profound and largely unpredictable ways.

Framing agroecosystem health and resilient food security

Agroecosystems are occasionally referred to as if they are defined by a single crop (e.g., the soybean or rice agroecosystem) or some other component associated with agriculture (e.g., an irrigated agroecosystem). A systems perspective, however, requires recognition of people and all of our interactions with each other, with other organisms, and with our environment and at landscape scales in the definition. Agroecosystems typically include many farms and neighboring land uses along with many people, both farmers and non-farming neighbors and community members. Although there is no clearly preferred geographic boundary that encompasses both the biophysical and social interactions in an agroecosystem, scales such as watershed or production region would be more likely to encompass them than a single field, crop, or farm.

Agroecosystem health is a concept that has been used to describe the functioning of an agroecosystem as it relates to meeting human needs. Views on what constitutes agroecosystem health range from the absence of deleterious organisms or contaminants to a set of functions that maintain or increase the capacity of the system to meet human needs (reviewed by Vadrevu et al. 2008). Many of the attempts at assessing agroecosystem sustainability or health focus on measuring the various ways in which agroecosystems are degraded or impacted, such as pesticide residues, erosion, biodiversity loss, or other typical impacts of human activity. More holistic descriptions of the relationship between structure and function of the system include a set of properties: productivity, stability, sustainability, equitability, and autonomy (Conway 1987; Marten 1988; Lopez-Ridaura 2002; Vadrevu et al. 2008). These properties are not mutually exclusive nor are they necessarily mutually supportive. For example, productivity might be increased in ways that are neither equitable nor sustainable, and likewise, equitability may be achieved in ways that are not particularly productive. But such tradeoffs are a result of specific management practices, and would be avoided or at least balanced in healthier agroecosystems to achieve each of the properties listed above. For example, a common tradeoff, often perceived as unavoidable, is between specialization in one or two commodity crops with high purchased inputs to achieve high productivity and associated negative environmental impacts that may compromise sustainability. Yet Davis et al. (2012) show that a more diverse and lower input cropping system can achieve the same productivity as the less diverse and high input system, including economic gain, with significant reductions in environmental impact; in this case choosing the more diverse cropping system would lead to greater productivity and sustainability and, therefore, greater agroecosystem health.

Proposed measurement of agroecosystem health has been in terms of indicators. These indicators represent capacities or capitals that can be measured at a point in time, but indicate the likely outcome or status of processes, where the processes over time determine agroecosystem properties and, therefore, agroecosystem health. Most definitions of agroecosystem health include both biophysical and socioeconomic dimensions (Vadrevu et al. 2008; Rao and Rogers 2006; Gomez-Limon & Sanchez-Fernandez 2010), which contribute in various ways to the properties listed above. For example, both may be equally important in determining productivity, because it takes human management skill and decision making to take advantage of biophysical capacity for production that is of human value. In contrast, socioeconomic dimensions may be more important in determining equitability, as the extent to which production and value are shared within the agroecosystem and among human

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communities at a range of scales, through trade. The biophysical and socioeconomic dimensions of agroecosystems have been well characterized in terms of sets of capitals, which have been proposed to be the drivers of agroecosystem function (Rao and Rogers 2006).

Combining indicators to assess a current state of agroecosystem health in a structured way is challenging, but methods for calculating an index of agroecosystem health have been described (Vadrevu et al. 2008). The methods were described along with a case study of calculating and mapping the index (Vadrevu et al. 2008), so only a brief summary follows. Six key variables were proposed to describe a minimum set of conditions required to quantify agroecosystem health as a combination of the properties of agroecosystems described above (productivity, stability, sustainability, equitability): soil health, biodiversity, topography, farm economics, land economics, and social organization. These key variables were quantified with measures of one or more attributes for each throughout a study area in Ohio. Data sources included remote sensing, digital elevation models, soil surveys, county auditor records, and a questionnaire administered to a sample of landowners in the study area. These data were combined to yield an agroecosystem health index that could be mapped for the study area. Combination of variables was by analytical hierarchy process, which has been used in a variety of multiple criteria and multiple objective analyses (Saaty 1980, 2000). The analytical hierarchy process modeling included two steps: (1) combining the data at the pixel scale (30 m^2 in the case study) to represent the six key variables with normalized values and (2) combining the normalized key variables into a final normalized index, where each combination is a weighted sum of the normalized variables. Weights for the variables are calculated from a set of comparisons done by multiple individuals (with expertise in the topic, AMP research faculty in our case) between all pairs of variables, in which the variable that contributes more to the overall objective or concept (in our case, agroecosystem health as a combination of four properties: productivity, stability, sustainability, equitability) is identified along with an estimate of the difference between the variables in that contribution. Geometric means of these individual scores were combined into consensus weights, the weights were applied to the data, and the resulting index was mapped. Spatial patterns in the index were an emergent property of combined socioeconomic and biophysical conditions, none of which were apparent in any of the underlying data for the key variables. Furthermore, the agroecosystem health index and its underlying data can be analyzed for a particular landscape so that policymakers, educators, service agencies, organizations, and the people who live in the area can find and evaluate opportunities to improve agroecosystem health.

The initial development of an agroecosystem health index relied on extensive spatially referenced data that is not easily collected or generally available. In particular, the variables that measured social organization required a detailed survey of landowners throughout the area for which the index was being calculated. AMP researchers have since developed an approach for calculating the index based entirely upon publicly available data (Table 1). This newer version includes the same key variables as those used in the earlier study (Vadrevu et al. 2008), but the data used to measure each of these key variables was derived from public datasets. For example, social organization was calculated from four of the variables that are included in the US Census, at the finest resolution available. Table 1 provides the variables used and their sources along with the weights that were derived from analytical hierarchy process modeling and used to calculate the index, and Fig. 1 displays the resulting index for a Northeast Ohio region. The region is characterized by temperate climate, enough rainfall that irrigation is rarely used, flat terrain to gently rolling hills, and a wide range of soil types and naturally occurring plant communities. Agriculture represents approximately 40 % of the land area, along with large cities such as Cleveland and Akron. Markets are diverse, including commodity to retail, and farm scales and enterprises are diverse as well, including horticultural and agronomic crops, pasture, and livestock, particularly dairy. As in Vadrevu et al. (2008), the key take-home message from the index is that both the socioeconomic and the biophysical dimensions of the agroecosystem are required for a complete measure of agroecosystem health, and agroecosystem health varies spatially as a result of the combination of these factors. For example, one can find both urban areas (e.g., greater Cleveland, top center in the figure) and rural areas (e.g., the northeast part of the region, top right in the figure) that score relatively low in agroecosystem health index but for different reasons. The northeast part of the region has a clay fragipan layer that reduces drainage and water infiltration, creating a challenge in maintaining high soil quality for production, although many very successful farms are in this area. On the other hand, Cleveland has large areas of impervious surfaces and low social organization and low farmland production value scores. Areas scoring higher in agroecosystem health, likewise, may vary in the quantity of different capitals that lead to agroecosystem health.

How food security is embedded in agroecosystem health

Food security has evolved as a concept since a fundamental right to food was recognized in the 1948 Universal Declaration of Human Rights. The evolving definition of food security has been informed by further elaboration on the right to food (recently reviewed by Kuhnlein 2014), food sovereignty (recently reviewed by Edelman et al. 2014) and the relationships between the two (Beuchelt and Virchow 2012). For example, the 1999 Committee on Economic, Social and Cultural Rights (CESCR) description of the right to food in

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Table 1 Variables and analytical hierarchy weights used to calculate an agroecosystem health index for Northeast Ohio using publicly available data sources

Key variable	Source	Variable weights for Key variables	Variable weights for Index
Biodiversity	NASS[a] Crop Data Layer		0.1865
Topography	USGS[b] Digital Elevation Model		0.0692
Soil health	USGS SSURGO[c]		0.1359
Soil organic matter %		0.35	
Available water capacity		0.2	
Land capability classes (×100)		0.45	
Farm production value[d]	USGS SSURGO		0.18904
Land value	School district land market value		0.19263
Social organization[e]	US Census		0.22674
Education (US Census Block)		0.1	
Number of farms (US Census Block Group)		0.3	
Number of farm operations (US Census Block Group)		0.4	
Proportion of agricultural land, conservation, and wetlands		0.2	

[a] National Agricultural Statistics Service of the US Department of Agriculture

[b] US Geological Survey

[c] US Department of Agriculture, Natural Resources Conservation Service, Soil Survey Geographic Database

[d] The Ohio Current Agricultural Use Value (CAUV) is a monetary value that represents the value of land for farming. It is calculated as a function of soil type, so we used the SSURGO soil type data to calculate the CAUV for our study

[e] Social organization is hypothesized to be associated with variables that include education level, assumed to be associated with communication and democratic process, the prevalence of farming, and its association with conservation as an indication of healthy relationships between farmers and neighbors

General Comment 12 describes the realization of the right to food as a state of food security: "The right to adequate food is realized when every man, woman and child, alone or in community with others, has the physical and economic access at all times to adequate food or means for its procurement." Key elements of the evolving definition of food security include sufficient quantity and quality of food for everyone at all times. Sufficient quantity is met if the means of production or procurement are consistently available to all, with consistency implying sustainability of production and distribution including its social, economic, and environmental dimensions. Sufficient quality adds a host of additional considerations (i.e., what is meant by "adequate food") including nutritional composition that supports a healthy active life and satisfying cultural preferences through self-determination of the food system at various levels of organization from individual to household to community to national. We hypothesize that sufficient quality and quantity, or at least the means to procure sufficient quality and quantity if production is equitably shared and sufficient to acquire both, could be expected from a healthy agroecosystem.

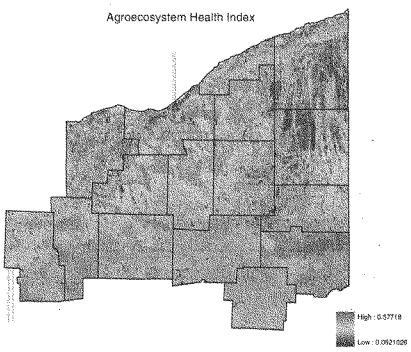

Fig. 1 Agroecosystem health index calculated for the 16-county Northeast Ohio region using publicly available data from the US Census, Agricultural Census, National Agricultural Statistics Service, and US Geological Survey following methods in Vadrevu et al. (2008). High and low are calculated according to a weighted combination of the socioeconomic and biophysical conditions in the region that are related to the properties of agroecosystem health. A modified version of this figure is also in Hoy et al. (2012)

Each of the agroecosystem properties described above is critical in food security, and we have described agroecosystem health as a combination of all four. Productivity must be above a threshold set by human needs for food. Stability and equity in production, including equitable access to production resources, are needed to ensure consistent supply over short-term intervals. Sustainability implies that production and equitable access are sufficient for long-term food security. Autonomy is the

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ability of people living within a particular boundary to meet their own needs for food, without having to rely on external sources for either food or the means of producing it. If production within a given agroecosystem is consistently sufficient for the population within, and does not require external inputs, and the food supply from external sources is not reliable over time, then autonomy would be a means to food security. However, if food supply is variable and not sufficient at least at some times, then autonomy would not be a means to achieving food security. Instead, capacity to trade for food from other agroecosystems becomes an important requisite for food security. The most food secure point on a continuum from complete autonomy to entirely reliant on external sources for food, a function of whether local or distant supply is most frequently at risk, is probably more important than capacity for either autonomy or trade. Climate change predictions include a number of challenges to food production such as drought, flood, and severe storms that could decrease productivity in any given location. The frequency, duration, and location of these challenges, however, are not predictable in current climate change models, so the ability to achieve both autonomy and capacity to trade for external food supply may be the prudent strategy for food security.

Conceptual linkage between agroecosystem health and resilience

Biological diversity is considered to be a driver of the agroecosystem processes that lead to agroecosystem health. Diversity in general is a key feature of resilient systems, because of the reliance of adaptation on sufficient diversity, and selection upon it. Human and cultural diversity play a role in how we manage the land in agroecosystems. Traditions, histories, values, and economies all become important elements of diversity that are subject to selection under profound environmental change, similar to selection on biological diversity. Therefore, both biological and cultural diversity should be considered to be key elements of the potential for adaptation, along with self-organization capacity in both biological and cultural dimensions of agroecosystems.

Biological diversity

Biophysical dimensions of agroecosystems focus on natural capitals, which encompass a wide range of attributes including soils, water, nutrients, climate, and biological diversity. Biological diversity is fundamentally genetic and occurs both within (biochemical, structural, phenological) and among species at population and community levels. Biological diversity occurs at spatial scales from millimeters to continents, depending on the organisms involved, and changes at temporal scales of minutes to years. It is relevant to agroecosystems primarily in how it influences key functions of yield and productivity. Both literature reviews (e.g., Altieri 1999; Lin 2011) and specific examples (e.g., Davis et al. 2012; Boody et al. 2005) have highlighted the important role of agricultural crop diversity in agroecosystem productivity and stability.

Large-scale production of a small number of crops represented by very few cultivars, although economically efficient in US agroecosystems, is clearly not a route to biological diversity. Biological diversity can be increased within agroecosystems by increasing the proportion of land area in unmanaged and minimally managed habitats, which are typically more biologically diverse, and by increasing the diversity of the crops and livestock produced. For example, diversity might be enhanced by farming at a wide range of scales, matching variation in what is produced with the natural and physical variation in the landscape as well as its social and cultural patterns. Increasing diversity of managed crops and animals at these same scales could be expected to result in greater biological diversity, more species-rich food webs, and improved ecosystem services that rely on this diversity. For example, biological control of insects could be enhanced by a complex of natural enemies with a broader range of requirements, such as pollen and nectar, than a single crop could provide.

Mechanistically, crop diversity increases available functional traits to increase biotic interaction and ensure consistency in production despite disturbance (Hajjar et al. 2008). In particular, crop diversity can enhance regulating ecosystem services such as pollination, pest and disease control, soil health, and CO_2 sequestration, each of which contributes to productivity and stability in the short term and sustainability and adaptation in the longer term. For example, preserving soil health and preventing erosion could contribute sustained ecosystem services in the short term and provide a greater capacity to reorganize and adapt under future environmental change. Biotic interactions resulting from crop diversity can be very complex, but models of such interactions are considered to be feasible (Médiène et al. 2011) and the data and models needed to manage this complexity are accumulating.

Farm enterprise diversity, with variation in what is produced providing greater landscape heterogeneity in plant populations at scales of meter to kilometer, can increase biological diversity overall and is, therefore, a bridge to the cultural diversity that will be discussed next. This enterprise diversity can arise from individual farmers and land managers engaging in more diversified farming or more landowners occupying smaller areas and, even if specializing individually, producing many different kinds of crops and livestock. In fact, both were evident in the area we picked for the case study of mapping an index of agroecosystem health (Vadrevu et al. 2008). The study area was selected by observation from an airplane flying at 600–900 m. A landscape pattern that transitioned from very large expanses of single crops with little else around them to one of much smaller fields containing a greater range of crops, including pasture, and with more forested and other minimally

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managed areas among them, was clearly evident. We knew from previous work that an associated pattern was large-scale cash grain producers in the areas with larger fields of few crops, and to a mixture of Amish and non-Amish farm owners with smaller farms and more integrated livestock in the areas with smaller fields.

Cultural diversity

Farmers in the USA have been declining in both number and diversity for many decades, following a long-term pattern of farm consolidation and people leaving farms for cities. Approaches to farming in the Midwestern US have largely bifurcated as a result of economic pressures on farmers, who tend to experience relatively constant prices for commodities while the cost of inputs increases. Farmers require some means of achieving a successful business model in response to these pressures.

One approach taken by farms that have typically been held within families for generations and that have continuously adopted new agricultural technology has been to become larger by acquiring surrounding farms that did not grow or transition within families. The typical business model is to specialize within a few commodities, for which prices have generally been constant, and deal with the rising costs of inputs (e.g., fertilization or feed, pest control, equipment, genetics) by expanding and maximizing yield per acre in the case of crops, or per animal in the case of livestock, and per farmer in either case. Farmers adopting this approach must be excellent managers of technology and inputs, with excellent business acumen to select and use both equipment and purchased inputs in ways that will maximize yield and profit over large and continuously growing land holdings with minimal numbers of relatively skilled, and therefore expensive, employees. In cases where hand labor is required (e.g., poultry processing, fresh vegetable production, large dairy management), the owner must be adept at managing a large labor force doing relatively unskilled (although often to exacting specifications) work at minimal wages, often by an imported and seasonal workforce. Producers in these systems can innovate in process engineering, human resource management, small modifications to equipment, and the use of technology and production inputs. However, most of the innovation in their production system takes place at global scales within the corporations that supply the equipment, inputs, and services that are absolutely essential to this large-scale and prescriptive approach to farming.

Other approaches to farming, typically stimulated by a lack of the extensive land and built capital (buildings, very expensive equipment, etc.) required to achieve economies of scale, provide an alternative to expansion and large-scale production: seeking a unique and profitable niche that permits specialization at small scale (e.g., organic dairy, wine, artisan cheese, rare spices); or seeking an *economy of scope*, which includes diversification and the ecosystem services outlined above. Production inputs tend to be refocused on labor and expertise of farm managers rather than purchased technology. These approaches are open to a wide range of new farmers, whether they have inherited land and have been taught the needed skills from an early age or are entirely new to farming but may be motivated by factors such as lifestyle and land ethic and may choose to farm in or near urban centers. Innovation is occurring as a result of new ideas and new approaches brought by people who are relatively new to farming. Although risk levels in these enterprises may vary widely and many of their experiments may fail, the unconstrained thinking and experimentation is likely to produce new innovations. Technology still plays a role in these production systems, for example, extending the growing season with unheated high tunnel (typically aluminum frames covered with heavy translucent plastic to serve as an inexpensive version of a greenhouse) production systems and new crops or livestock breeds. But individuals may play a greater role in developing and adapting technology in these less prescriptive systems through on-farm innovation. This increase in smaller and more diverse farming approaches may increase resilience in agroecosystems over time.

The history and traditions of people dwelling in the agroecosystem can be quite relevant to what is produced, a function of both the human and social capitals that lead to concentrations of particular kinds of production. Examples range from long-standing traditions of indigenous peoples that have been maintained over many centuries to more recent associations between members of a diaspora and a particular landscape. Such groups can be well organized as in the current member organizations of the international La Via Campesina or Amish communities in the USA, or more loosely organized socially and with less outwardly observable group identity. A few examples of the latter from our region include cabbage growers of Danish heritage in the Finger Lakes Region of New York, vegetable producers of Dutch heritage on high organic matter muck soils in Ohio, onion growers of Italian ancestry on muck soils in New York, and dairy farmers of German and Swiss descent in Northeast Ohio. Although specifics of agricultural practice may change over time, the ties between groups and what they produce may remain in agricultural communities and can lead either to specialization and a reduction in crop or animal diversity or to maintaining diversified farms despite economic pressure to specialize and grow in size. Therefore, the contribution of cultural diversity in farmers to agroecosystem health may depend upon the extent to which it supports enterprise and biological diversity and contributes to social organization among farmers at landscape scales.

Self-organization in agroecosystems

A key feature of agroecology as a production paradigm is managing agroecosystems to maximize ecosystem services that

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accrue from naturally occurring ecological processes. Specialized and simplified agricultural production systems, in contrast, must supply inputs that replace ecosystem services because the biological diversity in the system is insufficient or cannot be organized in ways that provide them. An agroecosystem that is managed in ways that achieve stable and sustainable production would likely include self-organizing and naturally occurring processes to achieve these ends. Self-organizing biological communities generally require sufficient functional diversity to fill niches across trophic levels in complex and stable food webs. Productivity in diverse systems can result from niche saturation, all niches being filled by organisms that are well adapted to their niche. Further contributions in diverse food webs include trophic cascades of both bottom up and top down regulation of agriculturally important population dynamics and cycles, providing the regulating ecosystem services that permit food production with less reliance on external inputs like pesticides (Lin 2011).

Self-organizing social and economic systems in globalized commodity production are often suppressed by top down provision of inputs and centralization of key supply chain functions, such as aggregation, transportation, processing, and marketing. In such systems, organization is imposed by global corporations, for example, via sales of a prescriptive set of products and technologies (seed, fertilizer, pesticides) needed to maintain the production system. Social organization in communities of farmers that share this production system, however, may support it with social and behavioral norms that place high value on conformity. An example of top down organization is a reliance on pesticide inputs to control pests. International corporations with global production and distribution systems supply most pesticide inputs. A typical outcome of reliance on pesticides is the evolution of resistance in pest populations. If no alternative pesticide option is available, then individual farmers who have resistant pests and rely on effective pesticides to control them can be at risk of substantial losses. Their solutions do not arise from within their farms; rather they must be passed down in the form of new pesticide technology from international corporations. The system itself, therefore, is regulated not by self-organizing properties of diverse entities at local scales but by relatively few global firms that rely on international supply chains and periodic introduction of new technology (Hoy 2009). When key inputs such as new cultivars or fertilizers must be obtained from global corporations to maintain production, then autonomy, equitability, and self-organization of production decline. Farms that rely on such inputs can be put out of business by such environmental changes as emergence of pest resistance without new pesticides or declining water availability without improved irrigation systems. Profit margins in large-scale agriculture tend to be very slim, a factor that drives continuous expansion as a means to ensure sufficient profits to maintain the farm enterprise. When the means to adapt to sudden changes in the cost or availability of needed inputs are not under the control of farmers, adaptation does not occur at the level of farms or even regions and may not occur quickly enough to keep farms in business. And some of the inputs that farms have counted on in the past, such as cheap and abundant fossil fuels, water, and consistently predictable climate, are widely predicted to become less reliable in the future.

Large-scale systems tend to be self-reinforcing, however, to the detriment of maintaining diverse production capabilities. An example is in large-scale diversified vegetable production, such as that found in the Salinas valley of California, Arizona, Texas, Florida, and in smaller production areas in other states including the Great Lakes Region and Canada. Marketing of these vegetables has evolved to a system in which buying and shipping is least costly if all items can be purchased from one location. The result, however, is that in northern production regions like Ohio, production that could be taking place year round and delivered locally is restricted to a few months when all items are available. Capacity for local production, therefore, is under developed and poorly used, *not because we lack the capacity* but because it does not fit well in national and global supply chains. It remains to be seen how quickly this unused production capacity could be enhanced and redirected if food supply from more distant sources becomes less reliable. Alternative production systems relying on economy of scope may provide new opportunities to explore self-organization of markets, innovation, and relationships among farms and other firms at local and regional scales. These are the kinds of qualities that would become necessary for a system to adapt to an unpredictable and uncertain new set of environmental and social conditions.

Opportunities for enhancing agroecosystem health for resilient food security

Based on the conceptual model of agroecosystem health described above, and how food security is expected to emerge from healthy agroecosystems, our approach to managing agroecosystems for both health and resilience has focused on promoting self-organizing social network behavior to build greater farm enterprise diversity into agroecosystems. A current opportunity appears to be supporting a diverse population of entrepreneurs who can launch a wide range of innovative and new production or agricultural supply chain enterprises at a range of scales, but especially very small scales. These small enterprises, typically not engaged with commodity production but rather differentiated products sold on shorter and more localized supply chains, could increase diversity in agricultural production (e.g., Goland and Bauer 2004). Entrepreneurship promotes several features of resilient complex adaptive systems, at least in economic terms: dispersed interaction, continual adaptation, and perpetual novelty. Furthermore, entrepreneurial approaches are an important feature of the literature

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on sustainable agriculture. Therefore, we have experimented with enhancing entrepreneurship in agroecosystems as a means of increasing diversity in both cultural and biological dimensions. Our basic approach (Hoy et al. 2012) has been to facilitate social networks among entrepreneurs at the business planning stage. We have developed online tools for identifying how their planned enterprises could build supply chains, rather than the individual links (Fig. 2, and see localfoodsystems.org). Social networking tools then encourage and promote business plans for collaborative business networks rather than just individual businesses. Therefore, our social networking tools are designed to enhance self-organizing entrepreneurial ecosystems that provide new adaptive capacity. Our hypothesis is that such self-organizing entrepreneurship will support more diverse food supply chain enterprises, more landscape diversity in production, and improved agroecosystem health.

Increase diversity of people and enterprises in agroecosystems

Research in business and economics has identified strong social networks as a key element of entrepreneurial ecosystems, featuring successful and active entrepreneurship, particularly in many small businesses at local and regional scales (Neck et al. 2004; Cohen 2006). Associated benefits to agroecosystem health should include biological diversity, accruing from greater landscape heterogeneity in crops and production systems at a range of scales from very local to regional. A common feature of such smaller scale and more diverse production systems is a reliance on economies of scope rather than economies of scale.

We hypothesize that self-organizing behavior in social networks can promote production diversity and associated economies of scope. Of equal importance to crop and livestock production diversity is greater diversity of participants in this economic activity. Given the importance of equitability as one of the properties of agroecosystem health, our hypothesis is that internet-based social networking tools that are accessible to anyone who can find an internet connection, will promote open-source innovation and development of inclusive cooperative business networks. Greater and more equitable access to tools that assist entry to the economy may also contribute to the self-organizing behavior of economic systems that enhance diversity in agriculture, ultimately improving agroecosystem health and resilience, and improving food security via more consistent access to fresh food at local and

Fig. 2 Home page of localfoodsystems.org, a social networking site designed to assist with planning local supply chains

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regional scales. Tests of the hypotheses proposed above will require adaptive management research. However, use of the social networking tools we have introduced to stimulate entrepreneurial ecosystems may eventually allow us to make regional comparisons as new supply chains develop.

Application of diversity concepts to large, economy-of-scale farming is more difficult than for small and diversified economy-of-scope farming. Possibilities may arise from new agricultural technologies. Precision agriculture, for example, is essentially a means of managing agricultural inputs in areas that are small enough (1 m^2 or smaller) to be effectively uniform, removing heterogeneity that typically results in less than optimal results when inputs are applied uniformly over much larger areas such as an entire field. In general, precision agriculture technology is shifting from an emphasis on monitoring yield at harvest, meter by meter, and adjusting subsequent inputs in future plantings, to more frequent monitoring during crop development and adjusting inputs from the planting stage on. Whereas adjusting application rates of inputs like fertilizer or pesticide has been an available technology for some time, newer technology is being developed for applications like choosing from among several cultivars based on conditions at the specific location for each seed in the furrow. By doing so, biodiversity within fields could be increased, perhaps creating greater incentive for more genetic variation within cultivars or increasing the number of crop species within a field, reserving uniformity for key characteristics such as days to maturity and suitability for machine harvest. If, and perhaps only if, farmers regain a means of tailoring the diversity in their crops to the conditions on their farms, then the technology could increase both biological diversity and farmer innovation across multiple scales.

As noted above, work in AMP has focused on increasing the social organization and self-organizing behaviors in building local economies associated with agriculture and food production. Tools we have used include social media, and have been designed to connect entrepreneurs along supply chains to form collaborative business networks that meet local needs with local supplies. The rationale is both to take advantage of economic opportunity in new and shorter supply chains and to provide the economic support for more diversified agriculture, on a wider range of farming scales. The self-organizing collaborative business networks we are supporting with social media tools are intended to increase social organization in agroecosystems, as well as biological diversity and autonomy via local production.

Impediments to the social organization we are encouraging arise from the typical approaches to economic development applied to agriculture, which place greatest value on large-scale, export-oriented production and global competition. Entrepreneurs are often advised to maintain confidentiality, under the assumption that they may have intellectual property that would be lost if they share ideas or collaborate with other businesses. The focus of business planning is on competition rather than collaboration; for example, the standard US business plan contains a section on the competitive situation, but no section for collaborative arrangements with supply chain partners. Furthermore, the typical entrepreneurship service provider, needing to meet standards and quotas for impacts on such metrics as jobs and income, tends to focus on relatively large firms poised for global growth rather than many small businesses engaged with local import substitution. Entrepreneurship is often cast as requiring a drive to grow continuously, rather than grow to a point where the business is stable, providing jobs, meeting needs, and performing a useful function in a business ecosystem. Likewise business ecosystems are often conceived as the set of interacting businesses that support a single large and dominant firm (e.g., Iansiti and Levien 2004) rather than a set of collaborating businesses that share economic power and trade along a supply chain on relatively equal terms. Examples of the latter do exist, for example Zingerman's Community of Businesses in Ann Arbor, MI, a collection of eight independent food production/preparation businesses with synergy in marketing; Great Lakes Brewing Company in Cleveland, OH, which partners with a number of farms and food producers to recycle spent brewing grains into food products for their restaurant; and a number of local to regional food hubs such as the over 150 businesses associated with the Detroit Eastern Market. Our experience has been, however, that despite the logic of collaborative business networks in reducing waste, increasing efficiency and markets, and reducing risk, business owners and entrepreneurs are reluctant to enter into such business relationships because the required levels of trust are challenging to establish. Teamwork and collaboration seems to be valued within firms, but less so among them. The social media tools we are developing, like most social media sites, gain value with more users. The combination of this lag in use, inherent in social media, and the tradition of competition and low trust in business ecosystems need to be overcome to develop self-organizing entrepreneurial ecosystems associated with agriculture and food.

Social organization that ensures a balance between autonomy and trade for needed goods such as food may require different and larger scale means of gaining self-organizing capacity for adaptation to environmental change. As noted above, the system that organizes and facilitates large-scale farming is not self-organizing below very large scales, and adaptation depends on very few organizations delivering new input technology and products. The system lacks diversity and, as a result, becomes fragile when such key inputs as fuel or phosphorus become limiting or when the climate changes in unanticipated ways or extents. Localities and regions that depend on distant supplies may become increasingly at risk if these supplies are disrupted. But local and regional systems could also be at risk if climate events such as large storms threaten their production capacity. If production

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capacity is greatly reduced at local or regional scales due to extreme weather events for example, then people in those areas will be dependent upon other regions for needed goods. The social networks needed to establish these more extensive regional to international scale networks may be more difficult to develop, particularly with justice and equity among all food producers and consumers, than more localized networks. The internet, however, removes many of the impediments to personal communication that come with larger scale. Enhancing the balance between local production capability and efficiency of trade and distribution across scales, particularly in adaptive and self-organizing ways, will be critical to evolving resilience in food security.

Focus on the diversity-productivity-adaptability nexus

Interdisciplinary research is needed to test the hypothesis that self-organizing social and economic activities in more diverse agroecosystems will increase both productivity under current conditions and adaptive capacity under extreme changes in the environment. Simulation of these scenarios would require a very interdisciplinary mix of spatially explicit biophysical models that could predict output of particular production systems under various climate scenarios and agent-based models of economies and human population behaviors that could explain and predict levels of self-organization, diversity, and their basis in social behaviors. Empirical studies would require adaptive management with repeated cycles of a sequence of planning, implementation, observation or monitoring, and analysis. One could expect the experiment to influence the system over time, given the scale and potential impact of experiments, like the introduction of social media tools described above, on agroecosystems.

Transition pathways are currently clear for expansion and consolidation of farms, but not for diversification, particularly once farms have grown to a very large scale. Farm consolidation has taken place for decades, increasing economies of scale and skewing the size distribution of farms to the point where a very small percentage of farms produce a very large percentage of farm output in the USA. Information on how to specialize, consolidate, and expand farms is much more prevalent in the USA than information on how to split and diversify farms. At least in Ohio, commodity farmers occasionally diversify a small area near a busy road or intersection to experiment with direct sales of vegetable or fruit crops, and such experiments may lead to further diversification if successful, but little data exists on trends in these activities or long-term impact on land use and farm management. A traditional means of reducing farm size has been division of farms among family members when a farm is passed along from one generation to the next. Given the advanced average age of farmers in the USA (58.3 years according to the 2012 US Agricultural Census), farm transfers could become more common in the coming decade or two. However, farms are often sold and either converted to another land use or added to a larger farm. Therefore, farm transition strategies, policies, and associated research and education programs are needed that clarify options for converting, through sale or inheritance or other means, a large specialized farm to multiple smaller and more diverse farms. Sustainable agriculture education programs will be important in preparing a next generation of farmers for the entrepreneurial and more complex management required of such diversified systems, more so than specialized education programs that prepare individuals to maximize the use of technology for a specialized and restricted set of commodities. Support is needed for research grant programs such as the currently available USDA Agriculture and Food Research Initiative (AFRI) Small and Medium-sized Farms, Food Security, Agroecosystem Management, and Organic Research and Extension Initiative, and the USDA Sustainable Agriculture Research and Education programs to encourage the successful growth of more diversified production and distribution systems.

Examples of recent research by students following a specialization in Agroecosystem Science of The Ohio State University Environmental Science Graduate Program will highlight some of the research questions that are important in shifting perceptions regarding production scale. Students have begun to explore what changes in production are possible, working within the boundaries of land already in crop production or in other managed systems, to shift the diversity and productivity of agricultural ecosystems in Ohio. In one such study (Kolbe 2013), scenarios for temporally and spatially diversified production, based on agroecological design, were developed at 3 scales (approximately 0.1, 5.25, and 42.5 ha). The designs were then used to estimate yield from a scenario in which these designs would be used for production wherever they could fit in contiguous land that was either already in agricultural production or in other land uses suitable for production, such as managed turfgrass (including residential and commercial lawns). The scenario was developed by "placing" the three designs, from largest to smallest in sequence, on the landscape of NE Ohio. The yield from each design, in kilocalories and nutritional components of kilocalories produced, was then estimated based on methods developed for foodshed modeling (Peters et al. 2009), which include such factors as soil and topography data (Fig. 3). Estimated yield from this alternative and greatly diversified production, and nutritional composition of that yield, could then be compared with existing yield and nutritional composition afforded by the region's current production (predominantly corn and soybean rotations, followed by dairy, horticultural crops, and a wide range of other crops and livestock). The analysis demonstrated that at least four times the number of kilocalories could be produced by the diversified scenario compared to what is currently produced, with a nutritional composition that would be higher in vitamins (A, B6, C), minerals (Ca, Mg, K, but not Fe) and fiber, about the same in protein and carbohydrate, and lower in fat. Of course, the research question was about what production is possible on

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	Primary Data		Secondary Data		Biointensive Data	
	kg/ha	kcal/ha	kg/ha	kcal/ha	kg/ha	kcal/ha
	1,720	343,572	1,262	273,951	2,734	641,764
	5,160	1,030,715	3,785	821,854	8,143	1,925,291
	10,321	2,061,430	7,570	1,643,709	16,285	3,854,381
	17,427	4,123,764	13,056	3,994,342	36,990	3,850,582
	21,162	5,007,427	18,262	4,850,279	20,145	4,073,177
	24,896	5,891,091	21,509	5,706,210	23,700	4,791,973
	36,205	13,712,714	25,152	8,756,585	53,319	18,574,026
	43,963	16,651,153	30,541	10,632,996	64,745	22,554,175
	51,721	19,589,592	35,931	12,509,407	76,170	26,534,323

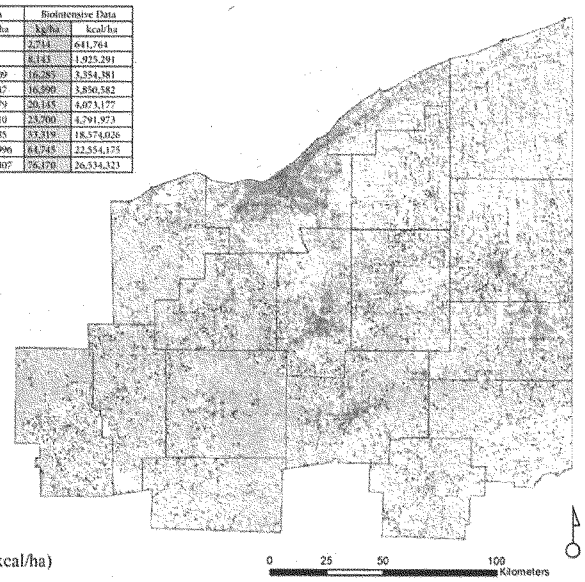

Fig. 3 Estimates of potential yield in Northeast Ohio from contiguous land that is either inagricultural production or in a soil capability class that would permit production (i.e., cleared land with slope and soil class suitable for production)

this landscape, not what it would take to produce such a change in land use. That would include a host of profound economic and social changes, such as land ownership or access, labor, equipment and livelihoods in such a production system.

Another recent project focused on what could be produced if private land that was not currently being used for food production were to be shifted to production of fruits and vegetables (Kerrick 2013). The concept explored in this study was usufruct, the productive use of another person's land. This study examined the land resources available across a rural to urban gradient in Ohio under both public and private ownership. The proportion of public and private land that could be usefully converted to fruit and vegetable production, based on land capability factors (solar exposure, soil quality, slope, and water access) was calculated first. Then, the potential annual fruit and vegetable production was estimated within randomly selected study sites of 500-m radius along the rural-urban gradient, based on the land capability factors for both public and private

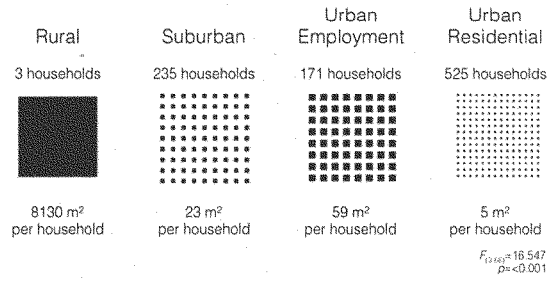

Fig. 4 Differences in the area of private, vacant land that is suitable for vegetable production that is available per household in neighborhoods representing four points on the rural to urban continuum, in a study area in Franklin County Ohio (including the City of Columbus)

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land. Potential for meeting dietary requirements for fruits and vegetables was then estimated within these study sites. As expected, rural areas have few households and abundant vacant land on which production is possible, whereas urban residential areas have many households and little available public or private land. As a result, the vegetable needs of rural residents could be met through production on available private vacant land within their neighborhood many times over, whereas only approximately 2 and 8 % of the urban and suburban population's needs could be met by production within their residential areas, respectively (Fig. 4). Interestingly, in urban commercial areas with relatively few residences but relatively abundant vacant private land, approximately 20 % of the residents' recommended vegetable intake could be produced. These results are a good example of the variation in feasibility of food autonomy at very local scales in the USA.

Conclusions

Predicted climate change impacts, including shifts in growing seasons and more extreme and unpredictable severe storms, droughts, and floods, could require system wide change in food production, distribution, and consumption. The studies and activities described above begin to address what is possible with diversified production and begin laying out alternatives that could be explored for a transition to more resilient agricultural and food systems. Agroecosystem health can be increased, at least in agroecosystems that have become dominated by large-scale and specialized production, by increasing the diversity of production within them. A shift in focus on managing diversity in an agroecosystem rather than managing production of any particular commodities would be a good first step. Accounting for productivity in such systems should include the value of ecosystem services—an accounting stance that would clarify the lack of efficiency in ecological terms of many current production systems. In a more detailed accounting, farmers would seek additional payoffs by augmenting ecosystem services, managing biological diversity in production systems to progress toward this goal.

Social and cultural diversity could add to agroecosystem health if accompanied by sufficient self-organizing capacity to spur innovation. Our work with social media to support planning for increased supply chain diversity has highlighted several obstacles to be overcome. The typical focus of economic development currently is not supportive of collaborative business networks that localize supply chains with diverse enterprises. Entrepreneurial training and support for collaborative business plan development, with greater efficiency and lower risk in a diversified business ecosystem would contribute needed self-organizing capacity at local scales. A combination of naturally occurring biological, crop, livestock, and business enterprise diversity could engage a diverse set of livelihoods, perhaps supporting many cultural traditions. Cultural and social diversity that is sufficiently harmonious to self-organize in support of the biological diversity needed to achieve agroecosystem health and resilience will be key to resilient food security as a property that emerges from healthy agroecosystems.

System-oriented agroecology research that creates a better understanding of managing diversity, rather than replacing it with purchased inputs, would help to achieve healthy and resilient agroecosystems. Both educational programs that train scientists and practitioners and grant programs that support ongoing work in this area are available but remain in the minority at least in the USA. Particularly valuable would be a focus on the mechanistic relationships between social and biological diversity, including self-organizing processes and their contributions to the properties of agroecosystem health.

The global economy is functioning as expected, with large-scale enterprises that find the greatest economies of scale wherever they can be found. Its function is to ensure low prices, but it also results in concentration of wealth. The global economy is not currently organized or regulated in ways that ensure food security in Ohio or any other particular place. This is evident in that approximately 805 million, one in nine of the world's population, were chronically undernourished in 2012–2014 (FAO, IFAD, and WFP 2014) despite abundant production. And despite what are generally considered to be low food prices in the USA, an estimated 16 % of households in Ohio were food insecure in 2011–2013 (Coleman-Jensen et al. 2014). Our economic opportunity is to meet basic needs that the global economy does not meet, such as food security, at local scales and via an alternative business ecosystem that supports agroecosystem health.

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Knowing the Real Value of Food: Blockchain in a New Sustainable Food Economy

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This publication provides an introduction to blockchain technology as it relates to marketing sustainably produced food products through a supply chain in novel and more transparent ways. Blockchain technology offers promises of a new and disruptive form of algorithmic economic trust. Three case studies explore how blockchain is and is not yet living up to its many promises to build trust in sustainably produced food products with multiple attributes delivered to increasingly discerning consumers.

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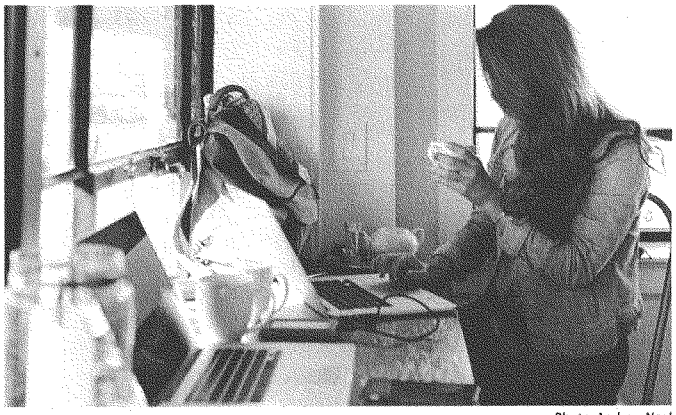

Photo: Andrew Neel

Introduction

"A cynic is a man who knows the price of everything and the value of nothing."
—Oscar Wilde, 1892

Getting off the plane at the international airport in Lima, Peru, one cannot help seeing a massive Coca-Cola® six-pack sculpture. Whether a sign of significant multinational global capitalism or simply a surprising reminder of one of the most trusted world-wide brands, the Coca-Cola® brand does represent an embedded trust that no matter where one travels a Coke is a Coke (Ciafone, 2019). Blockchain technology may provide a verifiable means to create a different and simpler level of the trust that brands like Coca-Cola have developed over many years.

One recent (2016) definition of blockchain is *"a distributed database of records, or public ledger of all transactions or digital events that have been executed and shared among participating parties"* (Crosby et al., 2016).

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Blockchain technology, as applied to agricultural product supply chains, offers promises of a new and disruptive form of what has been called *algorithmic economic trust* and has been even referred to as a *trust machine* (Anon., 2015; Constantinides et al., 2018). Can blockchain technology usher in a transformation to a new, transparent "sharing" food-supply economy? Several researchers have argued that blockchain, or distributed ledger systems, enhances supply-chain management, creating trust-embedded systems where increased transactional efficiency and transparency allow consumers greater access to highly differentiated and identity-preserved products (Jouanjean, 2019; Hawlitschk et al., 2018). Authors also claim blockchain can clarify how economic value is shared from farmer to consumer (Tripoli and Schmidhuber, 2018).

Here we will explore blockchain technology as applied to agriculture supply-chain management and product marketing. A comparative examination of three case studies of lamb supply chains showcases how blockchain both is and is not living up to its many promises of improved transactional efficiency and transparency. Most importantly, the case studies illustrate when blockchain is likely to provide benefits in building trust in food products with multiple attributes delivered to increasingly discerning consumers.

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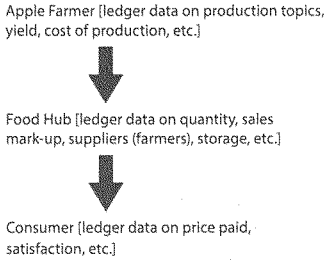
Blockchain 101

Distributed Ledgers, Immutability, and Crypto-Security

There are three important elements to understanding blockchain technology. First, blockchain technology derives in part from the field of computer science, particularly the sub-field of database management. A distributed database is distinct from a central database in that data is not stored on a single computer or device, but rather on multiple computers and/or devices across a network.

Second, blockchain is also often referred to as a distributed ledger system. This means, in the case of an agriculture supply chain, that each party in the supply chain is in control of a "ledger" of information. These ledgers are called "blocks," hence the name. For example, in the very simple agriculture supply chain shown in Figure 1, each party has control over some information contained in a *ledger*.

Figure 1. Direct Apple Market Supply Chain



Third, the data in each ledger is, in computer-science terminology, "immutable" or unchangeable. This means, for instance, that the data input into the blockchain by the farmer is unchangeable by other members of the blockchain. Also, depending on the terms of the blockchain establishment, all data is available to all "blocks" in the blockchain. Thus, blockchain is a distributed ledger system with the property of immutability and full "sharing" or transparency of information.

A final characteristic of blockchain is general security, referred to as *cryptology*. Blockchain is connected and often confused with the development of crypto-currencies such as Bitcoin. The term *cryptology* is similar to the idea of a secret code. Each transaction in the blockchain supply chain is both verified by other members (known as a *distributed consensus*) and protected by an embedded security system within the system itself. Hacking into a blockchain requires not only hacking into a particular block, but also all preceding and following blocks.

Another way to think of this is that the blockchain has a kind of embedded trust system, whereby there is no single central authority needed to insure the validity of transactions within the chain. Rules of governance are based "solely on the correctness of pre-defined rules" (Hawlitschk et al., 2018) and secured by cryptological algorithms and the very nature of the technology itself. Essentially, in the context of agriculture and food, blockchain technology offers the potential to have greater transparency of how food is produced and processed, as well as how economic value is distributed within complex national and global supply chains for all those participating, including the end consumer.

Complexity, Models, and Blockchain Agriculture Supply Chains

Figure 2 demonstrates a more generic model of an agriculture supply chain in its current and blockchain form. As can be seen, the blockchain model demonstrates its distributed nature, as well as the basic functions of moving food from farmer to plate. The model also shows a more circular model of a market economy rather than a traditional linear view, which is arguably an important change that could lead to more sustainable food systems.

Another way to understand blockchain agricultural supply chains is to think of them as multi-agent systems (MAS). In Figure 2, producer, processor, transport provider, retailer, and the blockchain are agents in the system and, in the blockchain version, all parties can view all parts of the system. Ultimately, the consumer can also view all parts of the system, allowing for greater transparency of the entire chain. This transparency, security, immutability, and embedded trust provide unique, even disruptive, changes to supply-chain management over the current agriculture supply-chain system. As noted in one recent (2018) research paper, blockchain supply chains provide traceability that can give "confidence to the final consumers about the origin of the products, whether they are recycled, whether they are first use, etc." (Casado-Vara et al., 2018).

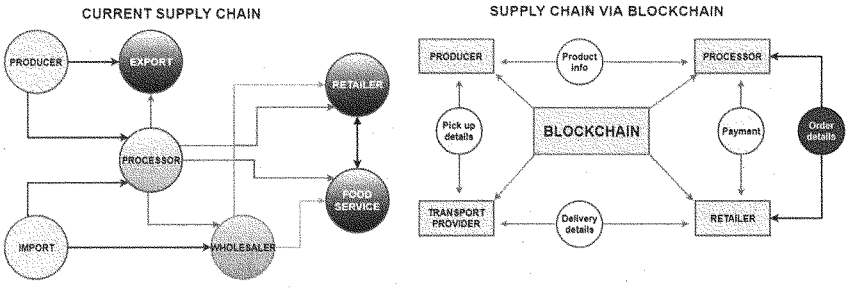
Disruption in Food Supply Chains

In March 2016, *Newsweek* magazine awarded money to 11 entrepreneurs using blockchain for good, stating, "there is a great deal more to blockchain than cryptocurrencies" (Crosby et al., 2016). Advocates maintain blockchain's potential to be a disruptive technology (APTTUS, 2017), despite warnings that it may take longer than we expect (Iansiti and Lakhani, 2017). A "disruptive" technology is one that displaces an established technology or creates a completely new industry:

> "The blockchain establishes a system of creating a distributed consensus in the digital online world. This allows participating entities to know for certain that a digital event happened by creating an irrefutable record in a public ledger. It opens the door for developing a democratic open and scalable digital economy." (Crosby et al., 2016).

Consumers increasingly demand information concerning the safety of their food, its origin, and the sustainability of the processes that have produced and delivered it. For instance, Walmart uses blockchain to provide for traceability of produce through its complex supply chain. One principal motivation for this is to more quickly identify sources of product contamination. Though the protection of the health of Walmart produce consumers and brand reputation are critical, there are also other benefits to Walmart. By requiring the farmers and intermediaries that supply produce to Walmart to be in the company's blockchain system, there is an inherent lowering of broad economic transaction costs related to general supply-chain management that also may be of great importance to Walmart. For example, when blockchain is applied to other areas of business management, proponents claim that business practices are streamlined by making intermediaries such as notaries, banks, and escrow companies

Figure 2. Agricultural Supply Chain Models. Source: Casado-Vara et al., 2018



obsolete in the field of commercial real estate and in general by supporting self-executing, smart contracts. Smart contracts are computer-generated, self-executing contracts free from human interaction. So, for instance, a farmer delivering grain to a mill would instantly be paid for the grain delivered under the terms of a smart contract that would self-execute upon delivery.

Blockchain applied to food supply chains has also been, in part, about the economic topics of transaction costs and product identity preservation, as well as the role of the individual consumer to express demand for a product. Through blockchain technology, transaction costs can likely be lowered and therefore greater economic "value" created for all participants in the chain. Also, with blockchain technology, the abstract and assumed "perfect information" in "free-market" transactions between buyer and seller may be more closely approximated. Because of the potential high level of information about the entire supply chain embedded in blockchains, the food consumer may again be "king," even if the level of sovereignty may still be precarious (Birmingham, 1969).

Through blockchain technology, transaction costs can likely be lowered and therefore greater economic "value" created for all participants in the chain.

Blockchains have also improved the efficiency of distribution by providing the right information at the right time (Tian, 2016). BeefChain applies blockchain to Wyoming beef sales to preserve identity of the product from farm to consumer. Although similar to the broader topic of "smarter and more accessible data and market information," identity-preservation blockchain efforts again present more of an intentional effort to use blockchain as a disruptive technology (Tripoli and Schmidhuber, 2018).

One recent example of this "disruption" in agriculture is the start-up Canadian firm Grain Discovery's claim to have executed the first field corn transaction using blockchain (Grain Discovery, 2019). The transaction was interesting because the original sale of the corn in question was rejected by the farmers' traditional buyer because it tested for a slightly high level of vomitoxin (caused by mold on corn), However, Grain Discovery could facilitate a new buyer quickly, in part because of their use of the blockchain platform. More broadly, Grain Discovery claims that it is

> "...focused on untangling the complicated supply chain paths for grains. The Grain Discovery platform gives more control to both farmers and buyers and has endless applications, from allowing consumers to see the path their food travelled, to calculating the carbon intensity behind the production of food and biofuels." (Grain Discovery, 2019)

The Real Value of Lamb: Three Supply-Chain Case Studies

Scope

This exploration is a qualitative comparative examination of three case studies of the potential application of blockchain technology to three different lamb supply chains. This investigation is based on information from informal interviews and provides some insights based on actual challenges of marketing lamb.

The three supply-chain cases all consider direct-marketed lamb, illustrated first by a small-scale business/ranch, Montana Highland Lamb, based in Whitehall, Montana (owners Dave and Jenny Scott). The second case is the wholesale distribution of "locally" grown Montana lamb through a cooperative food hub, the Western Montana Growers Cooperative (WMGC) based in Missoula, Montana. Food hubs are defined by the U.S. Department of Agriculture (USDA) as "a business or organization that actively manages the aggregation, distribution, and marketing of source-identified food products primarily from local and regional producers to strengthen their ability to satisfy wholesale, retail, and institutional demand" (Pressman and Lent, 2013). Another useful term is *intermediated markets,* i.e., farmers and ranchers selling directly to grocers, restaurants, schools, assisted living facilities, food hubs, and brokers.

The final case study is that of the traditional generic lamb supply chain, illustrated by a natural grass-fed lamb brand developed by a major national grocery chain. To simplify our discussion, we identify these three supply chains as follows: local direct (LD), regional intermediated (RI), and national retail (NR), respectively.

A direct participatory approach was used to develop these case studies, based on informal interviews that included owners/operators in both the LD and RI case studies. In the NR case, information was derived from an interview with the meat procurement manager at the major national grocery store, as well as from research on national commercial lamb supply chains.

In all cases, we asked three general questions, followed with various additional topics, depending upon the direction of the conversation as determined by the interviewee. The three questions were as follows:

1. Have you heard of the term blockchain? (If not, we provided a simple explanation of the term and continued to have the interviewee respond to the basic implications of blockchain technology.)

2. Do you think your customers want detailed information about the lamb products they purchase, including where the lamb was from; how the lamb was raised; how the pasture was managed to produce the lamb; how humanely the lamb was treated; how the lamb was slaughtered, processed, and packaged; whether the cuts were all from the same lamb; how many miles the end product travelled to get to you the consumer; and, finally, how much of the value of the final lamb was received by the farmer/rancher?

3. If blockchain technology can lower transaction costs, improve the efficiency of distribution, and better inform the consumer of the product they purchase, would you be interested in using the technology?

Results: The LD Experience

This case study explores blockchain use for direct-marketed lamb by a small business/ranch, Montana Highland Lamb, based in Whitehall, Montana. Major themes include:

Really *Knowing* Your Lamb Rancher. Montana Highland Lamb offers, for those lucky enough to be living in Montana, a chance to directly know their lamb rancher. For purposes of full disclosure, the author is a patron of Montana Highland Lamb, has visited the ranch, and is familiar with the special system of production used in producing these lambs. Montana Highland Lamb is known for its high-intensity, multi-paddock rotational grazing system, producing 200 lambs per season on 30 acres of irrigated pasture. With a well-designed compost system and pasture management and an emphasis on soil and human health, there appears to be no need for third-party certified labels. Trust for the individual buyer of these lambs comes from direct social and economic bonds built over several years of friendship.

Nonetheless, the LD supply-chain experience at Montana Highland Lamb is not without its production and economic issues. For instance, the ranch is dependent on irrigation based on a water right that in times of severe drought could be limiting. Slaughter, processing, and packaging involve the perennial issue of cost and data retention. Critical data such as weight, frame size, and genetics on each lamb need to be maintained. The lambs have to be sent 250 miles round trip to be processed, and, amazingly, the processor ships back each lamb in a separate box, allowing for data on each to be recorded. Since lamb-processing costs are per head, smaller-framed lambs cost as much as larger-framed lambs to process, thereby creating a known likelihood of economic loss on smaller-framed lambs. Coordinating the individual finished cut-box data and frame size is critical to developing a breeding program that leads to the production of more consistent and larger-framed lambs.

Montana Highland Lamb sells to individual consumers, the Montana State University student cafeteria, high-end restaurants (that may or may not feature the Highland Lamb brand), various rest homes for the elderly where food quality is recognized, and finally, the Western Montana Growers Cooperative. These *client* relationships are critical and require significant effort and data management.

Blockchain Applicability to the LD Supply Chain. When asked about the applicability of blockchain, the co-owner of Montana Highland Lamb, Dave Scott, could envision blockchain use in improving production and marketing data and possibly broad financial management. Again, the key to financial viability for Montana Highland Lamb is the ability to garner data on each individual lamb, as well as to track the value of the various "cuts" sold. These issues could likely be handled with an improved integrated centralized software system, but because the supply chain is relatively simple, there may be no need for a blockchain system. Interestingly Dave, also works part-time for the National Center for Appropriate Technology and the ATTRA Sustainable Agriculture Program that it manages under a cooperative agreement with the USDA. In that position, Dave has created several publications on the production and direct marketing of lamb and other livestock, as well as a useful spreadsheet-based tool called the "Lambulator"— a cut-yield pricing calculator that helps optimize profitability.

Another important topic that may suggest use of blockchain in LD supply chain centers is the topic of economic profit. Montana Highland Lamb is NOT making a true economic profit. Essentially, the business generates some income

over costs, but if that gross income is divided by the actual hours of labor spent, the rate of pay for the operators is well under minimum wage. Even at this low labor rate, there simply is no actual return on invested capital. While it may seem surprising to many as to how a ranching "business" could continue to operate with no—or even negative—profit, in Montana this is not unusual in any given year. For example, net farm income in Montana in 2017 was negative for all farms without federal government support payments (USDA, NASS, 2018).

This is significant because even with the very high level of trust between the rancher and direct or nearly direct consumer of the lambs, Dave and Jenny are reluctant to raise prices for fear of losing customers. One alternative is to expand production, but as that occurs, the probability of maintaining trust in the product possibly diminishes. That is, unless a blockchain system could possibly substitute for the great labor-intensive trust-building effort that goes beyond the current customer base.

Results: The RI Experience

This case study explores blockchain use for wholesale distribution of "locally" grown Montana lamb through a cooperative food hub, the Western Montana Growers Cooperative (WMGC), based in Missoula, Montana. Major themes include the following:

Lost in Translation? The WMGC is first and foremost a cooperative of farmers and ranchers who want to pool their products to increase sales through the WMGC Community Supported Agriculture (CSA), grocery stores, restaurants, and institutions (such as schools, colleges, and hospitals). Community Supported Agriculture "consists of a community of individuals who pledge support to a farm operation so that the farmland becomes, either legally or spiritually, the community's farm, with the growers and consumers providing mutual support and sharing the risks and benefits of food production" (Prial 2019). The WMGC sells their products mostly in western Montana, but also covers markets in Northern Idaho, Eastern Washington, and the city of Portland, Oregon. The mission of the WMGC is "to provide communities within the western Montana region with a wide range of fresh, quality products from western Montana independently owned ranches and farms." The WMGC, while a classic food hub or intermediated market, in some sense is simply a wholesaler of locally/regionally produced food. There are several issues relevant to this type of operation and the sale of lamb.

First, the WMGC currently sells lamb acquired from four major suppliers: Montana Highland Lamb, Lifeline Produce, Montana Natural Lamb, and Will Tusik, as well as other small ranchers as needed to meet demand. Despite the WMGC having individual brands associated with other livestock products, such as beef, bison, bone broth, eggs, cheese, butter, and milk, the lamb is only portrayed as "generic" lamb. Thus, the particular rancher is, in a sense, lost in translation.

Second, the WMGC tracks several important attributes (stated as "values") of the products they sell. These are: cooperation, appropriate technology, land stewardship, and social equity. While these are all very noble values, there is no easy way to independently verify that these values are met. For instance, the WMGC sells certified organic eggs via the branded Mission Mountain Organic Eggs, as well as eggs labeled "cage free," "free ranging," and "fed a 100% vegetarian diet free of antibiotic stimulants, steroids, or hormones" from Spencer's Valley View Farm. Although organic is a third-party verified, legally enforced label, the claim of "cage free" is not, making it more difficult to verify.

Finally, without further investigation and direct contact with the WMGC staff, it is impossible for an individual or commercial buyer of the lamb to know any product attributes of the lamb being sold, other than the producer's general commitment to the values stated above. Even the crucial, overall value of "buying local" is not clear when it comes to lamb.

Blockchain Applicability to the RI Supply Chain. In interviewing the WMGC manager, David Prather, it was clear that he had some notion of blockchain, at least regarding its connection to Bitcoin. He was not sure that blockchain would be an appropriate technology for the WMGC to adopt. Despite the WMGC website not making it clear who produced the lamb it sold, Prather did state that buyers could purchase from a specific lamb supplier if they wanted, and if the lamb was available.

Although David Prather thought it would be great in some ways to have information flows via blockchain to the ultimate consumer, he had mixed feelings, speculating that many consumers would not want many details about their food. Those buying from the WMGC seem to have trust in the brands being sold (as long as those brands are identified). They seemed to care more about localness than how the food was produced. David Prather did not believe that being certified organic is a critical issue to the WMGC's customers. Though it's not the subject of this publication, it's worth noting that WMGC sale of produce is even more complicated, as the sources are many and not all products are branded. There seems to be even greater translation loss with produce than with lamb, making it appear that blockchain technology may be very valuable to organizations like food hubs, even if only for improving transaction costs and distribution efficiency.

For outlets such as food hubs and intermediated markets, third-party verification can be important for establishing trust. Apparently, the WMGC's customers value producer cooperation, appropriate technology, land stewardship and social equity (the WMGC values listed earlier). Incorporating pictures demonstrating appropriate technology use, such as a soil sensor detecting soil quality, placed into a blockchain, may be valuable to the WMGC's customers.

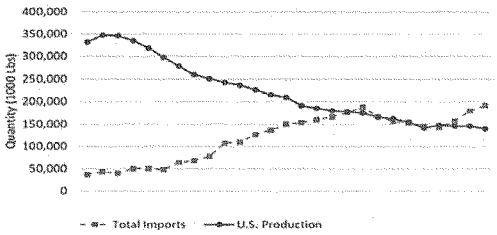
Results: The NR Experience

The final case study explores blockchain use with the traditional generic lamb supply chain, illustrated by a "natural, grass-fed" lamb label created by a major national grocery chain. Major themes include the following:

Deliberate Confusion? Lamb is an international commodity, and most lamb in the United States is imported from Australia (AU) and New Zealand (NZ). Despite the distance from AU and NZ to the United States, lamb ranchers there can produce lamb, year round, at such a competitive price that they dominate the U.S. lamb market. Interestingly, sheep and lamb coming from outside the United States are required to have a country of origin label (COOL) attached. Even when the meat is differentiated by country of source, most American consumers do not seem to mind only having foreign lamb available for purchase. In our interview with the meat manager of a national retail grocery chain in Montana, it became clear that this national grocery chain has not purchased American lamb for at least 20 years. Its current lamb is sold under an exclusive in-store natural label with defined attributes: raised without antibiotics, no added hormones, animals fed an all-vegetarian diet, and no artificial preservatives. As previously discussed, the consumer has to assume honesty because, unlike the organic label, these attributes are not, nor do they have to be, independently third-party verified. (No added hormones does not apply to beef products under this label, which the grocery chain makes semi-clear by an asterisk on its label.) So why, as Robyn Metcalfe asks in her recent book, *Food Routes*, does a major grocery chain or even a restaurant in Maine order lamb from NZ or AU (2019)?

Figure 3 demonstrates the reality of U.S. loss of the lamb market to AU and NZ (Ufer, 2017). The major reasons for this loss of market are: (1) the year-round pasture-based (grass-finished) production system in AU and NZ; (2) U.S. livestock farmers shifting to higher-value livestock production products such as beef; (3) COOL labeling actually highlights the quality of AU and NZ lamb products; (4) the U.S. economic power concentration of the slaughter/processing industry makes lamb processing relatively more expensive here than it is in AU and NZ; and finally, (5) the cost of production is simply higher in the United States, perhaps principally due to the higher relative cost of rangeland (Ufer, 2017). In short, in economic terms, AU and NZ lamb has a "comparative competitive advantage" compared to U.S.-produced lamb. While it is hard to point to any one of these reasons as a definitive cause for loss of U.S. domestic lamb production, even when they are taken together, blockchain could theoretically help in changing this current economic reality.

Figure 3. Annual Lamb Imports vs. U.S. Lamb Production. Source: Ufer, 2017



A fundamental issue is that perhaps consumers are confused. Without good and "truthful" information (beyond simply the important price basis) for making a purchasing decision, they are truly at a loss to really consider other reasons for buying American lamb. Other possible reasons exist: the top four food retailers sell more than 60% of the total groceries bought in the United States and because these four only sell AU or NZ lamb, choice is simply not an option. Perhaps the natural grass-fed lamb label from AU or NZ may seem to be a better product, although all lamb eats some grass during its short life cycle (they are ruminants). Nonetheless, many consumers believe that eating "grass-fed" lamb is healthier, and because all AU or NZ lamb is "grass-finished" and because grazing is less expensive than feed grains, AU and NZ lamb has a built-in added economic advantage.

Blockchain technology shines when processes involve multiple organizations.

Blockchain Applicability to the NR Supply Chain. The major grocery retailers in the United States may find blockchain useful for very different reasons than one might initially think. In our interview with the 20-year meat manger in the major grocery chain in Butte, Montana, there was obvious disappointment with the corporate decision to only sell foreign lamb. When told what blockchain technology might do to better inform the lamb consumer about the product, the meat manager did seem to have faith that the natural-branded lamb chop from AU was truthfully labeled. He felt that the consumer was well informed and had all the information they would want to know about the product. He also related that the COOL labeling was handled well for lamb by this national grocery chain, as compared to his experience with trying to apply the same COOL requirements to beef and pork. (COOL labeling of beef and pork was implemented for a brief period in the United States, ending in 2015.) Indeed, he did think that if blockchain technology could be applied to help with COOL labeling of beef and pork in the future, this would be very helpful and assure greater support for American beef and pork farmers.

Though consolidated grocery retail businesses might be interested in blockchain for purposes of tracing contaminated product, it does not seem yet to be of significant interest for improving provision of consumer information about the lamb they are purchasing. One slight exception to this more general rule is the example of Whole Foods, which prides itself on offering lamb possessing similar attributes to the national grocery chain's natural in-store brand, but goes even further to provide information on some American brands of lamb products they sell, along with various AU lamb products. Whole Foods has introduced an animal-welfare standard that seems positive and is third-party verified.

Thus, blockchain may not be of interest to the NR lamb supply chain, even if ultimately useful, because of the desire not to expose the economic power embedded in this global food supply system. Although this may not be an intentional desire to keep consumers confused, it might be inherent to the structure of the kind of unsustainable capitalism that we find ourselves a part of today (Henderson et al., 2017). Recent authors spoke to this issue:

> "Increasing consolidation and vertical coordination in the food chain have made the prospect of market power abuses by powerful food manufacturers and retailers an issue and a policy concern worldwide, in terms of potential impacts on farmer and consumer welfare and sector efficiency. A key conclusion is that considerations that go beyond the bounds of standard models likely can cause market power to be less than would be predicted based on the highly concentrated structures of many modern agricultural and food markets. These considerations include downstream buyers who rationally internalize long-run implications of their pricing decisions to farmers, powerful food manufacturers and retailers who countervail each other's market power, and the complex pricing decisions of multistore and multiproduct food retailers." (Sexton and Xia, 2018)

Discussion and Conclusion

From this qualitative analysis, we would suggest that blockchain technology has great potential to be a truly disruptive technology if applied to all three examples of the lamb supply chain considered here. However, the closer consumers are to the actual producer of their food, the less valuable blockchain technology will be, because "real" trust does not need to be embedded in a blockchain.

Companies use information systems, supported by centralized databases, to track significant aspects of their processes and products effectively. Blockchain technology shines when processes involve multiple organizations. Tracking where and when produce was contaminated, finding niche markets for contaminated grains in the case of Grain Discovery, and even understanding the carbon intensity behind grain production cannot be easily captured in a single centralized database.

Most products move through multiple phases before consumers purchase them. In our example, lambs are born and raised on a farm, shipped, processed, shipped again, and marketed, before customers purchase them. Typically, no centralized database can track the process a lamb goes through from the farm to the consumer because each organization uses different informational systems.

Blockchain technology provides a distributed database that each participant in the process can access, both to read and to write. The consumer purchases a product whose significant aspects have been recorded and can be perused. Furthermore, at each step in the process, once information was recorded into the distributed database, it could not be changed. Whatever story was recorded as the lamb went through the various phases on its way to the consumer could not be changed later, in order to cover up a problem or create fraudulent information. This transparency allows customers to trust their products, executives to improve their processes, researchers to understand processes, and workers along the product's journey from farmer to processor to see the big picture.

Future research could include the use of more quantitative research methods that would explore whether food-retail distributors truly want to provide consumers with knowledge of attributes such as the value returned to the farmer who truly undertakes sustainable farming practices. Also, will such knowledge communicated to the consumer be the basis of a new competiveness between products? In other words, will a consumer by apple A versus apple B if they know for certain apple A was not only sustainably produced but that the farmer received a fair share of the true value (not just price) of apple A?

Solving technical issues such as the need and cost for greater distributed immutable ledgers that could keep the chain of information "trustworthy" through the supply chain might actually make consumers "kings" in the simple economic neoclassical models taught in so many introductory economic courses. As earlier suggested by Adam Smith in *An Inquiry into the Nature and Cause of the Wealth of Nations:*

> "Consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to, only so far as it may be necessary for promoting that of the consumer. The maxim is so perfectly self-evident, that it would be absurd to attempt to prove it." (Birmingham, 1969, p. 377)

The structure of the current industrial system, because of its lack of any semblance to a free market, and the exercise by a few of significant economic market power over the industrialized food system does contradict the perfectly self-evident truth of consumer sovereignty over our food choices (Henderson et al., 2017).

Producers should benefit from blockchain as well: in this case, the American lamb farmer. How interesting would it be if, sitting down at a fancy restaurant, we could take out our smartphones and read a "code" on the menu that would provide not only truthful information about how the rack of lamb we are about to order was raised, but also how much of the value we pay for the item is returned to the farmer? Although food tracking systems have been around for some time, blockchain provides the added technological means to assure trust in the product one is purchasing at the final stage of the supply chain: the consumer.

Could a new era of product competition be emerging where we can buy products with complete assurance of the multiple important values the consumer desires, including supporting our regional economy and the lamb rancher who truly did the bulk of work to provide us with something so very good? Perhaps we need to reassess what is both the real—and just—price of lamb. Maybe blockchain technology could help enormously with that assessment. We share with others the hope that "the perception of value, within a certain techno-economic context, is instrumental to unlock the potential for societies to prosper" (Pazaitis et al., 2017). So think hard the next time you buy your lamb chops.

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Further Resources

Agriculture and Food Blockchain Examples

Agriledger
www.agriledger.io/home
Provides blockchain software to manage agriculture supply chains.

BeefChain
https://beefchain.com
Use blockchain technology to support beef ranchers in recapturing the value now realized by third-party feedlots and processors.

BlockGrain
https://icotokennews.com/icos/blockgrain
BlockGrain supports well-established agricultural supply chains with a new dynamic and seamless blockchain software technology. BlockGrain encourages farmers and their supporting businesses to better connect with buyers to develop and grow their own supply chains.

Grain Discovery
www.graindiscovery.com/about
Provides improved grain supply-chain management with greater transparency and traceability.

OriginTrail
https://origintrail.io
OriginTrail brings greater transparency to complex international supply chains of several agricultural products.

Provenance
www.provenance.org
Provenance is a digital platform that empowers participating branded products to provide greater supply-chain transparency. The participating businesses can easily gather and present verifiable information and stories about their products and their supply chains.

Ripe.io
www.ripe.io
Brings long-lasting trust and confidence in food supply chains through a software platform where any consumer can access transparent and reliable information on the origin and quality of her food.

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Knowing the Real Value of Food: Blockchain in a New Sustainable Food Economy

By Jeff Schahczenski, NCAT Agriculture and Natural Resource Economist, and Emily Post, NCAT Agricultural Specialist

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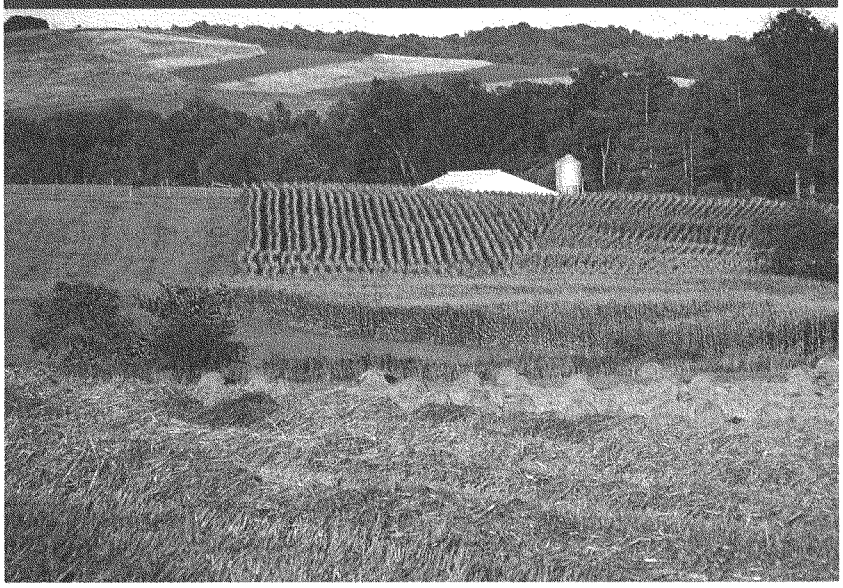
NCAT ATTRA SUSTAINABLE AGRICULTURE

A CALL TO ACTION



Ohio Smart Agriculture: Solutions from the Land

A Call to Action for Ohio's Food System and Agricultural Economy

Ohio
Smart
Agriculture
SOLUTIONS FROM THE LAND

Ohio Smart Agriculture: Solutions from the Land Steering Committee

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Executive Director, Ohio Association of Foodbanks

Fred Yoder* – Plain City, OH
Fourth-generation farmer; Co-Chair, Solutions from the Land; Chair, NACSAA

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FOREWORD

Our recent initiative, *Ohio Smart Agriculture: Solutions from the Land*, was organized to identify and begin implementing pragmatic, proven, and innovative solutions to challenges confronting Ohio farmers in the face of environmental uncertainty and in support of a food system that benefits producers, the public, and the planet.

Driven by farmers — with participation from experts in agribusiness, health, nutrition policy, ecology, and conservation — the initiative explored ways to place farming at the forefront of resolving the extensive challenges facing Ohio today: hunger, poor health, degraded environments, broken economies, trade, tariffs, and limited inclusion in global economies. In doing so they considered food, agriculture, the environment, and rural and urban communities as a *system* rather than separate challenges. This effort is about creating new options and opportunities for farmers, agriculture, and consumers that together benefit all.

Through months of brainstorming, research, and dialogue with communities of interest across the state, the project leaders forged consensus on strategies to:

- **Reduce hunger** and **improve nutrition** by supporting the production of fruits, vegetables, animal proteins, and food-grade grains for human consumption.
- **Create jobs** and **generate economic growth** by diversifying and sustainably intensifying production and processing of food, feed, fiber, and renewable energy.
- Augment ecosystems services to **improve the environment, enhance the resilience** of agricultural and forested landscapes and **improve the farmer's bottom line.**

This call to action outlines their collective findings and recommendations and offers a series of priority actions needed to help Ohio's farmers and woodland managers further improve the state's quality of life through solutions they can sustainably deliver from the land.

At a time of historically high yields but low commodity prices, climate and environmental threats, and widespread hunger in a skilled and prosperous state, Ohio agriculture can diversify its production with a resilient agricultural model focused on ecosystems services.

We will succeed when the direction we set forth engages the broader community in a joint response to these issues and promotes collaboration among Ohioans. We invite you to join us in bringing this vision to life through *Ohio Smart Agriculture: Solutions from the Land.*

Fred Yoder, *Co-Chair*
4th Generation Farmer
Plain City, Ohio

Lisa Hamler-Fugitt, *Co-Chair*
Executive Director,
Ohio Association of Food Banks
Columbus, Ohio

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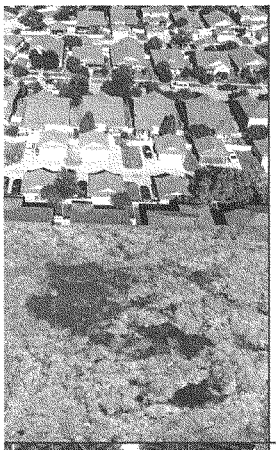
Ohio Smart Agriculture
SOLUTIONS FROM THE LAND

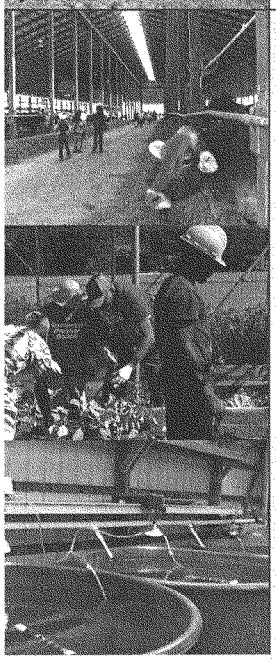
The project is funded by a generous grant from the W.K. Kellogg Foundation. WKKF, founded in 1930 as an independent, private foundation by breakfast cereal pioneer, Will Keith Kellogg, is among the largest philanthropic foundations in the United States. Guided by the belief that all children should have an equal opportunity to thrive, WKKF works with communities to create conditions for vulnerable children so they can realize their full potential in school, work, and life.

W.K. KELLOGG FOUNDATION

EXECUTIVE SUMMARY



PROBLEM: Increasingly complex markets, low commodity prices, and more volatile weather exacerbate crop losses and degrade environmental conditions, such as the creation of the harmful algal blooms, that have combined in ways that threaten Ohio agriculture. At the same time, household food insecurity in Ohio, a state that should be a land of plenty, ranks well above the national average (15.1 percent of the population of Ohio, including one out of five children, suffer from food insecurity). Clearly, the commodities we are so good at producing are not relieving that insecurity, nor are they keeping all farms and farmers on the land. The American Farmland Trust estimates that Ohio has been losing more than 50 acres of farmland per day as the long-term trend toward fewer farmers and fewer farms continues.



VISION: Facing the specter of a rapidly changing and more unpredictable global environment, Ohio agriculture will adjust to these conditions and maintain a style of farming and a food system that benefits producers, consumers, the public, and the planet. Our vision is to boost profitability for farmers at all scales and in all settings, rural and urban, while improving environmental resilience, building strong communities, engaging consumers, and ensuring public health and access to nutritious food.

EXECUTIVE SUMMARY

For more than 200 years, agriculture in Ohio has nourished us at the national and local levels. It has been a powerhouse economically and culturally, and a consistent national leader in providing a wide range of products. Its farmers have changed with the times — steadily boosting their yields, embracing technology, adopting new practices, and deepening a connection with the land and soils.

Yet the changing times have also revealed a disconnect between farms and cities. Many rural farm towns have fallen on hard times. But the highest percentages of food-insecure households fall at both the most urban and rural ends of the spectrum. Changing weather patterns have made prices — and yields— more volatile. And, despite improvements in how farmers apply nutrients, agricultural runoff still is a problem in Ohio's waterways. These are the loose threads in Ohio agriculture today.

Ohio Smart Agriculture: Solutions from the Land has studied this landscape for nearly two years and now unveils a comprehensive strategy to re-weave these threads into a beautiful, strong, and valuable tapestry that reconnects Ohioans, helps reduce hunger, and strengthens communities — all in a way that draws from and gives back to our ecosystems.

The Ohio Smart Agriculture Steering Committee developed this vision for mid-century agriculture after intensive research, presentations, and discussion of the challenges and opportunities that Ohio

agriculture faces. Four workgroups delved into climate, ecosystems, market opportunities, and hunger, and identified three pathways for achieving these solutions from the land:

- **Reduce hunger and improve nutrition** by supporting the production of fruits, vegetables, animal proteins, and food-grade grains for human consumption.
- **Create jobs and generate economic growth** by diversifying and sustainably intensifying production and processing of food, feed, fiber, and renewable energy.
- **Augment ecosystems services to improve the environment, enhance the resilience of agri cultural and forested landscapes and improve the farmer's bottom line.**

The result is a set of 50 goals and recommendations apportioned among these pathways to guide the next generation of Ohio agriculture. The steering committee then identified four major initiatives that could be launched in the very near future and, together, set the stage for all the recommendations. Each of the four initiatives encompasses several of the goals and recommendations.

This taxonomy of pathways, goals, and initiatives should not in any way be considered a form of prioritization. This call to action emphasizes that Ohio Smart Agriculture is a **long-term**, comprehensive initiative that requires sowing seeds along all three pathways at once: Agriculture is a *system*, and *all the recommendations together* are priorities that will enable the transformation we envision.

The four sweeping initiatives are the kinds of **short-term** actions that can attract financing for this effort and enlist others to join the quest for a wider range of goods and services from Ohio's farms and woodlands. **The order in which they are presented here does not connote any ranking. These steps are interconnected and interdependent "launching pads."**

Initiative I: Make Ohio agriculture and the food system a public policy priority.

A) Form and properly resource a Farm, Food, and Health Partners Alliance (a non-governmental group of stakeholders from across the spectrum of food and agriculture).

B) Create an interagency task force to align state agencies toward effective and coordinated food, health, and agricultural programs.

C) Restore state government as a marketer and champion, as well as a regulator, of agricultural goods and services (through such programs as Ohio Proud).

Initiative II: Diversify and sustainably intensify the production of food, feed, fiber, and fuel.

A) Integrate commodity with diversified, identity-preserved, value added agricultural production to enhance ecosystem services and public support for Ohio agriculture.

B) Promote workforce development and resources, such as land access, to ensure a strong agricultural economy.

C) Create a strategy to strengthen value-added woodland supply chains and create new markets for residual forestry products.

Initiative III: Use institutional buying power to ramp up demand for "Ohio Smart Food."

A) Jump-start infrastructure development by quantifying demand for and encouraging commitment to local food purchasing by public institutions.

B) Develop an independent "food system finance authority" to pay for development of processing infrastructure.

C) Develop and pilot a small-scale, mobile meat-processing unit.

D) Regularly evaluate the food needs and preferences of Ohioans through surveys.

Initiative IV: Implement landscape-scale, climate-smart agriculture strategies to ensure sustainability and abate agricultural runoff.

A) The state of Ohio and all stakeholders should, by 2020, formulate and oversee the implementation of a new state water quality strategy that includes current public and private sector response initiatives.

B) Develop and implement a climate-smart action plan for Ohio agriculture to help farmers adapt, improve resilience, and deliver products and services that mitigate climate-change impacts.

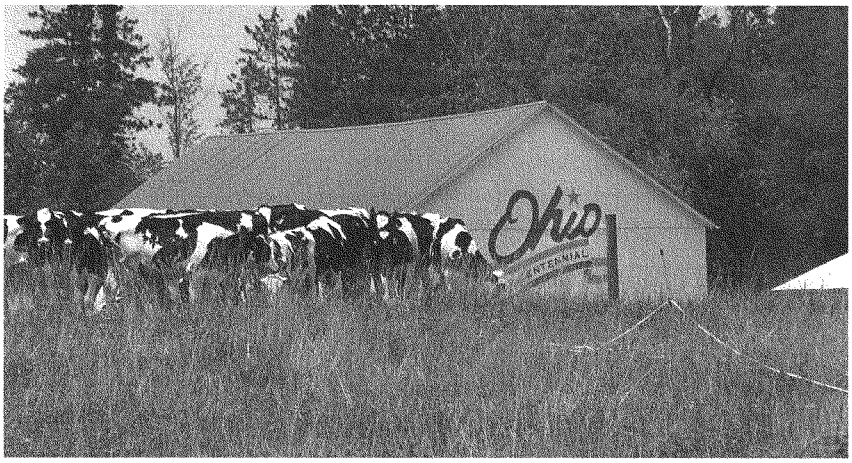
C) Track and publish statewide progress data to assure and celebrate continuous improvement.

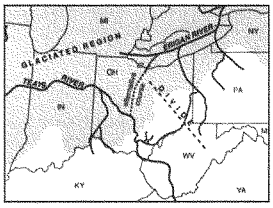
Among the remaining recommendations are recurring themes that illustrate the interconnectedness of these strategies:

- Local and regional supply chains offer great potential for growth once the processing and marketing infrastructure are in place; they can reduce food insecurity while creating jobs and strengthening local economies.
- A greater variety of grains and grasses can improve soil health and reduce runoff from fields; developing markets for winter cover crops can make them and the ecosystem services they provide more attractive to farmers.

The goals and recommendations in this call to action are the result of collaboration among many interests: commodity growers, produce farmers, foresters, public health and nutrition experts, agribusiness leaders, academics, environmentalists, agriculture advocates, and others. A coalition this diverse, coming to consensus on a 30-year vision, shows the seriousness of this call to action and provides a strong foundation for a widespread movement to prepare Ohio agriculture for a challenging future.

The current coalition, however, is only a start. We need agriculture industry leaders, political voices, community and consumer support, and institutional backing if we are going to ensure that political, economic, and social frameworks are ready for these changes. We encourage you to study the vision we've described, share it with those who would appreciate its message, support and join us as we move forward with *Ohio Smart Agriculture: Solutions from the Land.*





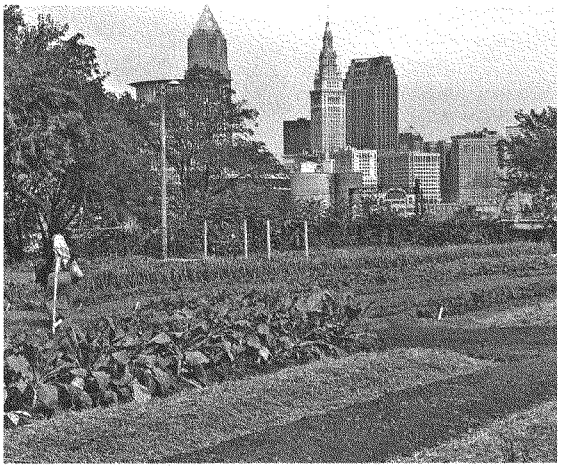
The story of Ohio agriculture is as old as the hills. The richness of many Ohio soil types is a product of glaciers that reshaped the landscape and left deposits when they receded. The resulting woodlands, wetlands, and prairies were cleared, drained, and plowed to make way for subsistence agriculture for early settlers, and later — as towns grew and industry emerged — to feed the population in the burgeoning towns and regions.

Two hundred years of agricultural change and industrial growth, however, have further remade Ohio's landscape and climate. Farmers and others are now trying to figure out what Ohio agriculture will look like in 2050: How will we adapt to changing weather patterns? How do we make sure that the products of our land will nourish even the most vulnerable among us? What practices will nourish the soil and water? How will we cultivate an agricultural economy that ensures strong Ohio communities?

Ohio Smart Agriculture: Solutions from the Land started planning for this future by looking to the past.

Even two centuries ago, early Ohio farmers balanced the locally oriented frontier economy by producing commodities for sale in distant markets. Corn was easier to transport if it was distilled to make whiskey — a product that, as one Ohio historian has written, was "both potable and portable" for the journey east across the mountains or south down the Ohio and Mississippi rivers. By 1850, Ohio

Farmers and others are now trying to figure out what Ohio agriculture will look like in 2050.



was the nation's leading corn producer and second in wheat. Livestock, too, had both local and commodity markets, though many of the hogs raised in Ohio went to processing plants that turned Cincinnati into a "Porkopolis" that fed much of the country.

Through the 20th century, building on advancements from "agricultural and mechanical" land-grant colleges like The Ohio State University (OSU), Ohio agriculture became steadily more commodity-oriented. Again, for much of the century, it was balanced with the production of local foods. Even small cities had public markets, dairies, slaughterhouses, and truck farms to feed local populations. Many also had large greenhouses as Ohio became a hotbed of hothouse tomatoes. As recently as 1970, the City of Cleveland had 400 acres under glass, providing produce for a large swath of the region. Greenhouses in surrounding towns and counties added to that total.

In 2017 Ohio was:

- **8th in corn production**
- **7th in soybean production**
- **4th in tomato production**
- **3rd in egg production**
- **8th in hogs and pigs**
- **7th in number of farms nationally.**

In recent decades, in a significant departure from farm economies of the past, agriculture in Ohio and around the country evolved into an efficient specialization of production in different regions: produce in Florida and California for year-round growing, for example, and commodity grains in the Midwest and Plains states. In Ohio, the changes led to a decline in the tomatoes, peppers, cucumbers, and other produce grown for large national processing facilities in the state. Ohio became more specialized — and was very good at what it did. It has long been among the leading national producers of corn, soybeans, pork, dairy, and many other goods.

Today, Ohio is an agriculture powerhouse. Food and agriculture make up Ohio's largest industry, contributing more than $124 billion in annual economic impact and employing 1 in 8 people.[1] That total includes much of the $26 billion the forest sector generates. Ohio has some of the most fertile land in the country with 14 million acres in production; 75,000 farm operations; and more than 1,200 food processors.[ii] In 2017 Ohio ranked third in egg production nationally; eighth in hogs; fifth in floriculture; sixth in wine production; first in home furniture production; seventh in soybeans; and eighth in corn. Much of the corn and soybeans are used as feed for the state's high-value livestock and poultry industries.

Despite Ohioans' skill and success in production, the new model runs counter to the historical balance between local markets and commodity markets. This has contributed to a disconnect between farmers and consumers — to the point that today many young Ohioans identify food as coming from the grocery store rather than the land.

Against this rich history and current conditions, several big challenges cloud the future of Ohio — setting the stage for a lot of new opportunities.

In 1987, Ohio and the nation were still in a farm financial crisis that accelerated the trend toward fewer farmers and bigger farms. Tractors and combines did not have GPS technology. There were no GMO seeds. No-till practices were still just taking root. Lake Erie was getting healthier. Average corn yields in Ohio had reached new highs of over 120 bushels per acre. Soybeans averaged 37 bushels and wheat 58. The average age of an Ohio farmer was 51. Even accounting for inflation, the cost of a combine in 1987 was about half of what today's farmers pay for more comfortable combines with bigger headers and bins. This same axiom holds true for today's loggers trying to purchase new log skidders or timber harvesters.

A lot has changed in the 30 or so years since then. A lot more will change in the next 30 years, as technology increases the pace of innovation and ecological and economic factors drive even more change. Have the changes been good for the Ohio agricultural industry? For Ohio agricultural output? Have the changes been good for Ohio farmers or Ohio consumers?

What can we expect by the year 2050? Will weather patterns continue to shift? Will we see heavier and more sporadic rains? Hotter and drier weather? Will annual algal blooms in the Western Lake Erie Basin appear sooner and grow larger? Will we see 300-bushel corn? Will the average age of an Ohio farmer — 56.8 years in 2012 — continue to rise? Or will a new generation of farmers start to reverse that trend? How will those farmers differ from today's typical farmer? What challenges and opportunities will they face?

In 1987:

Corn yield:
120 bushels per acre

Soybeans yield:
37 bushels per acre

Wheat yield:
58 bushels per acre

Average age of Ohio Farmer in 1987:
51.1 years

In 2017:

Corn yield:
177 bushels per acre

Soybeans yield:
49.5 bushels per acre

Wheat yield:
74 bushels per acre

Average age of Ohio Farmer in 2012:
56.8 years.

SOURCE: NASS, UNITED STATES CENSUS OF AGRICULTURE 1987 AND 2012 (NASS.USDA.GOV/AGCENSUS); NASS, QUICK STATS 2017 (QUICKSTATS.NASS.USDA.GOV)

Those are some of the conditions and questions we began to examine in March 2017, when *Ohio Smart Agriculture: Solutions from the Land* convened a steering committee from all facets of agriculture and the food system across the state. The team's mission was two-fold: to identify challenges confronting Ohio farmers in the face of environmental uncertainty and market volatility and to implement solutions that are pragmatic, proven, and innovative — and supportive of a food system that benefits producers, the public, and the planet.

Since then, the committee, along with four workgroups and external collaborators, has held numerous meetings (including regional sessions in Piketon, Springfield, Bowling Green, Wooster, and Reynoldsburg). They have studied reports and heard presentations

Will weather patterns continue to shift? Will we see heavier and more sporadic rains? Hotter and drier weather?

In Ohio, 1,758,310 people are struggling with hunger - and of them, 528,960 are children.

1 in 7 people

struggle with hunger.

1 in 5 children

struggle with hunger.

People facing hunger in Ohio are estimated to report needing

$829,430,000

The average cost of a meal in Ohio is $2.76. Data from Feeding America's Map the Meal Gap 2016 study.

Reconnecting Ohioans with food, and with agriculture, is a matter of survival.

from experts in nutrition and health policy, climate science, soil science, meat processing, agricultural economic development, forestry, finance, and other topics.

This work uncovered three recurring themes: 1) hunger and food insecurity; 2) climate and water quality; and 3) profitable farms and communities.

1. Hunger and food insecurity

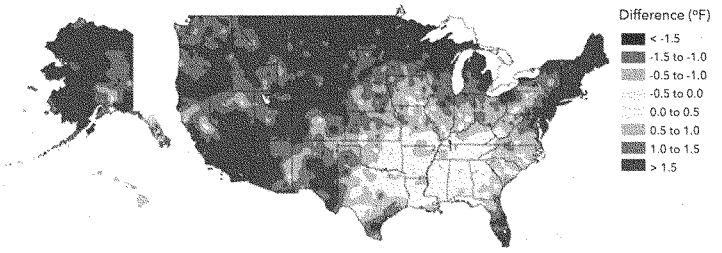
Today, 15.1 percent of Ohio's population is "food insecure," meaning they may need to make trade-offs between basic needs, such as housing or medical bills, and purchasing nutritionally adequate foods. Among Ohio's 2.6 million children under age 18, one out of five is food insecure. In fact, even in wealthy suburban counties, 15 percent of children are food insecure — leaving Ohio with the nation's 15th highest rate of child food insecurity.[xi]

Ohio is in the bottom quintile of states in several other health and nutrition metrics as well. It is ranked 42nd among the 50 states for preventable hospitalizations, 41st for cancer deaths and infant mortality, and 40th for obesity. Ohio's infant mortality rate of 7.4 out of every 1,000 births in 2016 was well above the national average of 5.9 per 1,000 births. Eleven percent of Ohio children have asthma (8 percent nationally), and 33 percent are overweight/obese (31 percent nationally)[x]. Many Ohio farmers are surprised and alarmed by this, and they want to develop ways to ensure Ohio agriculture sustains Ohio's people and land.

2. Climate and water quality

The incidence of heavy rains — a half-inch, one inch, or two inches in a day — has risen steadily across Ohio since 1950. Most regions now see at least five or more such rains per year than in 1950, and some as many as 10[x]. Unusually wet springs sometimes force farmers into the costly position of replanting crops. They also face longer droughts that reduce yields. These changing weather patterns have exacerbated water quality challenges.

Annual average temperature change over the contiguous United States for the period 1986-2016 relative to 1901-1960



SOURCE: NATIONAL CLIMATE ASSESSMENT, CLIMATE SCIENCE SPECIAL REPORT 2017 (SCIENCE2017.GLOBALCHANGE.GOV), WITH CREDIT TO AARON WILSON (OSU)

Across Ohio, farmers are dramatically expanding their efforts to reduce nutrient runoff into lakes and streams around the state. As documented in A Report from Ohio's Farm Community, the agriculture sector has been working for years to reduce nutrient loads in the Western Lake Erie Basin, yet more help and work in this area is needed.

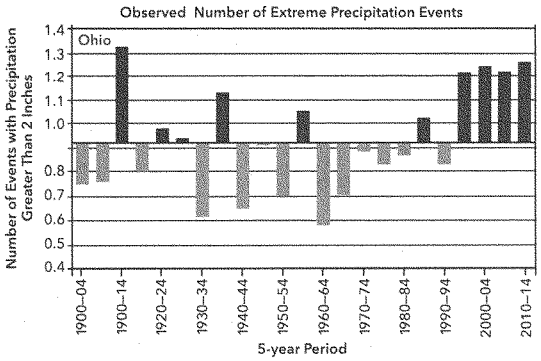
3. Profitable farms and communities

A new way of looking at agriculture would help farms become profitable while also addressing climate, hunger, and health-related social issues. Greater diversity in production would give farmers more options and opportunities to withstand market volatility. The variety would make Ohio-grown food more accessible to hungry Ohioans, while also enriching the soil in ways that reduce nutrient runoff and absorb carbon dioxide from the atmosphere, and that compensate farmers for those ecosystem services.

Reconnecting Ohioans with locally grown food, and with agriculture in general, is a matter of survival. The future of agriculture is critical for all of us, and we cannot take it for granted. We need action now to begin ensuring that Ohioans are sustaining Ohio and choosing stewardship practices that will sustain the people as well as the land.

By increasing options and opportunities for farmers — and by boosting the production, processing, and distribution of Ohio-grown food for Ohio consumption — more of Ohioans' food dollars will remain in their communities and, by the multiplier effect, strengthen local economies in ways that help reduce food insecurity.

As we began to organize the challenges and opportunities we identified for this call to action and to develop long-term, comprehensive recommendations and shorter-term actions and strategies, we got a concise summary of our mission. Casey Hoy, faculty director of the OSU Initiative for Food and AgriCultural Transformation (InFACT), said, "Our task is not a specific vision, but preparation for change."



CHALLENGES AND OPPORTUNITIES

"The foods most in need in Ohio are not the foods most widely produced in Ohio."

Hunger, Health, and Food

FOOD INSECURITY AND INADEQUATE SUPPLY

CHALLENGE: Despite Ohio's rich and diverse farm heritage, a disconnect has emerged between the people of the state and Ohio agriculture — to the point that many know little about farming, and one out of five children don't know where their next meal is coming from on any given day due to a lack of income, education, and access to available resources, such as access to federally funded nutrition assistance programs. These eye-opening facts provoked extensive discussion and brought farmers together with food and nutrition leaders, health advocates, and others to work toward common goals. As Jim Patterson, a longtime orchard operator and a member of the OSA Steering Committee, put it, "The foods most in need in Ohio are not the foods most widely produced in Ohio."

OPPORTUNITY: Ohio is blessed with ample sources of water and rich soils suitable for great diversity of food production. The state has fed itself in the past and has the resources to do so in the future. By re-establishing the infrastructure and supply chains for meat, poultry, fruits, and vegetables, Ohio can create more food-industry jobs, have convenient marketing channels for farmers, and make fresh food readily accessible to Ohioans of all

income levels. Consumers want more food that is produced in Ohio. To meet the demand, the state can develop more slaughterhouses, cold storage, and aggregation points, as well as facilities for cleaning and slicing produce, flash freezing, and high-pressure pasteurization. The supply chain must ensure market access to all farmers and food access to all Ohioans.

CONNECTING WITH CONSUMERS

CHALLENGE: Ohio farmers and farm organizations frequently lament consumers' lack of agricultural understanding, with tales of children who think food comes from grocery stores rather than farms. But at the same time, much of modern agriculture has become less visible, with most livestock raised indoors. The farmer-consumer disconnect is underscored by the number of food-insecure households in Ohio.

"I deliver exactly what my customer wants. But my customer is ADM and Cargill," said steering committee member Mark Drewes, a prominent Northwest Ohio grain producer. He added that farmers need to better understand the destination and end users for what they grow.

These concerns aren't new. Researcher Ken Meter, in his 2011 report, *Ohio's Food Systems – Farms at The Heart of It All*, noted:

> Over the past 40 years, Ohio, as a farm state, has been caught in a conundrum. Population has increased, personal income has risen rather sharply, and food consumption has increased. Yet farmers' income has steadily eroded. Not only are farmers and consumers disconnected from each other in economic outcomes, they have also become more and more disconnected physically as well. Until this disconnect is healed, it will be very difficult for Ohio to find balance in its food economy. In a rapidly changing system such as the food system, continual communication between farmers, consumers, and other stakeholders is essential, if the state is to adapt to changing conditions.[vi]

Food deserts are high-poverty urban or rural areas ill-served by grocery stores. The rural food version is compounded by great distances and fewer transportation options — and the sad irony of having to drive for miles past corn and soybean fields only to find an inadequate selection of fresh food at convenience stores. Vinton County and its 13,000 residents, for example, were without a single

"I deliver exactly what my customer wants. But my customer is ADM and Cargill."

grocery store for several years until 2017. Farmers are doing what their markets ask of them, but there is a disconnect in the food system.

Today's consumers, as well as young students, are also disconnected from the source of their forest products. Many will write an essay bemoaning timber harvesting while using a pencil and notepad made from wood fiber, while sitting at their wooden dining room table. Or they may think that timber harvesting kills and displaces all wildlife, while a wildlife manager espouses the benefits of timber harvesting as the best method for enhancing wildlife diversity and populations.

OPPORTUNITY: The growing interest in local food has tended to focus on high-end and niche markets, though the food banks supplied by the Ohio Agricultural Clearance Program are an important example of farmer-led contributions to address hunger in our communities. Both approaches provide a model for reconnecting Ohioans with the agricultural bounty that surrounds them. The unmet demand for Ohio-raised meat, produce, and other food offers a great opportunity for expansion of existing local-food producers and an opportunity for all farmers to differentiate and/or diversify on some of their land. With the right marketing and policies, the demand can grow for years to come — and consumers will better understand how the food that nourishes them is raised and grown.

Agriculture and Economic Growth

AGRICULTURE DIVERSITY

CHALLENGE: Two generations ago, diversified family farms were still common in Ohio. The primary cash crop may have been corn, wheat, or soybeans, but many farms also produced some combination of poultry, dairy, beef, pork, produce, hay, and small grains. As markets consolidated, many livestock producers got out of the business, and the fields where they produced hay and silage were instead planted in grain. Those who remained in livestock often ended up specializing in one commodity at a larger scale. Such specialization contributed to loss of balance between commodity production and feeding local populations in an economy that tied farms more closely to the cities.

OPPORTUNITY: Many steering committee members look to younger farmers — such as newcomers capitalizing on the growing demand for local, organic, or civic agriculture (food produced by someone you know personally). This includes urban farmers trying to bring fresh food and a sense of community to challenged neighborhoods and "new Americans" — immigrants and refugees who want to retain their traditional diets and allow community elders to pass on their agricultural knowledge to youth.

Agricultural diversity also refers to the range of goods produced on a given farm and to adding value through processing and marketing, whether on-farm or in town. It also can mean "agritourism," pick-your-own sweet corn or berries, and Christmas-tree farms. For many grain producers, diversity could mean growing specialty grains for niche markets or developing markets for small grains or other crops that can be used for winter cover or to expand the rotation. It could mean non-GMO crops or grains for brewers and distillers, biofuels or other industrial needs.

One of many important reasons for developing a local food system is strengthening the local economy by keeping food dollars circulating locally. If farmers can have a stake in the value chain (through co-ops,

for example), it can add stability. Local processors and distributors can expand as more local food becomes available and the demand grows. They can forge partnerships—collaborating with producer co-ops to ensure steady supplies. OSU studies of businesses in the local-food value chain have shown that their success is often linked to their business-relationship models.

FARMS AND FARMERS

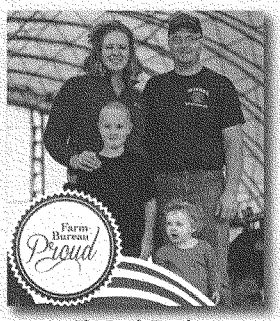
CHALLENGE: Ohio currently has about 13.96 million acres of working farm land — down from 15 million in the mid-1980s and 20 million in 1954. Some of the loss was from urban development. Even urban agriculture, touted for its growth in recent years, has far less acreage than 50 years ago. Competition is stiff for remaining farmland, and land values, startup costs, and high capital investment costs make it difficult for new, young farmers to gain a foothold. The coming generations of farmers will need to find profitable niches and products. That does not mean abandoning the leading commodities produced today — Americans will continue eating beef, pork, and chicken; markets for corn and soybeans will not go away. It does mean, however, that farmers will seek new sustainable strategies and, most likely, diversity of production to ensure whole-farm profitability.

OPPORTUNITY: Ohio already has a valuable asset on which to expand: It is among the country's top 10 producers of corn, soybeans, dairy, eggs, pork, processing tomatoes, apples, wine grapes, and other value-added products like Swiss

Former dairy farmers find a new way

What do you do when forces beyond your control put an end to the vision you had for your farm? Is there a Plan B? Danielle and Andy Burch found out the hard way how important it is to have diversity, new markets and options in agriculture.

The couple married in 2009 – a bad year for dairying – but weathered the tough time and even increased their herd in 2014. Andy had been running the farm near Salem in eastern Ohio largely on his own since he was 17. He started with 20 cows and was up to 120 when they had to sell the herd in 2017.



The Burch Family

"It didn't make sense any more – financially, nothing panned out," Danielle said. "Any proper businessperson would tell you there's no reason to continue on when the books are in the red so consistently you cannot dig out."

The Burches suffered the one-two punch of high feed costs and low milk prices in 2015 and 2016. Danielle calls it a "perfect whirlwind of problems" and said a lot of other dairies failed in Columbiana and nearby counties.

"After a pretty significant mourning period that we both had to go through after the cows were gone, our small farm has re-identified," she said. The couple began "finding a new way," initially with about 90 replacement heifers from their breeding stock.

In addition, Danielle and her father have a diverse Angus herd and are working on breeding – including an Angus-Holstein cross as more dairies close and their market for heifers declines. They also produce pork on pasture – expanding from two pigs in pasture to three pregnant sows. Though right now they mostly sell freezer meat directly to customers, they are considering a CSA model to distribute a mix of cuts to a larger pool of buyers.

"Things are smoother now that I've learned how to rely on others," Danielle said, crediting a good business relationship with Horst Packing – known locally as the Columbiana Candy Store. Still, she said, it's not easy or cheap for a farm to develop a whole new business model. She'd like to see programs to assist farms in transition.

"We're in it because it's a passion. But sometimes, we just need help."

cheese and maple syrup. Strengthening domestic markets and seeking new export markets for corn, soybeans, dairy, beef, pork, and other commodities remain important priorities. At the same time, there is steadily increasing production of local food for local markets. For example, organic product sales are increasing much faster than overall food product sales (6.4 percent versus 1.1 percent in 2017 according to the Organic Trade Association).

The future offers a chance to ease tension among, and intertwine, all forms of agriculture no matter what label it carries. More and more, Ohio's commodity growers are looking to diversify. Some have set aside acres for the cut-flower market to generate a steady stream of income amid fluctuating commodity prices. Others have embraced on-farm processing to create new markets for small grains, as with malt houses for the brewing and distilling industries (Ohio already has a healthy wine industry). For years, many have grown fields of sweet corn to supplement their income or create a college fund for their kids.

Farmers know that the best way to preserve farmland is to make farming profitable. Opportunities for farmers can grow if their work has a higher profile and greater connection with the community. The Black Swamp Conservancy, Ohio Ecological Food and Farm Association, and Ohio Farm Bureau Federation are among the entities trying to mentor young farmers and link them with land and opportunities. Establishing a mixed portfolio of crops and spreading risk among markets can help maintain their stability. Some in Northwest Ohio — perhaps because they see the large Canadian-owned greenhouses built in recent years — are returning to the green beans, tomatoes, and other produce that used to be more common in the region.

AGRICULTURE INFRASTRUCTURE AND JOBS

CHALLENGE: The 2011 *Farms at The Heart of It All* report showed that the 40-year period when Ohio farms grew larger and less diverse coincided with the decline of rural communities. Farmers doubled productivity in that time, which suggests that the extra effort they took to assume more debt, work more efficiently, and produce more did not bring them or their communities financial rewards. Rather, that extra value created by farmers was realized by others in the food system.

Many markets have shifted away from small Ohio towns. The local elevator, long a foundation of the small-town rural economy — for sales, marketing, feed, seed, etc. — is empty in many places, replaced by larger, more-distant facilities or by on-farm grain storage. In the same way, meat processing has shifted from local to regional or national facilities. Ohio still has more slaughter facilities than many other states, due to its long history of a state inspection program. Most remaining plants are small and focused on custom slaughter, and only one is certified as an organic meat processor to serve the burgeoning organic market. Pork and beef producers typically need to schedule slaughter with their butchers months in advance. Often, the bottleneck is in cold storage, not on the kill floor.

Similarly, the raw timber value in high-poverty Appalachian Ohio has a very low value-added segment, while Northwest Ohio has little raw-timber value but a high value-added economy for forest products. In both regions, the timber workforce is aging and is not being replaced. The capital cost of timber

operations has risen steadily, making it a difficult field for young foresters.

OPPORTUNITY: If Ohio's focus is on keeping food dollars in the region — emphasizing Ohio's food industry as an economic engine — people might make different decisions on job training, hiring, investment, and even deciding which crops to grow and livestock to raise. New slaughter plants in Michigan, North Carolina, and Virginia in recent years have led to increased local production of beef and pork.

Dairy farmer Eric Grimm in Lorain County worries that if consumers focus only on the lowest retail price of a gallon of milk, smaller local dairies could be squeezed — and consumers will lament the disappearance of the Holsteins and Jerseys that gave them comfort and a sense of place on drives in the country. But if consumers see how the price of milk is related to the landscape and the economic health of the county, they might make different decisions. Grimm has worked with instructors in Lorain County Community College's sustainable agriculture program. With the local Farm Bureau, they organized community events such as a showing of "Forgotten Farms," a 2017 documentary film about the struggles of New England dairy farmers and efforts to bring together different agricultural factions, such as older conventional farmers and young organic produce growers.

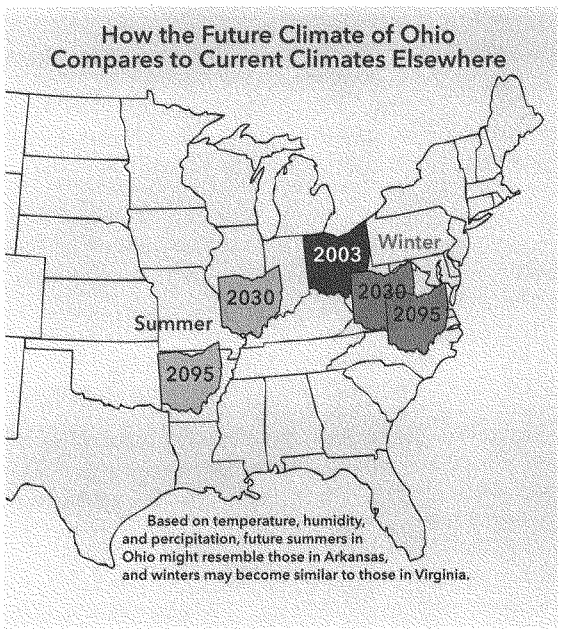
Such initiatives are one strategy to reconnect farms and cities, and rural and urban economies. Others include increasing the sale of locally raised fruit, vegetables, meat, and dairy products to local schools, colleges, and hospitals; keeping our food dollars in Ohio with more value-added processing facilities in the state; understanding and promoting the ecosystem services that farmers can provide by sequestering carbon in the soil and reducing nutrient runoff into rivers and water supplies; and making environment, agriculture, food, and nutrition a more fundamental part of our educational system.

The Ohio Department of Natural Resources (ODNR) Division of Forestry and OSU Extension have designed the Ohio Woodlands Job Corps to provide temporary employment, job training, and skills that employees can use in forest management careers. It was supported by federal recession recovery funds in 2012 but is currently unfunded. There are opportunities for forestry education and training to be elevated at our vocational schools, career centers, and adult education centers.

Environmental Resilience and Ecosystems Services

WEATHER, CLIMATE, ENVIRONMENT

CHALLENGE: "Climate change" can be a polarizing term, but one thing farmers agree on is that weather patterns in recent decades have changed significantly. Late springs, wet springs, and dry summers have always been a threat to Ohio farmers. According to the fourth *National Climate Assessment Report*, the degradation of critical soil and water resources will expand as extreme precipitation events increase across our agricultural landscape.[vii] Sustainable crop production is threatened by excessive runoff, leaching, and flooding, which result in soil erosion, degraded water quality in lakes and streams, and damage to rural community infrastructure. These predicted impacts are already happening today. Thunderstorms are often much heavier, droughts often last longer, false springs threaten orchards, and abnormal



weather events and climatic conditions are forcing farmers to adapt to challenges that are affecting their productivity and waterways.

OPPORTUNITY: Fortunately, opportunities are plentiful, because the cost of continuing the status quo is incalculable. We cannot continue to suffer debilitating rains and droughts, the loss and degradation of topsoil, or nutrient runoff into water supplies. We have choices and already are moving forward with incremental remedies. But this call to action outlines more-concerted and comprehensive strategies that showcase the economic benefits of ecosystem services like the adequate water, fertile soil, and pest control that farmers don't have to buy.

Soil health is a factor in the two biggest environmental challenges addressed in this project: nutrient runoff into waterways and extreme weather patterns characterized by very heavy rainfalls and extended droughts. The 4R Nutrient Stewardship Certification Program, developed by a coalition of industry groups and institutions, provides a model for addressing nutrient runoff into water bodies across the state, serving 2.7 million acres, two-thirds of them in the Western Lake Erie Basin.[vii] Many farmers also are experimenting with winter cover crops, which can replenish the soil and leave space in their root systems to absorb rain and hold water for periods of drought.

"Soil is a living entity," says Dr. Rattan Lal, a renowned soil scientist and director of the OSU Carbon Management and Sequestration Center. He speaks of soil health with reverence: "Soil is where death is transformed into life. … soil health is a journey, not a destination." He adds, "Soil is instrumental to mitigating climate change, and healthy soil suppresses disease and needs less fertilizer. … Agriculturalists have the greatest control over the environment."

WATER QUALITY

CHALLENGE: Nonpoint-source nutrient runoff from farms into the Maumee River watershed, along with a variety of point-source discharges, has led to algae blooms in Lake Erie. The blooms in the lake's shallow Western Basin have on occasion shut down the intake for Toledo's water supply and have appeared earlier in the season in recent years. Grand Lake St. Marys in Mercer County and other water bodies have had similar problems in various corners of the state — including runoff into the Ohio River that is carried down the Mississippi to the Gulf of Mexico. But there's no one-size-fits-all solution: the various sites are in different parts of Ohio, with different geology, different soil types, and different types of agriculture. The role of agriculture in those areas may vary from place to place.

OPPORTUNITY: In other parts of the country, communities and farmers have collaborated on "ecosystem

services" projects. A Watershed Memorandum of Agreement in 1997 was designed to protect the 1.4 billion gallons of water per day that New York City draws from 19 upstate reservoirs in the Hudson River watershed. The plan saved the city billions of dollars in filtration costs by preserving sensitive reservoir buffer lands and assisting farmers in adopting practices that reduce runoff. In many ways, the ecosystem services arising from those practices set the stage for recognizing the value that farmers offer to the environment as they produce food, feed, and fiber. Ohioans are beginning to understand that, in order to have both a stable food supply and a safe environment, they may have to share the costs of a transition to more-sustainable agriculture practices. It is in the best interest of urban water utilities, and of Ohio residents, to work with farmers upstream.

WOODLANDS

CHALLENGE: Ohio's predominant forest type is oak-hickory — dominated by tree species that produce strong, valuable, desirable lumber and other products, while also providing high-volume, nutritious mast crops for many of Ohio's iconic wildlife species. Ohio is beginning to see declines in oak-hickory regeneration, due to changes in timber harvesting practices, lack of use of prescribed fire, and a dramatic increase in pests, pathogens, and non-native invasive species. Losing this forest type will have major implications on the forest economy as well as wildlife populations and diversity.

OPPORTUNITY: Forest managers are working to restore oak-hickory forests in southeastern Ohio, part of the oldest and most biologically diverse forest systems in North America. Through the Joint Chiefs' Landscape Restoration Partnership, the federal Forest Service and Natural Resources Conservation Service are working with the ODNR Division of Forestry, OSU Extension, and others to begin reversing this trend on public and private woodlands across the project area. This is a good first step, but more must be done to improve the resilience of forests and the ecosystem services they provide.

REGULATORY CLIMATE

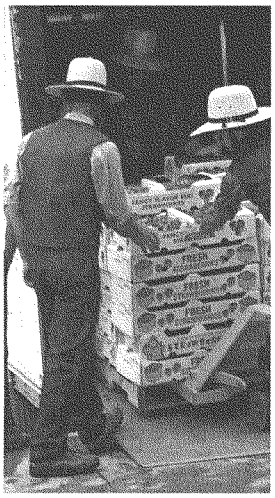
CHALLENGE: Farmers sometimes feel under attack by the regulation of their profession and practices. Often, it's not so much the intent of the regulation that bothers them, but the way it is presented and enforced. Agriculture is a highly regulated industry, and farmers want a voice in developing solutions for problems. Whether it's new restrictions on use of fertilizers, use of land with standing water, or controls on how they raise animals and process food, farmers recognize that regulation is part of the solution, but they emphasize that there is no simple or quick fix and that solving problems in silos doesn't work. Going forward, policy frameworks need to be harmonized, and overlapping and contradictory regulations need to be harmonized.

OPPORTUNITY: Farmers feel that a better regulatory strategy would ensure their voices are shared with those of other collaborators and would be aimed at long-term, comprehensive solutions that benefit the environment, the public good, and farmers. Collaborative approaches could also be applied to food-safety regulation in ways that allow flexibility and encourage new techniques without compromising safety standards. Other topics that frequently came up in the preparation of this call to action include: the waters of the United States, licensing for fertilizer application, Food Safety Modernization Act, restrictions on rabbit processing, hurdles for mobile meat processing, and workers compensation.

At a sustainability conference in Columbus in 2014, an Ohio farmer in a panel discussion of agricultural runoff started his presentation by showing his yearly budget for corn, soybeans, and wheat — seeds and inputs, land rent, harvest assistance, anticipated commodity prices, etc. He said that farmers are concerned about the environment and want to do the right thing, and the "right thing" also includes making a living and supporting a family.

An urban resident told the farmer she was not aware of farmers' financial challenges. She wondered if consumers and their demand for cheap food are partly culpable for the Lake Erie algae blooms and other environmental problems related to agriculture. She suggested that all Ohioans share culpability in nutrient runoff and should perhaps share in the costs of fixing the problem. As farms increase the ecosystem services they provide for the public good, Ohio can create policies and programs that recognize the value of those services.

PATHWAYS TO OHIO SMART AGRICULTURE



It's a model with incentives to help farmers harness the full range of goods and services that they can sustainably produce from the land.

Well-managed agricultural landscapes can produce food, feed, fiber, energy, and a wide range of ecosystem services that generate environmental, economic, and social benefits. Achieving these "solutions from the land," however, requires an immediate start on a new, 21st-century approach to land management and problem solving. This model is characterized by broad initiatives through which multi-stakeholder collaboratives take an integrated approach to food system challenges, rather than the siloed management of the past. The model we envision brings production, environmental, food, and nutrition policies into harmony and streamlines overlapping and contradictory regulations. It's a model in which markets compensate land managers for ecosystem services that benefit farmers and the public. In short, it's a model with incentives to help farmers harness the full range of goods and services that they can sustainably produce from the land.

Achieving this transformation in land management cannot be done by decree. Instead, it requires commitments, investments, and participation on the part of government, business, industry groups, academia, non-governmental organizations, landowners/managers, consumers, and many other stakeholders in an emerging ecosystem services model. It requires new regulatory approaches that are less adversarial but achieve the same ends in ways that are flexible enough to encourage new, creative solutions. It requires engaging the marketplace in new and flexible ways that create economic incentives for sustainable management of natural resources and develop markets for agricultural goods that help both people and the land.

These key themes — which encompass collaboration, interconnectedness, proactive regulation, ecosystem markets, stewardship, and benchmarks/results — enable broad, landscape-scale planning and integrated strategies that deliver multiple solutions from the land to meet the broad needs of landowners and society.

What follows is a *comprehensive, interconnected* set of recommendations to transform Ohio's agricultural system to achieve the full range of goods and services that can be sustainably delivered from the land. We do not identify priorities because our recommendations are designed to work together. This is a crucial point that we must continue to stress. We have an agricultural *system*. If weather patterns or nutrient runoff affect production, they also will affect distribution, price, and availability. As consumer preferences evolve, they may force changes in production and processing; they may even affect the environment. We can't address a challenge in one segment of the agricultural system without considering how other segments will be affected. Thus, an integrated vision and action plan is essential.

These recommendations are organized under three interrelated work streams designed to:

- **Reduce hunger and improve nutrition by supporting the production of fruits, vegetables, animal proteins, and food-grade grains for human consumption.**
- **Create jobs and generate economic growth by diversifying and sustainably intensifying production and processing of food, feed, fiber, and renewable energy.**
- **Augment ecosystems services to improve the environment, enhance the resilience of agri cultural and forested landscapes and improve the farmer's bottom line.**

Evolution and continuous improvement alone, long hallmarks of Ohio agriculture, will not get us there. This is a huge challenge, and it requires immediate steps toward transformational change. Policy, institutional research, industry action, investments and the innovation of individual farmers must all come together in this effort.

Hunger and Nutrition

The startlingly high numbers of food-insecure Ohio families and children may suggest a disconnect between what Ohio farmers produce and what Ohio residents need, but there is no simple solution to hunger. Rebuilding Ohio's local-food processing and distribution infrastructure will create new opportunities for farmers, create jobs, strengthen local economies, and make local food more widely available in stores and institutions. But it will not, by itself, feed families that are food-insecure. Families will still need to pay for the Ohio fruits, vegetables, and animal protein — which could mean subsidizing production, subsidizing the purchase, or, in the long run, developing an economy in which everyone can afford to eat. In the meantime, here are the recommendations aimed at addressing hunger, nutrition, and local food systems:

- **Form and properly resource a Farm, Food, and Health Partners Alliance.**
  To ensure the recommendations we've described are addressed, Ohio needs a non-governmental organization with members representing farmers, food and nutrition advocates, environmental organizations, food industry leaders, land grant universities, government agencies, and others as policy reviewers and advocates.

- **Align state agencies toward effective and coordinated food, health, and agriculture programs.**
  Whether through creation of a single comprehensive agency or greater collaboration among existing agencies, Ohio should ensure that food, health, and agriculture programs are working toward common goals.

- **Restore the Ohio state government's role as a marketer and champion of agricultural goods and services.**
  A vast majority of the Ohio Department of Agriculture's (ODA) functions are regulatory. Of the department's $82 million budget, commodity and marketing programs make up less than $2 million — most of which comes from producer assessments or special taxes on the products. To meet the needs of next-generation agriculture and expand the agricultural processing capacity, the ODA will need to balance its regulatory authority with an economic-development role.

- **Restructure the ODA Ohio Proud program to make it relevant and engaging to today's consumers, institutional food-service markets, and commodity-scale agriculture.**
  Ohio Proud is the only program that promotes Ohio-produced goods to the public. With a 30-year history of rising and falling state support, currently at $79,000 per year (or 0.09 percent of the budget), it must grow significantly to accommodate an increase in local food, new markets for specialty grains, and other emerging opportunities.[ix]

- **Quantify and regularly assess demand for local food.**
  Ohio needs more processing infrastructure to meet growing institutional demand for local food, but we must quantify that demand to attract investment in facilities that can slice, dice, and butcher food for those institutions.

- **Quantify and regularly assess the food preferences of Ohio consumers.**
  Our workgroups cited a need for research into consumer food preferences. Growing demand for local food, healthful options, and sustainable production has changed what is sold in grocery

stores. Knowledge of emerging trends will help Ohio's food and agriculture industry.

- **Expand and remove barriers to institutional purchase of Ohio food and agriculture products.**
  Until recent years, all apples purchased by Columbus City Schools came from out of state. The food-service director found policy and market hurdles that made it difficult to buy from Ohio orchards, but persisted. Now the state's largest school district buys only Ohio apples. If local, state, and federal governments can remove purchasing policies that inadvertently create barriers to local food, farmers can produce more of what Ohioans need.

- **Grow more of what Ohioans need.**
  Ohio has the soils and climate to produce a great variety of food that Ohioans need. When the marketing channels and infrastructure exist, Ohio farmers will meet the demand.

- **Develop an independent "food-system finance authority"**
  A major barrier to scaling up Ohio food production is the lack of a financing mechanism to redevelop the sort of food supply chain that Ohio once had. A legal entity with the capacity to raise and manage funds for investment in local food aggregation, processing, distribution, and marketing infrastructure would open a door to new opportunities for any Ohio farmer.

- **Restore processing capacity and supply chains for Ohio-raised food.**
  One of Ohio agriculture's most significant problems – and most lucrative opportunities – is a lack of sufficient supply chain infrastructure. Many Ohio school districts, universities, hospitals, and other large institutions are interested in buying locally grown food but want much of it to be sliced and diced, or for leafy produce to be separated and bagged. Potential demand is greater than current processing capacity.

- **Restore processing capacity and supply chains for Ohio-raised meat and poultry.**
  The lack of processing infrastructure is particularly acute in the case of meat and poultry slaughter. Operators of Ohio meat-processing plants say their biggest barrier is a lack of skilled butchers and meat cutters. Small-scale producers need to schedule months in advance because a lack of qualified workers, and insufficient cold-storage limits the processing capacity.

- **Develop markets and supply chains that serve immigrant populations.**
  Supply chain development needs to accommodate immigrants, whose needs may provide new opportunities for current farmers and for the refugees themselves. Goats, for example, are the primary meat source for many African and Asian immigrants, who now struggle to find local sources of traditional meats and other ethnic products.

- **Develop and fund a pilot, small-scale, mobile meat-processing program.**
  Kentucky State University, collaborating with state government, developed a meat-processing trailer that serves producers at sites such as county fairgrounds. The ODA, which began work on a similar model 10 years ago, should rejuvenate its effort with a pilot project.

- **Improve access to affordable and nutritious food, especially in underserved communities.**
  State agencies collaborating on food, health, and agriculture programs should develop pilot projects — for example, mobile food markets, promotions of produce and meat at convenience stores, and efforts to double the value of federal Supplemental Nutrition Assistance Program (SNAP) benefits for food purchased at farmers markets.

- **Promote food as medicine.**
  Ohio spends 96 percent of its health dollars on care and 4 percent on prevention. Amy Rohling McGee, of the Health Policy Institute of Ohio, told the steering committee, "We view increased health care spending as bad. We spend a lot of time, effort, and money downstream, trying to fix the effects of a problem. We need to go upstream to prevent the problem."

- **Expand Ohio farmer outreach and advocacy to address food insecurity challenges.**
  Through the collaboration of state agencies and agricultural organizations, efforts are needed

to educate each other and the public about different aspects of the food and public health systems.

Jobs and Economic Growth

Ohio's earliest settlers relied on agriculture for sustenance. In today's global economy, agriculture is no less important to the state: It will continue to feed the people; it will provide services from the land even while preserving and improving the soil; and it will be an economic powerhouse that creates jobs in our cities and rural areas. It will do these things as long as we keep sufficient land in agricultural production. That means ensuring we always have young Ohioans willing and able to work the land and pass it on — in an even more productive and healthy condition than it was before — to the next generation. It means having the workers and equipment to produce the food and harvest the crops, livestock, and timber. It means having the facilities to add value to those products in Ohio communities with Ohio workers, and to keep the revenues recirculating in local economies. Here are recommendations to help us realize Ohio's economic potential:

- **Welcome and support the next generation of farmers.** The average age of Ohio farmers has risen steadily for decades. Fewer people raised on farms are choosing careers in production. Land prices make it hard for young farmers to get into the field. Minority farmers and farmers with limited resources have a particularly tough row to hoe.
- **Develop programs to assist young, underserved, and "new-American" farmers.** Immigrants are among the potential new farmers in Ohio. Nonprofit organizations in Cleveland already offer farm and market training to immigrants and refugees. More such programs that assist immigrants interested in farming are needed.
- **Develop programs to assist limited-resource farmers.** Establish a joint task force to explore possibilities for land grant universities to support limited-resource agriculture in a way that ensures prospective farmers, regardless of race, creed, or socioeconomic status, have access to land, loans, state and federal programs, and markets.
- **Promote training in schools, colleges, and prisons in support of the entire food system.** Ohio agriculture in the coming decades will need a larger and better-trained agricultural workforce, whether it be regular farm hands, seasonal harvest workers, laborers in food-processing facilities, or the whole range of related skills: mechanics, technicians, welders, equipment operators, builders, and electricians.
- **Create new agriculture education programs for adults, communities, and students.** Public schools should reinstate or strengthen agriculture-education programs. The National FFA Organization and 4-H programs are still widely available, but vocational agriculture programs should be, too – with on-the-job training opportunities and internships, with programs catering to those who aren't currently on farms.
- **Build human capital in the form of workforce development and community resources.** Similar programs, through community colleges and other entities, should promote the agricultural field and prepare adults for agriculture and food-related jobs.
- **Reform immigration policy to help fill agriculture jobs.** Two of the most labor-intensive, food-related challenges are the harvest of produce and work in processing plants. In both cases, the current workforce is dominated by immigrant labor. The future of agriculture in Ohio may depend in part on passage of a new federal immigration policy.
- **Ensure living wages for farm and agriculture-related jobs.** All of these initiatives should be aimed at ensuring that producers, farmworkers, and employees of supply chain businesses are not only well-trained but are ensured a living wage.
- **Support local food aggregation and processing to ensure ease of marketing for farmers.** As farmers look to expand or diversify — whether it be in local or specialty markets — they need to have clear marketing channels and confidence in a stable market for their goods.

Produce Potential

Based on the 2016 State of Ohio Agriculture report, a 1 percent shift of 2016 grain acres to specialty food crops by 2050 would increase acres dedicated to specialty crops from 42,340 acres to 132,040 acres. Using 2016 yield data per acre, total production of food specialty crops would increase nearly 312 percent.

Specifically, production in millions of pounds:

Crop	2016 Production	2050 Production
Tomatoes	428 mil lbs	1335 mil lbs
Sweet Corn	115 mil lbs	358 mil lbs
Peppers	65 mil lbs	203 mil lbs
Apples	34 mil lbs	105 mil lbs
Pumpkins	93 mil lbs	290 mil lbs
Cucumbers	51 mil lbs	159 mil lbs
Grapes	11 mil lbs	34 mil lbs
Peaches	3 mil lbs	10 mil lbs
Total	799 mil lbs	2493 mil lbs

These estimates are rough, but illustrate how such a small change in grain acres converted to food specialty crops can increase local food production dramatically.

SOURCE: NASS, QUICK STATS 2016 (QUICKSTATS.NASS.USDA.GOV), WITH CREDIT TO BILL LYNCH (OSU - RETIRED)

- **Adjust state regulatory policies to be more collaborative and/or less adversarial.**
  Government models for food and facility inspection policies should focus as much on helping entities ensure safety as on enforcement.

- **Increase number of malt houses, grain mills, and other processing facilities to assist the brewing, distilling, baking, snack food, livestock feed, and other industries.**
  A small, on-farm Union County malt house for barley in 2016 led to what is believed to be the first all-Ohio beer in a century. Ohio needs more facilities that can process barley, rye, and wheat for brewers and distillers. Markets for those and other grains — even if it's for feed — can revive production and bring additional crops into farmers' rotations. Likewise, companies such as Shagbark Seed & Mill in Athens have generated markets for organic corn and black beans.

- **Promote controlled-environment production for horticulture and floriculture.**
  Interest in controlled-environment production systems for horticulture, aquaculture, floriculture, and fresh fruit and vegetable production is exploding as new technologies enable vertical and urban production systems.

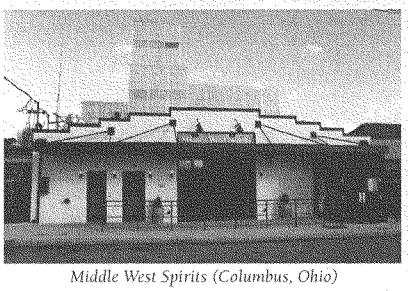
- **Support development and expansion of aquaculture and creation of a processing and distribution supply chain for fish.**
  The potential for growth in Ohio's fish-farming industry is limited by a lack of processing capacity.

- **Promote new processing options and markets for Ohio wood products.**
  Ohio foresters want more opportunities to process wood for energy, bio-char, green buildings, and home furnishings.

- **Promote new processing options and markets for Ohio bio-products and the bio-economy.**
  Ohio is a leading producer of glues, adhesives, paint, soap/detergents, rubber and polymers, all of which have agricultural roots.[x] Value-added processing in Ohio keeps dollars here instead of sending raw commodities out of state for further handling.

- **Invest in rural broadband infrastructure.**
  Today's farmers need fast internet connections at home as they make complex marketing decisions, but also in the fields to assist in GPS-driven precision farming. Technologies and information sharing must be enabled via broadband internet service that is available statewide.

Planting the seeds of a small-grain economy



Middle West Spirits (Columbus, Ohio)

It's widely known that cover crops are good for soil health and can make fields more resilient in times of drought and excessive rain. What's less clear is how to ensure such practices are as good for the farmer's bottom line as for the soil.

An answer to questions about this winter's cover crop may lie in next winter's hot toddy or Christmas ale.

As co-founder and distiller at Middle West Spirits in Columbus, Ryan Lang already works with Ohio farmers to grow non-GMO corn, rye, and other grains for his products. They are processed at Bluegrass Farms Inc. in Jeffersonville and Mennell Milling Co. in Fostoria. Lang, like some other Ohio distillers and brewers, wants to buy more grain from Ohio farmers.

"In distilling, lots of people are looking for different grains – spelt, millet, oats," he said. "It may be cheaper to get them out of state. Rye is a challenge here because there are not a lot of growers in Ohio. Most distillers go to Canada for it. But there's always potential for small grains, and lots of opportunities to change the patterns in Ohio for growth."

Lang hopes farmers who today talk about corn, soybeans, and wheat will someday be just as comfortable talking about rye, barley, and sorghum, or spelt, millet, and oats.

"Anything we can do to add value to those crops will make it more attractive for farmers to grow them," said Steve Maurer, former Ohio director of the USDA's Farm Services Agency. "It's an economic issue and a water-quality issue: Add value to small grains. If we develop markets for these grains, with prices posted at the elevator, farmers will grow it," even if as a secondary crop for livestock feed.

"Anything we can do to add value to those crops will make it more attractive for farmer to grow them," Lang added. "It's an economic issue and a water-quality issue to add value to small grains, such as low-protein soft red winter wheat used for distilling; like low-protein barley valued for brewing." In addition to the processors Lang uses, Ohio has had a few small malt houses open in recent years to process malted barley to brewers. But they are not sufficient to drive the market for grain production.

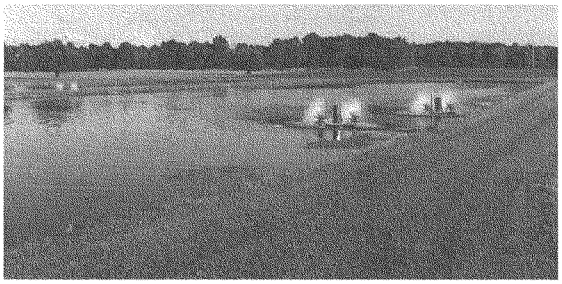
Even bakeries might have a need for rye, spelt, millet, and others. If there's a demand for it, there's an opportunity – and bakeries and breweries can create the demand.

"Most distillers go to Canada for [Rye]. But there's always potential for small grains, and lots of opportunities to change the patterns in Ohio for growth."

Lang sees infrastructure as the barrier to more cover crops and different types of grains. But he considers "infrastructure" to imply much more than processing and distribution facilities.

"We need seed developers," he said "And growers who can manage the seed. We need agronomy studies, research on the benefits of small grains. If you get into something in a substantial way, you need a foundation – a diversified infrastructure." Allow shifting storage without contamination.

"We need to think about our future and what is required for change," Lang said.



Environmental Resilience and Ecosystem Services

Farms and forests provide vital goods and services to society; we call them "ecosystem services." The food we eat is a product of ecosystem services. But these lands also give society benefits such as clean water and air, wildlife habitat, and carbon storage. Market-based approaches to conservation are a cost-effective method to achieve environmental goals and sustain working and natural landscapes. Farmers also rely on and benefit from ecosystem services for such basic needs as adequate soil moisture, pest control, and healthy soils that support plant growth. Farmers can manage their land in ways that produce each of these services, avoiding expensive inputs that would otherwise be needed to replace them. These recommendations seek to nurture the ecosystem services that benefit both farmers and the broader society:

- **Diversify commodity production with identity-preserved or value-added products.**
  On-farm diversification includes tapping into markets for local food, but also to regional specialty markets and options for adding value on-site. The new markets can strengthen the farm's bottom line and greater diversity of crops can improve the soil.

- **Develop and implement a climate-smart action plan for Ohio agriculture.**
  The plan should identify specific vulnerabilities posed by increasingly erratic weather extremes and include a comprehensive adaptive-management strategy for Ohio agriculture.

- **Create and implement a new water quality strategy.**
  Such a strategy should include current public and private sector response initiatives and develop industry standards through a process with diverse stakeholders.

- **Identify pathways for accelerating and scaling up the delivery of ecosystem services to Ohio farms and from Ohio's agricultural landscapes.**
  The City of Columbus has considered a program that would help farmers upstream from its water reservoirs manage the financial risks of reducing the nutrients applied to their fields — which would in turn reduce the city's water treatment costs. A similar nutrient trading program was established as a collaboration between Alpine Cheese in Holmes County and its Amish dairy producers upstream. These and other efforts need to be promoted as ways farmers can help communities and in which communities will share risk with farmers.

- **Through knowledge sharing, increase the use of precision farming technologies.**
  Universities, government agencies, and industry groups need to gather and disseminate information for farmers. Satellite technology has enabled advancements in precision farming, which allows application of only the amount of fertilizers or manure needed to suit the precise characteristics of the soil in different parts of a field.

- **Create a strategic forestry roadmap and strengthen programs to promote good management of woodlots on farms.**
  Most of Ohio's privately-owned woodlands are not under an active forest management plan. Ohio should reform forestry policy initiatives to incentivize healthy forest management and consistent management standards across the state.

- **Harmonize tax incentives to protect working lands.**
  Woodland and farmland property tax incentives need to be harmonized to encourage proper forest management and integrated management of landscapes and to discourage the loss of forest

and farmland through conversion to non-agricultural uses.

- **Boost awareness of the role that farmers play in Ohio's economy and environment.**
  Ohio's agriculture stakeholders should establish a speaker's bureau of farm leaders who can promote awareness about food insecurity and its connection with farming in Ohio; the economic and community benefits of the food and agriculture industry; and the importance of ecosystem services.

- **Create a network of government and private consultants to help develop a landscape-scale plan for ecosystem management.**
  Such a network should be drawn from city, county, and state agencies.

- **Promote research and education about cover crops and other soil-enhancing practices.**
  David Brandt, in 50 years of farming near Lancaster, has slashed fertilizer use and not tilled the soil. He is also a "Johnny Appleseed" of cover crops, sharing his experiences with farmers and others. His message — legumes hold nitrogen, rich soil absorbs carbon, and decayed roots leave channels in the soil that help absorb water — is one that needs to be more widely learned.

- **Track and publish statewide data in order to assure and celebrate continuous improvement.**
  Ohio needs statewide baseline estimates of soil organic carbon, soil organic matter, and total continuous living cover on agricultural lands so these categories can be tracked every few years.

- **Increase research and data on the handling and application of manure on fields.**
  Researchers should learn from manure management programs elsewhere, such as those in Maryland and Virginia, and develop metrics in Ohio for proper handling and application.

- **Increase research and data on the services that come from the land.**
  Data on current nutrient runoff from farms could be a benchmark for future reductions. These and other data could provide models that show the value of the full range of goods and services that can be delivered from the land, as well as to the farms themselves.

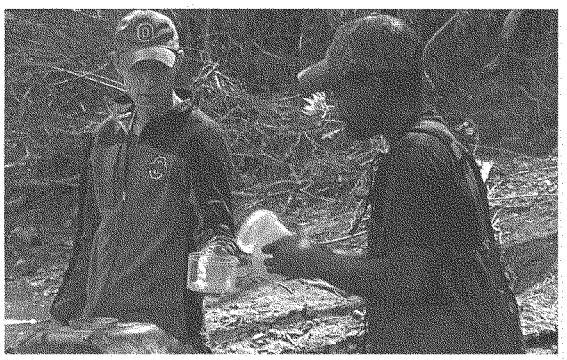
- **Promote policies and practices that support the ways in which agricultural land can provide public benefits: zoning policies, water resource protection, forestry and woodlot management, and tracing the sources of food.**
  The state or universities should also pursue research and standards for a variety of policies and practices that support the ways in which agricultural land can provide public benefits from all types of farms.

- **Strengthen land use policies that keep land in agricultural production.**
  The ODA's Office of Farmland Preservation should promote local and regional policies as well as manage the Ohio Agricultural Easement Purchase Program. Keeping land in agriculture is essential to the goals and recommendations we share and, while some economic trends make this kind of preservation easier today, Ohio needs to strengthen and fund farmland and forest preservation programs.

- **Develop a brand and recognition for Ohio farm products of all kinds, including ecosystem services.**
  To complement improvements to the ODA's Ohio Proud program, Ohio farmers and organizations should develop a brand and recognition program for Ohio Smart Agriculture farms — leading the way for a public discussion of smart agriculture that engages wider communities of interest.

- **Create risk management programs.**
  American consumers spend a smaller share of their income on food than just about any place on the planet. Because of that benefit, we should share the financial risk that farmers often face by providing incentives for practices that enhance ecosystem services. This could take the form of technical assistance for such things as cover crops, manure storage and handling, and cost sharing for variable rate nitrogen.

- **Increase awareness of ecosystem services.**
  Develop information and education programs that explain and communicate the value and importance of ecosystem services and help to build stakeholder buy-in and support.



LET'S GET STARTED

This call to action has emphasized that Ohio Smart Agriculture: Solutions from the Land is a long-term, comprehensive, multi-stakeholder collaborative that requires integrated leadership sowing seeds in three primary areas all at once. In that sense, there are no priorities because all the recommendations are priorities that will enable the transformation we envision for Ohio agriculture. We've identified challenges that present us with opportunities, and we have charted three pathways to develop those opportunities, and many of the steps needed to accomplish that.

In this chapter, we have identified four major initiatives and associated action steps as having the greatest potential to advance the recommendations in the previous section. They are "priorities" only in the sense that they are the kinds of short-term actions that can attract financing for our vision of mid-century Ohio agriculture and enlist stakeholders to join the quest for a wider range of goods and services from Ohio's farms and woodlands. The order in which they are presented here does not connote any ranking. Together, these steps are interconnected and interdependent "launching pads" for Ohio Smart Agriculture: Solutions from the Land.

Policy

MAKE OHIO AGRICULTURE AND THE FOOD SYSTEM A PUBLIC POLICY PRIORITY.

It is a startling statistic — a clarion call to action — that one out of five children in Ohio does not know where his or her next meal will come from. This sad reality, coupled with the fact that Ohio ranks in the lowest quartile nationally in health value, requires a re-examination of state priorities and the allocation of resources, programming and leadership to resolve these chronic life-shortening problems.[xi] The time for action is now. Ohio agriculture and the food system must become a public policy priority. Towards this end, we recommend the following:

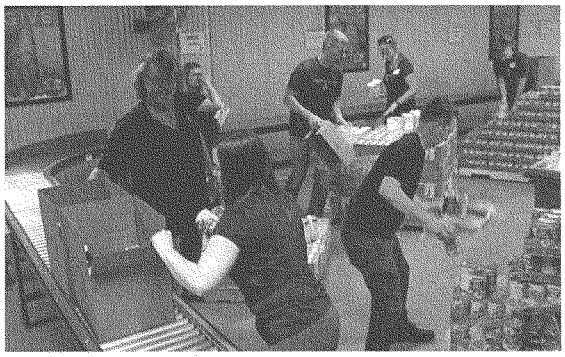
A. **Form and properly resource a Farm, Food, and Health Partners Alliance.**
An alliance of farmers, policymakers, consumers, academics, advocates, and others should forge ongoing links among different aspects of the food and public health systems and serve as a hub for education, consumer and producer outreach, problem-solving, and advocacy for public policies to improve food security.

A recurring theme in this call to action is the growing disconnect between farmers and the general public. The gap is widened by an agricultural economy characterized by regional specialization and economies of scale. As the nation and state become more urbanized, people grow further removed from the farms of their family heritage. In the eyes of young children, food comes from the store; the farm is merely an abstraction. And so, as many go hungry, farmers are stunned to learn that the crops they grow to feed the world may not meet the needs of those in their home state.

An Ohio Farm, Food, and Health Alliance could change this. Bringing these disparate yet overlapping interests together could make agriculture not only an integral part of the state economy, but also a valued foundation of the state's culture. More importantly, and as a practical matter, such an alliance could shape the state's policy

agenda in a way that links agriculture more closely with food and hunger, and food more closely with health and health spending. Such an alliance could be a cohesive statewide voice to help shepherd this call to action and its recommendations into the future. Initial recommendations for areas of strategic direction and focus include:

- Establish a statewide food strategy that addresses food insecurity from producer to consumer and campaigns for a network of regional food supply-chain infrastructure. The strategy could build on the *2009 state-funded Ohio Food Policy Advisory Council plan* and integrate it with the *Ohio Food Policy Network Report: Mapping the Vision for the Future of Ohio's Food System*.
- Maximize use of and increase public commitment to programs that directly connect Ohio-raised food to low-income families (e.g., Produce Perks, prescription programs for local fruit and vegetables, Community Food Initiatives' Donation Station program, and WIC coupons at farmers markets).
- Enhance and expand commodity-led programs and producer efforts to increase demand, strengthen consumer trust and confidence, and minimize food system risks.
- Support livable wages in the food system, including income for farmers, farm labor, and other workers in the food industry.



- Examine the health benefits of trees and forests.
- Invest in economic development (market and infrastructure initiatives) that will expand markets for agricultural commodities, improve access for underserved Ohioans, and provide workforce development in the agriculture and food industries.
- Explore options to identify and assist food-insecure people who do not qualify for existing state and federal programs.

B. Create an interagency task force to align state agencies toward effective and coordinated food, health, and agricultural programs.

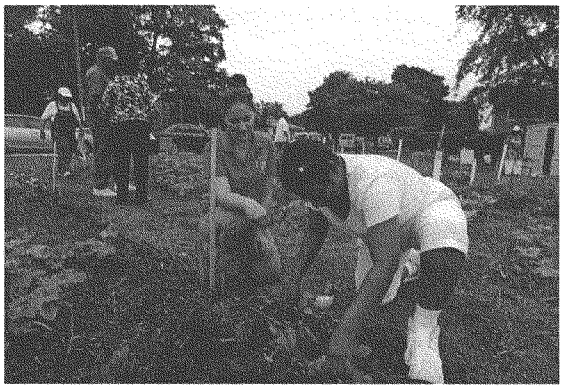
Currently, leadership and programming for agriculture, food, health, and nutrition needs are spread across multiple agencies and departments in Ohio government. The result is many different interests working in silos to achieve narrow objectives, while failing to share their expertise and political support to solve broader economic, nutrition, and public health challenges. A budget-conscious administration should seek efficient ways for agencies to jointly address agricultural, forestry, food, and health programming. We stand ready to facilitate such an analysis, which should be completed by a team of leaders appointed by the governor and drawn from the affected communities of interest, along with academic, government, and business leaders with expertise in these areas.

This team should give Ohio agriculture a higher public-policy profile — not just in terms of food and nutrition, but also in trade, economic development, workforce training, and jobs. Ohio has little voice in international trade and tariffs, which have great impact on farmers, but state officials can work to hold Ohio's congressional delegation accountable for representing agricultural interests. The team should also advocate for greater promotion of agriculture in economic

development initiatives; in developing a broader workforce; and in matching workers with jobs on farms, in processing facilities, and in mechanical and technical fields that serve agriculture.

C. Restore the Ohio state government's role as a marketer and champion, as well as a regulator, of agricultural goods and services via the following initiatives:

- Redefine and restructure the ODA's Ohio Proud program to make it relevant and engaging to today's consumers and institutional foodservice markets, and enhance the reach of Ohio Proud to make it accessible to both small-scale and commodity-scale agriculture.
- Promote and incentivize practices that increase ecosystem services that support Ohio farms, land, and water.
- Expand and strengthen the *Ohio Development Services Agency's Ohio Global Agriculture Trade Program.*
- Remove regulatory barriers blocking the introduction and use of high-octane/low-carbon biofuels.
- Support value-added processing of agricultural commodities and new markets for bioplastics and other bio-economy products through research and enabling policies.
- Curate multiple government and university data streams about soil, weather, and conditions into one accessible, up-to-date resource.



- Fund agricultural education, basic research on maintaining soil and water quality, and intentional research to enable precision agriculture techniques.
- Address chronic labor shortages through collaboration with federal and state leaders.

Diversity

DIVERSIFY AND SUSTAINABLY INTENSIFY THE PRODUCTION OF FOOD, FEED, FIBER, AND FUEL.

As noted above, Ohio agriculture involves much more than the production of food, feed, and fiber. Ohio's farmers, livestock producers, and foresters also produce clean energy. They filter water, sequester carbon, enhance biodiversity, underpin national security, improve the environment, and create jobs and wealth. In short, they contribute to improved quality of life.

Supporting the sustainable development of our growing world provides a rare opportunity to define the next phase of Ohio agriculture. As the state's top-ranking industry for generations, agriculture can become even more relevant by adopting the three pillars of climate- smart agriculture: 1) sustainably increasing agricultural productivity and livelihoods (i.e., sustainable intensification); 2) enhancing adaptive capacity and improving resilience; and 3) delivering ecosystem services, such as sequestering carbon, and reducing and/or avoiding greenhouse gas emissions. To do so, Ohio agriculture needs to evolve by embracing the following foundational priorities.

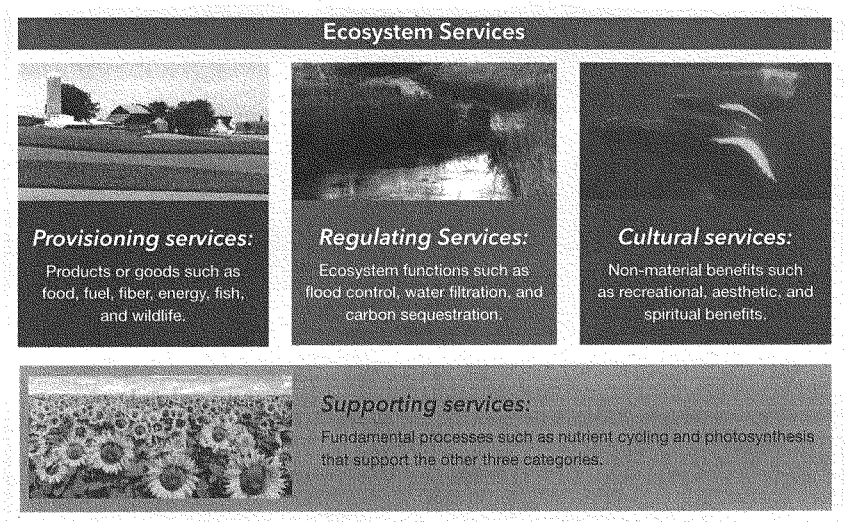
A. Discern and promote ways to integrate commodity production with diversified, identity-preserved, or value-added production in ways that enhance ecosystem services, farm and forest profitability, and public support for Ohio agriculture.

Ohio agriculture has a rich heritage, but broad change is needed to maintain this status and engender ongoing public and policymaker support. We view diversification as a critical pathway to strengthen the future of Ohio agriculture. Achieving this would require collaboration among diverse agricultural interests on issues that have sometimes divided them, but the time is right to bring them together. Ohio Smart Agriculture: Solutions from the Land again stands ready to facilitate such a process — which in many ways is an extension of what we've already achieved to generate this document. The effort also should include multi-agency government ex-officio partners; academics from land grant universities; representatives of agricultural organizations such as the Ohio Farm Bureau Federation, Ohio Farmers Union, and Ohio Ecological Food and Farm Association; and environmental organizations such as the Ohio Environmental Council and The Nature Conservancy.

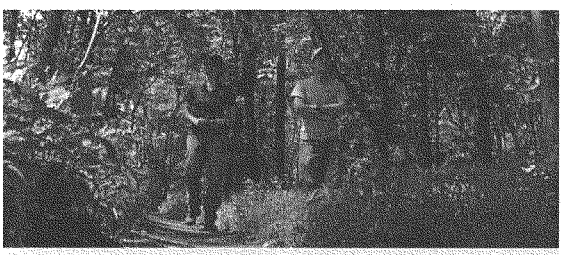
A key element of this collaboration should be exploring ways to place ecosystem services at the foundation of agricultural production in Ohio, in terms of supporting both agricultural production and broader societal benefits, such as green space and water quality. A priority outcome of this work should be implementing an ecosystem services action plan for the state to transition agricultural production to this approach, decreasing the need for inputs to production from outside of Ohio, and for widespread understanding of, and appreciation for, the ecosystem services that both support and are provided by Ohio agriculture.

B. **Build human capital in the form of workforce development and community resources, including access to land for rapidly changing rural and urban agriculture.**

Farming is hard work, and it takes a skilled workforce to grow, harvest, process, and



Ecosystem Services, based on UNEP, Millennium Ecosystems Assessment. Source: Based on WRI materials



What does the forest industry mean to Ohio?

- Converting raw materials into various forest products resulted in $9.95 billion in added value
- $26.3 billion in total economic activity was generated
- Over 122,000 people were employed in 463 sectors of Ohio's economy
- Those workers earned $6.54 billion in wages and benefits

How does Ohio rank nationally in the Hardwood Industry?

- 1st in employment in the production of Wood Household Furniture – 4,168 employees
- 3rd in employment in the production of Pallets – 4,004 employees
- 8th in employment in the production of Cabinets – 4,176 employees
- 9th in employment in the production of Millwork – 3,754 employees

market the goods and services produced from agricultural landscapes. In examining the current state of Ohio agriculture, we have confirmed that Ohio's farmers are aging and the state lacks a comprehensive succession plan to ensure that the next generation of farmers will be equipped with the knowledge and resources they need to maintain economically viable operations.

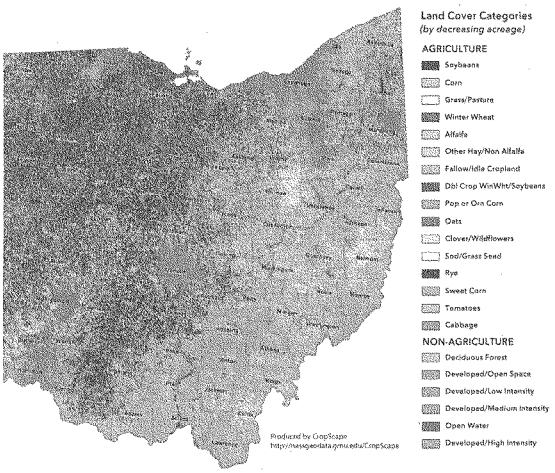
We urge the development of a roadmap to guide intentional agricultural workforce development. Programs should be developed to remove barriers and enhance aspiring farmers' access to land, capital, and knowledge. These programs should include mentoring and apprenticeship opportunities through which new and beginning farmers can work alongside experienced farmers who can train and influence future career decisions.

Of particular importance is the opportunity for land grant institutions such as OSU and Central State University to collaborate with community colleges, trade groups, and industry partners in training non-traditional growers and workers such as veterans, limited resource producers, and immigrants who have prior experience and interest in farming. Other ideas worth considering are having vocational agriculture curriculums in more high schools and community colleges, developing farm internship work programs, and offering loan forgiveness in return for becoming an agricultural educator or farm apprenticeship mentor.

We strongly support these initiatives and ideas in our recognition that, in order to be successful, the next generation of farmers must have access to land, be offered livable wages, and be properly trained in their critically important craft.

C. **Create a strategic forestry roadmap to strengthen value-added woodland supply chains, and create new markets for residual forestry products.**

Forestry is a powerful force in Ohio's landscapes, with $26 billion total economic impact, abundant forested lands, and many value-added supply chain processing inputs. However, the 72 percent of forested lands managed by individual owners in the state are badly under-supported, with only three forestry extension agents and 20 state foresters to provide knowledge-sharing and planning services to 88 counties and tens of thousands of forest properties. As fewer and fewer owners understand the value of their woods or create management



plans, consolidation and loss of knowledge and infrastructure — barriers familiar to other agricultural producers — reduces the power of forestry-adjacent industries which once enriched Appalachian Ohio (representing one-third of the state).

Several important elements must be considered in the creation of a strategic forestry roadmap to enhance resilience and productivity across forest and woodland landscapes. We must:

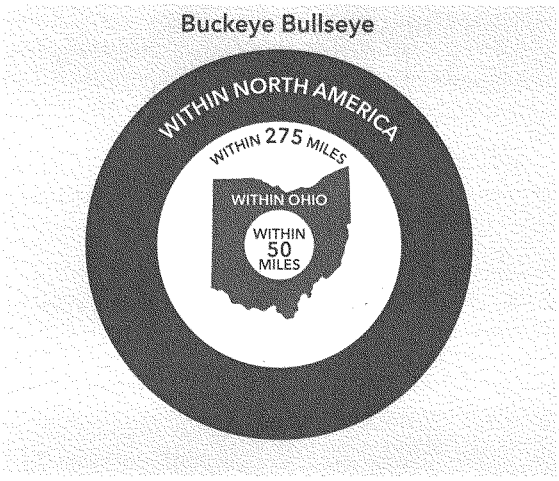
- Find funding and resources to hire state-level foresters and university extension agents who can expand the use and availability of professional forest management for state woodlands.
- Create programs to train and certify landowners and forest management consultants in woodland use and best practices.
- Strengthen forest health programs to promote the regeneration of valuable woods and protect against pests, invasive species, land-use fragmentation, and the impacts of climate change.
- Harmonize regulation and implementation of state law for forested lands by creating a unified, sensible, and consistently applied tax policy.
- Highlight the natural partnerships among agricultural growers who own woodlands or manage operations that would benefit from agroforestry techniques in order to solidify a whole-state land management system.
- Investigate value-added byproducts (such as biochar and compost) and other initiatives for carbon sequestration and soil health.
- Explore labor development, new production models, and diversified production and processing infrastructure to capitalize on the economic value of forestry products and relationships among land-oriented rural communities.

Markets

DEVELOP INFRASTRUCTURE AND USE INSTITUTIONAL PURCHASING POWER TO QUANTIFY AND INCREASE MARKETS FOR OHIO SMART FOOD.

For Ohio farmers to significantly increase production of local food, they need assurance that reliable markets and infrastructure are in place — in the form of processing, storage, and distribution for fruit, vegetables, meat, poultry, dairy, and eggs. As noted above, over the last half century, Ohio has lost much of the local infrastructure that enabled local food systems. The good news is that there is significant interest across the state in rebuilding that capacity. Re-creating those facilities, connections, and markets will not be easy, however. It will require financing, market studies, networking, and new business models, and much of that will have to occur even before new processing plants or cold-storage spaces can open for business. The goal is to reconstruct a whole *industry*, and not just a few more facilities.

An often-forgotten part of food system infrastructure is marketing. For farmers, that means a simple way of selling their goods into the



The goal is to provide supplies, technical assistance, and training so families can both supplement their income and improve their children's nutrition.

marketplace. For consumers, it means — among other things — confidence in the quality of the food they buy. Increasingly, consumers like to know where and how the food was produced when they assess quality. Local-food advocates and councils around Ohio have long talked about some form of branding, or standards, for local food.

The idea for Ohio Smart Food came to our steering committee by way of OSU's goal to increase the amount of local and sustainably sourced food served on campus to 40 percent by 2025. That initiative has a "Buckeye Bullseye" model of concentric circles around the target markets. We suggest a working definition for the concept of Ohio Smart Food as follows: "Food for human consumption that is grown in an environmentally sensitive manner by Ohio producers and is immediately and conveniently available on an equitable basis to Ohio consumers with minimal handling and processing."

Exactly what the final local food standards will be, and whether Ohio Smart Food is the name for them, will be determined later. But the concept is consistent with the vision of *Ohio Smart Agriculture: Solutions from the Land.* With that in mind, we recommend the following actions as initial steps:

A. **Jump-start infrastructure development by quantifying current demand for local food and encouraging commitments of hospitals, schools, government agencies, and other public other institutions to buy locally.**

Large institutions can drive investment in facilities to aggregate, process, and distribute Ohio-grown produce and livestock products through the sheer volume of their purchases. As a major purchaser and provider of food for its network of campuses across the state, OSU's commitment creates new economic opportunities for those who wish to enter farming, especially aspiring limited resource and urban producers who have not found a way to participate and compete in the current system. OSU's Initiative for Food and AgriCultural Transformation (InFACT), through a grant from the W.K. Kellogg Foundation, is developing a network of low-income families with young children in the household, particularly in

communities of color that could grow food and sell it to OSU and other institutions and businesses in the community. The goal is to provide supplies, technical assistance, and training so families can both supplement their income and improve their children's nutrition.

The potential "market pull" and support from schools, hospitals, prisons, and other large institutional food providers highlights the need for processing and distribution infrastructure to meet the demand. Quantifying the value of current institutional demand will demonstrate that fresh local food, and the value added to it through processing, is an economic driver — not a passing fad. The studies and infrastructure-network models can be replicated or customized and scaled up across the state to help solve hunger and health challenges and simultaneously create jobs, stimulate economic growth, and generate wealth.

B. **Work with public, private, and university-based partners to develop an independent "food-system finance authority" that can attract and manage financing and work with market outlets to build new infrastructure.**

To do this effectively and comprehensively, Ohio needs development, support, and expansion of a local and regional food economy that includes administrative supply chain infrastructure (including food hubs and cooperatives), resources and services for food and agricultural enterprise, and innovative approaches for selling to institutions (such as OSU's 40 percent local and sustainable purchasing goal), and other market outlets.

An Ohio local-food financing mechanism would need an intermediary between producers and the marketplace to enhance and maintain a dependable revenue stream for agricultural producers and regional food businesses. This entity could be a new quasi-public, public/private, nonprofit, or even for-profit organization that would ensure the development and dissemination of new funding resources.

An additional partner, such as an existing or newly created finance entity, is necessary to provide financing for the vital local and regional food infrastructure to service Ohio markets with viable and consistent sources of Ohio-grown food. Consideration of specific bond-financing options for particular components of new regional food system infrastructure should also be explored as a priority within the purview of such an entity.

Sound decision-making should be based on research to examine the widely held view that infrastructure limitations are the primary barrier to the scale-up of food production in Ohio.

C. **Develop and fund a pilot project for small-scale, mobile meat processing.**

A decade ago, the Ohio Food Policy Advisory Council studied the feasibility of a mobile poultry processing unit, and the ODA began work on a prototype.[xii] Ohio needs to revive those efforts, which have been successful in other states, and investigate mobile processing options for meat, poultry, and fish, which would allow a decentralized, collaborative, regional process to develop among agricultural producers. Special attention should be paid to exploring collaborative cold-storage options and encouraging regulatory flexibility without compromising food safety. For example, many farmers would like to see Ohio policy changed to permit on-farm or mobile processing of meat rabbits.

Ohio is very fortunate to have a respected meat inspection program to work with mostly smaller processing facilities. Given the ODA expertise and a well-established animal science program at OSU, it should be simple and expeditious to build on the past work and develop a pilot project for mobile meat processing. There is an existing model for this kind of project at Kentucky State University in Frankfort.

D. **Reinforce the value of Ohio agriculture by regularly evaluating the food needs and preferences of Ohioans.**

A frequently recurring topic on the steering committee was the need to know and understand the food preferences and needs of Ohio consumers. It arose in

Climate Driver	Vulnerabilities
Warmer temperatures, especially during the winter and at night during the summer	Additional heat-stress on humans and livestock
	Accelerated pace of growing degree day accumulation may lead to changes in regional crop rotations and yields
	Increase pressure from weeds, disease, and insect pests
	Changes in timing and coincidence of pollinator lifecycles will affect growth and yields.
	Northward shifts in optimum crop production zones
	Degraded pasture and forage crop quality
Increased percipitation, changes in seasonal precipitation and extreme events.	Soil movement and erosion.
	Field nutrient maintenance, loss, and degraded surface water quality
	Loss of field work days; Delayed planting and harvest
	Seasonal disruptions during critical threshold periods of crop and livestock development.

discussions of food insecurity and in discussions about the end uses of agricultural commodities. And it drove the conversations about growing demand for vaguely defined local and sustainable food.

OSU has long conducted simple but useful surveys of consumers' interest in buying local food, usually focused on direct marketing. But a broader and more comprehensive analysis of consumer preferences — across the state and in reference to all food purchases — would provide an invaluable benchmark for Ohio farmers, food purveyors, and others. Development of the survey should be a team effort among farmers, consumer groups, nutritionists, grocers, academics, state officials, and other affected parties. It should be conducted at regular intervals, perhaps every two years, as was the case with the earlier local-food surveys.

Environment

IMPLEMENT LANDSCAPE-SCALE CLIMATE-SMART AGRICULTURE STRATEGIES TO ENSURE SUSTAINABILITY AND ABATE AGRICULTURAL RUNOFF.

Agriculture is a science-based industry and science is telling us that nutrient runoff from agricultural operations is impairing water quality. Science is also telling us that the climate is changing and, coupled with increasingly erratic weather, poses a major threat to Ohio agriculture and our vision of dramatically increased production of food in the state. The time for action is now.

Given that Ohio farmers and their agribusiness partners are respected stewards of the land, guardians of natural resources, and providers of high value ecosystems services, *Ohio Smart Agriculture; Solutions from the Land* endorses the following actions to address these twin challenges:

A. The state of Ohio and all stakeholders should, by 2020, formulate and oversee the implementation of a new state water quality strategy that includes current public and private sector response initiatives and meets the following goals:

- Nutrients are used in farming operations without negative environmental impacts.
- Ecosystem services are at the foundation of agricultural production in Ohio, both as the basis for supporting production and in the broader societal benefits of sustainable agricultural land management, such as green space and water quality.

In addition to strategies, desired outcomes, benchmarks and metrics to measure progress, the following elements should be included in the Ohio Smart Agriculture Water Quality Strategy:

- Develop standards for protecting water quality and aquatic ecosystems.
- Strengthen and expand locally led water-quality programming through conservation districts, including expanded technical assistance (public and private sector) to support sustainable farming.
- Establish and/or increase funding for government conservation cost share programs to incentivize the planting of fall cover crops (e.g., guaranteed minimum payments for cover-crop yield loss protection), offset the cost of

VanTilburg Farms makes the most of the poop it's been dealt

Across Ohio and especially in the western Lake Erie drainage basin, improving water quality is a big priority. One family farm is taking on this challenge and creating their own solution.

The VanTilburg Family

VanTilburg Farms of Celina, Ohio, goes back more than a century, when the great-grandfather of the current owners worked for room and board on a farm while saving up enough to purchase his own. VanTilburg Farms has evolved over the years, successfully following many markets.

The current operators – brothers Matt, Kyle and Luke VanTilburg – co-own 4200 acres of non-GMO row crops, a poultry fertilizer business, an excavation business, and an ag retail business. One of their newest ventures showcases their commitment to the land, soil quality and a prolific value chain.

In late 2018, they opened a 4,200-head dairy farm. MVP Dairy is a partnership between the VanTilburgs and McCarty Dairy LLC of Colby, Kansas. Their unique business perspectives align for collaboration on land, grain, manure management, and dairy experience. They will be part of the Dannon Pledge, with this new farm's specific production and management practices in sync with the needs of Dannon's giant yogurt plant in Minster, Ohio.

"It's about sustainability, it's about doing the right things," Luke VanTilburg said. "The sustainability part is a much bigger piece. The way we do things with no-till and cover crops is a pretty small percentage compared to conventional" acreage in Ohio.

Their farm made the switch to non-GMO two years ago and has been implementing no-till and cover crops for even longer. The fields are fertilized with the poultry litter they offer to other farms in the area. They take precautions and use saturated buffers to prevent water runoff on their fields.

VanTilburg Farms has volunteered to be part of the Great Lakes Restoration Initiative (GLRI) for a three-year study on phosphorus and nitrogen levels. The current levels are a fraction of the average in Mercer County and as the study comes to completion, the results could have a positive impact on the state.

"We felt we had a system and model that works – and taking care of the environment is one of the most important things we can do," VanTilburg said. "Water quality is at the top of everyone's mind. We have a solution and did not want to sit on our hands."

"Water quality is at the top of everyone's mind. We have a solution and did not want to sit on our hands."

The new dairy will uphold and increase water-quality standards. Cows will be raised in a positive, sanitary environment, with frequent manure flushing and constant ventilation to minimize pests. The manure will also go through a two-step system to separate solids from liquids; solids will be dried and handled like chicken litter. Meanwhile, liquids will settle in an anaerobic lagoon for nutrient dispersal and then be pumped through a central pivot to fertilize their crops.

Using all byproducts in the system allows the brothers to care for the environment, diversify their operation, and showcase their unique brand. In agriculture's "dog-eat-dog" commodity world, where primary consumers—millennials—have specific needs, they're finding their niche.

"What's the story that makes their dinner conversations different about the food they are eating?" Luke VanTilburg said. "You [agricultural producers] have to become a part of that story."

precision nutrient application soil tests, and expand the construction and use of manure storage facilities and other nutrient remediation practices.

- Establish a manure transport program modeled after those in Maryland and Virginia to help poultry, dairy, beef and other animal producers cover the costs of transporting excess manure off their farms.
- Innovate and add flexibility to crop insurance programs to help producers of non-covered crops manage risk; incorporate measures that encourage producers to use and provide ecosystem services.
- Expand research to enable precision agriculture techniques that enhance ecosystem services, such as better managing nutrient flows and balances.
- Adopt "safe-harbor" provisions for early adopters and those that are trying to adapt.
- Include an enforcement mechanism for bad actors and noncompliant producers.

We take note of the leadership that Ohio's soil and water conservation districts and their partners are providing in this area and hope these collaborations on proactive and pragmatic water quality strategy are productive.

B. Develop and implement a climate-smart action plan for Ohio agriculture to help farmers adapt, improve resilience, and deliver products and services that mitigate climate-change impacts.

To develop an array of solutions that enable Ohio agriculture to become "climate smart" — to sustainably intensify and diversify production on farms, grazing lands, and forest; to adapt, improve resilience, and mitigate impacts — we propose that a statewide, multi-stakeholder group be convened to build on our steering committee's work in the following ways:

- Conduct a climate opportunity and vulnerability assessment.
- Create a "futuring" document for Ohio that identifies the specific vulnerabilities posed by increasingly erratic weather extremes and a changing climate.
- Develop a comprehensive adaptive-management strategy for Ohio agriculture.
- Develop and implement an ecosystem services action plan that will enhance the resilience of Ohio agriculture.

The following elements should be included in a climate-smart action plan for Ohio agriculture:

- Climate-smart agriculture production systems
- Conservation systems and practice
- Risk management strategies
- Infrastructure improvements
- Decision support tools
- A program to recognize climate smart farms, grazing lands, and forests.

Several other states across the country, including California, Florida, Maryland, Missouri, and North Carolina, have begun to develop and implement climate-smart agriculture strategies. Ohio should do the same to protect and enhance the resilience of Ohio agriculture for decades to come.

C. Track and publish statewide progress data in order to assure and celebrate continuous improvement.

There is an overarching intention of improving soil health and achieving carbon neutrality (zero emissions) in agricultural production over time and asserting that agriculture can become, on balance, a strategy to mitigate challenges with both climate change and water quality — and not just a source of related problems. Therefore, we propose establishing statewide baseline estimates of soil organic carbon, soil organic matter, and total continuous living cover on agricultural lands, such that progress in these categories can be tracked and published to support continuous improvement in the conservation and re-carbonization of Ohio agricultural soils. Once baselines are established, new studies every two or three years would be sufficient to discern progress, or lack thereof, in these critically important statistics.

JOIN US!

Enabled by a grant from the W.K. Kellogg Foundation, Solutions from the Land, a national organization dedicated to advancing land-based solutions to global challenges, and OSU's InFACT teamed up to support and facilitate *Ohio Smart Agriculture: Solutions from the Land.* Through extensive dialogue and collaboration with a wide cross section of stakeholders, we have formulated a mid-century vision for Ohio's food system and agricultural economy. With input and guidance from these partners, we have also created a roadmap to achieve the vision for delivering a wider range of goods and services from the land.

Some of the actions we propose are immediate initiatives that can accelerate and energize a broader and more robust response to the mega challenges facing Ohio today. Others are longer-term strategies that require further vetting and enhancement, along with integrated and landscape-scale planning.

In advancing these findings and recommendations, we know that our work is far from complete. For our vision and mid-century goals to be realized, this call to action must be implemented. This can only happen if those who share a common vision engage all communities of interest in a shared clarion call to action.

Toward this end, we invite all farmers; philanthropic, business, community, and non-governmental organizations; academic and government partners; and advocacy groups that work at the intersection of land, food, health, and the environment. We ask that you join us in the actionable steps we've described that will help reduce hunger and improve nutrition; create jobs and generate economic growth; improve the environment; and enhance the resilience of agricultural and forested landscapes.

Going forward, the implementation phase of this initiative will continue to be guided by a self-directed steering committee composed, we hope, of leaders who step forward from each of the communities of interest that have been engaged so far. Three organizations have partnered in providing backbone support for the effort so far and are willing to continue into implementation: Solutions from the Land (including operating, administrative, and fiduciary support); the OSU Initiative for Food and AgriCultural Transformation (bringing expertise from across the university and its network leadership beyond), and Ohio State University Extension (providing a two-way connection with Ohioans in all 88 counties). We invite willing, able, and respected leaders from across the diverse Ohio agricultural and food system landscape to join us as core partners in advancing this vision and achieving expected outcomes.

In times of changing climate, markets, and preferences, the defining mission of *Ohio Smart Agriculture: Solutions from the Land* is to:

- Help farmers adjust to new weather patterns, nurture the land, clean our air and waters, and provide a healthy ecosystem for future generations.
- Reconnect consumers with agriculture; improve health, food access, and nutrition for Ohioans; and celebrate the importance of strong, vibrant farm communities and farmland.
- Build new opportunities and infrastructure for a more diverse and prosperous farm economy in which Ohioans feed Ohio and the world.

Evidence of transformational change in Ohio's food systems and agricultural economy is emerging across the state. Please join us in nurturing and growing these foundational efforts!

About Solutions from the Land

Solutions from the Land is a nonprofit corporation focused on land-based solutions to global challenges. Its mission is to identify and facilitate the implementation of policies, practices, and projects at a landscape scale that will result in land being sustainably managed to produce food, feed, fiber, and energy while protecting and improving critical environmental resources and delivering high value solutions to combat climate change. The president is Ernie Shea (*eshea@SfL.dialogue.net*). **For more information, see *www.sfldialogue.net/SFL/SfL_Vision.pdf***

About InFACT

InFACT The Initiative for Food and Agri-Cultural Transformation (InFACT) is a transdisciplinary Discovery Theme program at OSU aimed at designing and implementing sustainable food systems, which are defined as achieving a balance of ecology, economy, technology, and culture, and to promote the overall well-being of people, animals, and the natural environment. The InFACT mission is to transform the way we grow, process, and distribute our food, leading to vibrant, sustainable, and resilient agriculture that places nourishing food at the center of just and vital communities in Ohio and beyond. The program is co-led by faculty director Casey Hoy (*hoy.1@osu.edu*) and executive director Brian Snyder (*snyder.1534@osu.edu*). **For more information, see *discovery.osu.edu/infact*.**

About OSU Extension

OSU Extension is commonly referred to as the "outreach arm" of the university, having offices in all 88 Ohio counties. Because its employees live and work in the county they serve, they have a genuine connection both to the people of Ohio and the state's land grant university. Its current priorities are health and wellness, thriving across the lifespan, workforce development, sustainable food systems, community capacity building, and environmental quality. Extension's purpose is to translate and disseminate scientific knowledge in a way that is beneficial to the people of the state. Historically, this has occurred through workshops, seminars, field days, and one-on-one consultation. Today, Extension is also working in partnership with communities to co-create solutions to local problems. The director is Roger Rennekamp (*rennekamp.3@osu.edu*). **For more information, see *extension.osu.edu*.**

Acknowledgements

WORK GROUPS

The steering committee would like to thank the scores of agricultural, forestry, conservation, academic, and business leaders who have participated in this dialogue to date. During the period of 2017-2018, four workgroups, comprising a diverse cross section of supporting partners, forged consensus on initial steps necessary to ensure the realization of our vision and produced reports outlining their findings and recommendations. In producing this vision for Ohio agriculture, the steering committee drew heavily from the products of each workgroup. **A list of workgroup participants and their reports can be viewed at *www.ohiosmartag.net*.**

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Glossary

Climate change – Climate change is a consistent and long-term change in the usual weather found in a place. This could be a change in how much rain a place usually gets in a year, or it could be a change the usual temperature for a month or season. Weather can change in just a few hours; the climate takes many years to change.

Commodity – A standardized product sold in a competitive market that encourages the lowest price possible and in which the source of the product is irrelevant.

Ecosystem services – Farms, ranches, and forests provide vital goods and services to society that are called "ecosystem services." These services offer additional benefits to society beyond typical agricultural products, such as clean water and air, wildlife habitat, and carbon storage. Market-based approaches to conservation are a cost-effective method to achieve environmental goals and sustain working and natural landscapes. Farmers also rely on ecosystem services for such basic needs as adequate soil moisture, pest control, and healthy soils that support plant growth. Farmers can manage their land in ways that produce each of these services, avoiding expensive inputs that would otherwise be needed to replace them.

Low food security (14.8 percent of Ohio households, 2014-2016, ERS) – Conditions in which individuals or families may need to make trade-offs between basic needs (such as housing or medical bills) and purchasing nutritionally adequate foods, with diet quality suffering.

Very low food security (6.3 percent of Ohio households, 2014-2016, ERS) – Consistently living with malnutrition and hunger, and missing meals on a regular basis.

Infrastructure (as in local food) – Generally, the aggregation, processing, and distribution services used to get products from farm to market. It can include food hubs, cooperatives, slaughterhouses, produce terminals, and other facilities. The term is sometimes expanded to include marketing, land, equipment, and labor.

Local food – Food produced within a certain geographic area. Definitions in terms of distance varying from an hour's drive to a day's drive to 100 miles to 400 miles, but a key quality that people seek is the chance for the producer and consumer to know each other and perhaps to have met, which is sometimes called civic agriculture.

Ohio Smart Food – Food for human consumption that is grown in an environmentally sensitive manner by Ohio producers and is immediately and conveniently available on an equitable basis to Ohio consumers with minimal handling and processing.

Resilience – The capacity of an agriculture and food system to absorb or withstand small disruptions (e.g., a year with low prices for products or adverse weather) and adapt to large disruptions (e.g., permanent and profound changes in global markets, climate, or technology) without losing its structure and functions (producing food, fiber, and more). Resilience requires self-organization, learning and adaptation; the grist for adaptation is diversity.

Specialty crops – Defined in the 2014 Farm Bill as "fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery crops (including floriculture)."

Sustainable (social, economic, environmental) – Defined in InFACT's strategic plan as "Achieving a balance of ecology, economy, technology, and culture to promote the overall well-being of people, animals, and the natural environment."

50 x'50: Pathways to Ohio's Mid-Century Food System and Agricultural Economy

1. Form and properly resource a Farm, Food, and Health Partners Alliance.
2. Align state agencies toward effective and coordinated food, health, and agriculture programs.
3. Restore the Ohio state government's role as a marketer and champion of agricultural goods and services.
4. Restructure the Ohio Department of Agriculture's Ohio Proud program to make it relevant and engaging to today's consumers, institutional foodser vice markets, and commodity-scale agriculture.
5. Quantify and regularly assess demand for local food.
6. Quantify and regularly assess the food preferences of Ohio consumers.
7. Expand and remove barriers to institutional purchase of Ohio food and agriculture products.
8. Grow more of what Ohioans need.
9. Develop an independent "food-system finance authority."
10. Restore processing capacity and supply chains for Ohio-raised food.
11. Restore processing capacity and supply chains for Ohio-raised meat and poultry.
12. Develop markets and supply chains that serve immigrant populations.
13. Develop and fund a pilot, small-scale, mobile meat-processing program.
14. Improve access to affordable and nutritious food, especially in underserved communities.
15. Promote food as medicine.
16. Expand Ohio farmer outreach and advocacy to address food insecurity challenges.
17. Welcome and support the next generation of farmers.
18. Develop programs to assist young, underserved and "new-American" farmers.
19. Develop programs to assist limited-resource farmers.
20. Promote training in schools, colleges, and prisons in support of the entire food system.
21. Create new agriculture-education programs for adults, communities, and students.
22. Build human capital in the form of workforce development and community resources.
23. Reform immigration policy to help fill agriculture jobs.
24. Ensure living wages for farm and agriculture-related jobs.
25. Support local food aggregation and processing to ensure ease of marketing for farmers.
26. Adjust state regulatory policies to be more collaborative and/or less adversarial.
27. Increase the number of malt houses, grain mills, and other processing facilities to assist the brewing, distilling, baking, snack food, livestock feed, and other industries.
28. Promote controlled-environment production for horticulture and floriculture.
29. Support development and expansion of aquaculture and creation of a processing and distribution supply chain for fish.
30. Promote new processing options and markets for Ohio wood products.
31. Promote new processing and markets for Ohio bio-products and the bio-economy.
32. Invest in rural broadband infrastructure.
33. Diversify commodity production with identity-preserved or value-added products.
34. Develop and implement a climate-smart action plan for Ohio agriculture.
35. Create and implement a new water quality strategy.
36. Identify pathways for accelerating and scaling up the delivery of ecosystem services to Ohio farms and from Ohio's agricultural landscapes.
37. Through knowledge sharing, increase the use of precision farming technologies.
38. Create a strategic forestry roadmap and strengthen programs to promote good management of woodlots on farms.
39. Harmonize tax incentives to protect working lands.
40. Boost awareness of the role that farmers play in Ohio's economy and environment.
41. Create a network of government and private consultants to help develop a landscape scale plan for ecosystem management.
42. Promote research and education about cover crops and other soil-enhancing practices.
43. Track and publish statewide data in order to assure and celebrate continuous improvement.
44. Increase research and data on the handling and application of manure on fields.
45. Increase research and data on the services to agriculture that come from the land.
46. Promote policies and practices that support the ways in which agricultural land can provide public benefits: zoning policies, water resource protection, forestry and woodlot management, and tracing the sources of food.
47. Strengthen land use policies that keep land in agricultural production.
48. Develop a brand and recognition for Ohio farm products of all kinds, including ecosystems services.
49. Create risk management programs.
50. Increase awareness of ecosystem services.

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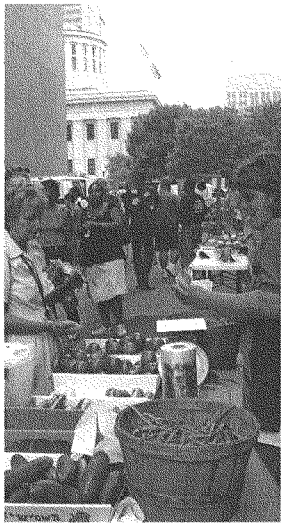
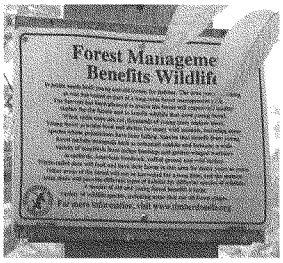
To learn more about the history of Ohio agriculture, please refer to the Center for Public History + Digital Humanities at Cleveland State University or the collected archives of Agricultural Census and survey data at the National Agricultural Statistics Service (nass.usda.gov).

To learn more about Ohio's forested lands, please reach out to the Ohio Forestry Association.





Ohio
Smart
Agriculture
SOLUTIONS FROM THE LAND

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THE OHIO STATE UNIVERSITY

Initiative for Food and AgriCultural Transformation | InFACT

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The **Initiative for Food and AgriCultural Transformation (InFACT)** is a transdisciplinary program at The Ohio State University aimed at designing and implementing food systems that are sustainable, defined as achieving a balance of ecology, economy, technology and culture to promote the overall well-being of people, animals and the natural environment.

Mission

InFACT will transform the way we grow, process and distribute our food, leading to vibrant, sustainable and resilient agriculture that places nourishing food at the center of just and vital communities in Ohio and beyond.

Core Values

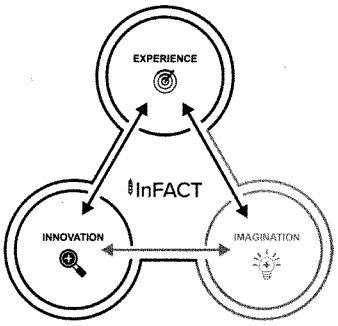
- **Innovation, leadership** and **ecological awareness** in our academic endeavors and engagement with communities.
- **Equity** and **social justice** for all.
- **Diversity, transparency** and **continuous improvement** in farming and food systems.
- **Indigenous knowledge** balanced with **scientific discovery** to honor diverse sources of knowing as well as generations of students, teachers, communities, families and farmers working together.

The Situation

While achieving unprecedented levels of productivity, the food system in Ohio and across the country faces some major challenges. This system leaves many people without access to safe, nutritious and affordable food, while others struggle with preventable and diet-related chronic diseases. In addition, the production and distribution of food causes a number of unintended environmental problems, including degradation of soil, air and water quality. Farmers are increasingly open to implementing practices to assure long-term resilience, but cannot bear the full costs of doing so alone. In brief, there is an urgent need for redesign and transformation throughout the food supply chain.

Ohio State's InFACT is poised to pioneer new conceptual and physical models of food systems that promote health, while balancing technological, ecological, economic and social justice issues.

Transdisciplinary Approach



Strategic Goals

1. Research Agenda and Progress Tracking
Continuously build research capacity and new models of transformational agriculture and food systems while measuring progress on our vision.

2. Network Convening and Goal Setting
Build a broad-based, interactive network of stakeholders convened at least once every year, to coordinate work on a set of common goals.

3. Local and Sustainable Food Availability
Facilitate a comprehensive system, involving production and purchasing, to make fresh food, produced as locally and sustainably as possible, available to all students, faculty and staff.

4. Transdisciplinary Food Systems Clinic
Establish a transdisciplinary food systems clinic, known nationally for its expertise in, and support for, the development of resilient, just and equitable food systems for all.

5. Six-Campus Collaborative Presence
Establish an InFACT presence on each of six Ohio State campuses with at least one part-time staff position that would work collaboratively to positively impact each campus community.

Research Agenda

InFACT is coordinating and supporting the work of faculty from 10 colleges to provide research-based transition pathways to new diversified agricultural landscapes that improve the economic, social and environmental well-being of both people and the land. InFACT faculty affiliates and our many partners work together using a transdisciplinary approach to discover how to transform agricultural and food landscapes, with new models that offer measurable improvements in food and nutritional security. Following is our current InFACT blueprint for transformational research to improve food security.

Availability
- Discover diversified farming systems with economic, social and environmental benefits.
- Discover economies of scope that support diversification of agricultural landscapes.
- Discover landscape designs and policies that support diversified agricultural systems.

Access
- Explore balanced and integrated supply chains from local to global scales for access, safety and transparency.
- Discover means of reducing food waste across the supply chain, and turn remaining waste into raw materials for value-added processing.
- Measure, expose and explore how to reduce inequities in food access among populations.

Utilization
- Explore how food landscapes impact geographic patterns of food consumption.
- Discover the multiple values that influence transitions in food culture and use.
- Discover creative new dietary patterns that improve health and well-being in communities.

InFACT
INITIATIVE FOR FOOD+AGRI**CULTURAL** TRANSFORMATION

Colorado Sugarbeet Growers Association and American Sugarbeet Growers Association

United States House of Representatives
Committee on Small Business
2361 Rayburn House Office Building
Washington, DC 20515

January 14, 2020

Dear Chairwoman Velazquez:

Thank you for the opportunity to submit a statement for the record for the January 9, 2020, hearing on Agriculture Technology (ag-tech). My statement will focus on ag-tech usage in Colorado, where I farm, but will also shed light on ag-tech usage adopted in the other sugarbeet producing states (California, Idaho, Michigan, Minnesota, Montana, Nebraska, North Dakota, Oregon, Washington, Wyoming). Sugarbeets are grown in 11 states by 10,000 family farmers who are the lifeblood of the rural communities in which they live and farm.

Background on Sugarbeet Industry: The sugarbeet is a vegetable that is 75% water, 20% sugar/molasses, and 5% pulp tissue. The US grows approximately 1.1 million acres annually. Over fifty percent of all sugar produced domestically is from sugarbeets and is identical to cane sugar. It is processed in twenty-one farmer-owned factories. The sugar extracted from sugarbeets is an essential ingredient in the U.S. food supply. Byproducts of sugarbeets, pulp and molasses, are used primarily as animal feed.

Environmental Benefits of Bioengineered Sugarbeets: From a global sugarbeet and sugarcane perspective, our industry is on the forefront of sustainability and environmental progress. Through the universal adoption of Roundup Ready ® bioengineered seeds, our industry has identified 25 environmental benefits that we have been able to achieve. We listed them in a 2015 submission to the National Academy of Sciences National Research Council Committee on Genetically Engineered Crops. In general, the environmental benefits of bioengineered sugarbeets can be broken into the following categories: lower herbicide usage, better plant health, better soil conservation and microbial health, and improved water quality and water conservation.

Advancements in all of these categories contribute to dramatic reductions in greenhouse gas emissions through less soil disturbance, less fuel consumption, and healthier plants converting more carbon dioxide into oxygen. Scientific studies have shown that bioengineered sugarbeets have reduced ecotoxicity and environmental risk by 92 percent and 98 percent respectively. Through biotech, our farmers are able to utilize more sustainable farming practices that have cut soil-derived carbon emissions by 80%.

Plant Breeding: We cannot underestimate the importance of ag-tech in breeding. In Colorado, over the past 15 years, advances in breeding and cultural practices have vastly improved farmers' land use efficiency; increasing sugar yield from around 8,500 pounds of sugar per acre to over 12,000 pounds per

acre. For example, breeders have been able to exploit molecular markers linked to disease or pest resistance genes that occur naturally in sugarbeet and its closely related wild relatives. As a result, the average sugarbeet grown in the U.S. contains upwards of seven native traits effective against common pests and diseases. The outcome is a sugarbeet that can naturally defend itself against pests and diseases without the need for pesticide applications. Breeders have also been able to use similar techniques to improve hybrid performance.

USDA Research and Gene Editing: Our industry greatly benefits from research being done through the United States Department of Agriculture's Agricultural Research Service (USDA ARS). For example, the USDA ARS's Edward T. Schafer Agricultural Research Center (ETSARC) in Fargo, North Dakota is leading critical research into one our industry's most destructive pathogens, *Cercospora beticola*.

The sugarbeet genome was mapped in 2014. Research to generate sugarbeet germplasm with new disease- or pest-resistant traits is conducted at ETSARC as well as in Fort Collins, Colorado at the USDA ARS Center for Agricultural Resources Research (CARR). These research centers along with other USDA-ARS laboratories conduct research that will identify critical targets that may be utilized for gene editing in the near future. As previously mentioned, we have achieved incredible gains from bioengineered sugarbeet seeds but new advances in plant breeding innovation, such as gene editing, will rely on continued and sustained research of the sugarbeet genome.

Seed Uniformity: Additional advancements in seed technology have assisted beet producers. The natural shape of sugarbeet seeds is a rough star of variable weight and size. These natural variances made planting uniformity very difficult. The first step was to give seeds a uniform shape, which was done by grinding the seeds to make them smoother. Coatings were then used to pelletize the seeds which made them round, but seeds still lacked weight uniformity. The lack of weight uniformity caused variances in planting distances as seeds of different weights dropped down the planting tubes at differing speeds. The result was varying planting distances that often that meant hand labor had to be used to thin out the beet stand to achieve proper spacing. Pelleted seeds are now weighed and sorted to assure that they are a uniform size and weight. In addition, seeds are X-rayed prior to being pelletized so that non-germinating seeds can be more accurately separated and removed. This results in a much higher percentage of viable seeds being sold to and planted by the grower.

Seed Priming and Coating: The seed coatings also include low-level pesticides applied in a way that provides direct protection of the sensitive seedling but prevents any side interactions with beneficial organisms in the environment. A major development in seed technology is priming. This process is achieved when the natural germination inhibitors in the seeds are washed off and then the seeds are treated to begin the germination process. Once the germination process is started, it is stopped and the seeds are coated where they are primed and ready to germinate once they are planted. Prior to this priming, it used to take 7-10 days after planting to see growth. Now it only takes 3-6 days from planting to see above ground growth.

Planting Technology: Uniform seeds work in conjunction with technologies developed by Precision Planting ®, Monosem, John Deere, Case IH, and other equipment manufacturers. These advanced planters control placement of seeds with precise spacings and depths. One way that planting efficiency is achieved is by utilizing sensors to monitor how smooth the ride is for the planter units. If the ground is rough, the tractor operator can slow down to insure proper seed placement. Growers are able to utilize advanced planters to accurately apply liquid fertilizer at the desired rate per acre at the time of planting.

Due to accurate GPS signal, the planter also uses swath control and row shut-offs to prevent seed from overlapping on areas of the field already planted thus preventing seed and fertilizer waste.

Water Issues: Water issues, both quality and quantity are of great importance to our industry but for different reasons in different sugarbeet growing areas. Sugarbeet growers in most of Michigan, Minnesota, and North Dakota do not have to irrigate their crops. Their main objective is often to get water off of the field while protecting the soil from erosion and oversaturation. Farmers in these states also have to practice water conservation under drought conditions. Sugarbeet growers in the irrigated regions of the country (California, Colorado, Idaho, Montana, Nebraska, Oregon, Washington, and Wyoming) are very focused on water conservation because water is a very limited resource in those states.

In Colorado and other western states, we have been able to achieve incredible gains in water and energy savings through the adoption of bioengineered sugarbeets and additional improvements in technology. For example, use of Roundup® ready sugarbeets has allowed me and my fellow farmers across the nation to adopt conservation tillage practices not possible with conventional production. We have reduced the trips across the field, reduced fuel usage, reduced soil disturbance, conserved water, and have promoted vastly improved soil and soil microbial health.

Irrigation: On my farm we also utilize fertigation, as do some other irrigated sugarbeet growing regions that use center pivot irrigation. Fertigation is the delivery of plant nutrients through irrigation. Combining practices reduces the energy and water used while also allowing more efficient use of fertilizers. By "spoon feeding" the sugarbeets throughout the season, we reduce nitrogen leaching and vastly reduce our carbon footprint.

On my farm we have flow meters on all of our irrigation sprinklers to record water usage. We recently started using Variable Frequency Drive (VFD) electric motors. These motors reduce the energy required to pump water to each sprinkler. As you know, water pumped uphill requires more energy. On farms with elevation changes, like my own, the VFD motors have proved to be a great energy and cost savings. We also use an app called ReinCloud ™ that lets us have full control of all of our sprinklers on our phones or iPad. The app helps us ensure that each sprinkler is operating as programmed and will immediately notify us of any issues. Water is a precious resource in Colorado and the west. In Colorado, water is drawn from surface sources or aquifers such as the Ogallala aquifer so any efficiencies that can be gained around water usage are significant.

Rural Broadband: Fortunately, much of Colorado has access to rural broadband. Unfortunately, that is not true across the country. The United States Department of Agriculture (USDA) outlined the importance of rural broadband infrastructure in the report published on April 30, 2019: "A Case for Rural Broadband: Insights on Rural Broadband Infrastructure and Next Generation Precision Agriculture Technologies." It is my hope that farmers across the nation will soon be able to access rural broadband and the corresponding benefits of that access which include more efficient weather modeling, pest prevention and monitoring, input use and management, and smart irrigation.

Satellites: Satellites have greatly improved farming. Satellite imagery allows growers to capture the different shades of green beet leaf canopies and use that data as a basis to identify varying rates of nitrogen in the soil. Maps from these images are developed and then used in the fertilizer applicator to vary the rate of nitrogen, putting more fertilizer where needed, and less where it is not needed. These efficiencies allow us to be more environmentally and economically sustainable.

Drones (On-Farm): Another example of technology that has greatly improved farming and processing of sugarbeets are drones. In the field, farmers use drones to scout fields for disease and pest pressures. Getting control of the issues before they become outbreaks allows us to decrease our use of resources such as pesticides and fuel. Our farmers are able to scout over 500 acres in less than two hours with much greater accuracy than can be achieved by the human eye. Drones are also used to measure harvested versus unharvested portions of the field, damage from flooding, and areas where drainage needs to be improved.

Drones (Sugarbeet Storage Piles): Drones are also incredibly useful to our industry after harvest. The majority of sugarbeets are stored in massive commercial piles, upwards of 25-feet high by 150-feet wide and a quarter-mile long, until they can be processed. The cool or sometimes freezing ambient air helps to condition the beets for long-term storage. The exact piling methods vary across regions, but the risk of pile loss is common across the country. Piles can suffer from "hot spots." This occurs because of uneven piling temperatures, diseased beets, or damaged beets within a pile. The rotting beets spread to other sections of the pile. Our cooperatives use drones with infrared cameras to identify hot spots that need to be processed immediately or discarded to avoid further loss. In addition, our industry uses fans to pump cold air into the piles to cool or freeze the beets. Drones can be used to accurately indicate when fans should be used, or when specific segments of piles should be excised for immediate processing when external ventilation is not available.

Soil Mapping and Variable Fertilizer Application: Sugarbeet growers can also fully utilize ag-tech to prepare for the next harvest about 10 months prior to planting. Growers can conduct extensive soil tests of fields. They then use an app that lays out GPS points in 2.5-acre grids on a particular field. Soil samples are taken at these points and then tested by a lab. The data from the tests can then be used in a software program to create prescription variable rate maps for applying fall fertilizer for the upcoming sugarbeet crop. This predictive technology not only helps to reduce input costs, but also increases yields to get more efficiency from production acres. Rates are varied based on the soil samples and are adjusted every pass. The tractor uses Real Time Kinetic (RTK) GPS signal to auto-steer and apply the fertilizer with sub-inch accuracy into strips that were previously made by a strip tillage machine. The following spring, growers are able to plant directly and accurately into the strips with the guidance of the RTK signal.

GPS Technology: The use of RTK GPS technology ensures that the tractor implements are always positioned in the center of the strips to achieve maximum efficiency of the fertilizer in the root zone. Following planting of sugarbeet seeds, growers make anywhere from 2-4 herbicide/fungicide applications throughout the season with a sprayer, depending on the need. Sprayers are pulled with a tractor equipped with auto-steer that follows designated GPS paths. Applications also utilize swath control to prevent overlapping treatments to fields through the monitor in tractor cab.

Spray Nozzle Technology: Sectional control of spraying was an important technological step, but nozzle-by-nozzle shutoffs has advanced us further. This technology has reduced excess chemical application and overlap, while also reducing harmful secondary damage known as "crop burn" which causes great stress to the plants. With these advanced nozzles, additional savings are achieved through "turn compensation." This accounts for spray overlap inside the boom's radius. The boom's outside radius speed increase is now calibrated for precise application. A direct injection monitor by KB Manufacturing, LLC monitors chemical usage and remaining product on enclosed spray systems.

Nanotechnology: A company called Vive Crop Protection ® uses nanotechnology to increase the efficiency of existing crop protection chemistries. Nanotechnology is the science of small things. Understanding how crop protection products behave at the "nano-scale" helps Vive optimize their performance when applied to a crop, or on the soil, or mixed with another product in the spray tank. Vive's first products are designed to be co-applied with a fertilizer in a single pass, which helps sugarbeet farmers increase yields and sugar content, while reducing water usage, fuel usage and soil compaction. This helps sugarbeet farmers do more with less.

Harvest: Ropa ®, which manufactures sugarbeet harvesters and loaders, has a new generation of on-board computers that is the basis for telematics, predictive analytics, online diagnostics, and partially autonomous sugar beet harvesting. Telematics allows Ropa technicians to monitor the machines by using GPS and onboard diagnostics to record movements on a computerized map. Amity Technology ®, manufactures sugarbeet carts with tracks instead of tires that can run in wet conditions and unload 35 tons of sugarbeets in 90 seconds. It manufactures sugarbeet defoliators with Active Height Control that auto adjust the height and location of the defoliator to lessen damage to the sugarbeet crop. Amity Technology also manufactures a variety of sugarbeet harvesters that are engineered to limit the amount of soil that is taken from the field and contain Active Depth Control to balance the constantly changing weight of the harvester to maintain the proper depth of the lifting mechanism in the field.

Conclusion: Since I began farming with my father 50 years ago, I have seen quantum leaps in technology. Our industry has made incredible advancements due to developments through technology. Ag-tech increases our efficiencies, improves yields and helps us become more sustainable. All facets of our production have benefited from improvements in ag-tech. These improvements help us avoid wasting resources which benefits the environment and allows us to be economically sustainable. We are constantly looking for new technologies and methods to improve our sustainability. The future for our industry and our ability to continually improve looks bright.

Thank you again for the opportunity to submit this statement for the record.

Sincerely,

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