2018 Michigan State University Combined Research and Extension Annual Report of Accomplishments and Results

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I. Report Overview

1. Executive Summary

Michigan State University (MSU) AgBioResearch (ABR) scientists and MSU Extension (MSUE) educators and specialists provide science-based knowledge to improve food and quality of life, as well as to generate economic viability and enhance sustainability. They are also committed to finding solutions to meet growing food demands with fewer resources.

The need for targeted research and outreach in the areas of agriculture and natural resources is immense. With emerging threats such as depressed commodity prices, global trade challenges, antibiotic resistance, bovine leukemia, spotted wing drosophila and other invasive pests, agriculture producers face a plethora of on-farm issues, many of which have human health implications. At a time when the growing world population is projected to exceed 9 billion by 2050, our global food supply needs to adapt to meet these demands with limited resources and variable weather patterns.

ABR conducts leading-edge research that combines scientific expertise with an understanding of real-world problems in the key areas of food, health of humans, animals and plants, and the environment. The research strives to find viable, workable solutions in many diverse areas from entomology and fisheries to microbiology and nutrition. ABR has university-wide reach with its multidisciplinary projects led by more than 340 scientists from the following MSU colleges:

- Agriculture and Natural Resources
- Natural Science
- Veterinary Medicine
- Engineering
- Social Sciences
- Arts and Letters
- Communication Arts and Sciences
- Osteopathic Medicine

An integral part of the pioneer land-grant university, ABR maintains a balance between fundamental and applied research and relies heavily on constituent and stakeholder input from the agricultural and natural resources industries to identify priorities. An emphasis is placed on integrated and multidisciplinary endeavors with programs continually evaluated for relevance and progress to meet the changing needs of both the agriculture and natural resources industries. The accomplishments and discoveries outlined in this report are reflective of some of the reasons why ABR (founded as the Michigan Agricultural Experiment Station) continues as one of the most successful entities of its kind 125-plus years after its formation.

A vital component of the land grant mission, Michigan State University Extension (MSUE) disseminates the research, experience and expertise of MSU to people throughout Michigan to improve their lives through an educational process that applies knowledge to critical issues, needs and opportunities. One of the hallmarks of MSUE is its willingness and ability to adapt programming to meet the needs of Michigan residents, communities and businesses.

The food and agriculture industry in Michigan is estimated to contribute more than $100 billion to the state's economy (direct, indirect and induced) and accounts for more than an estimated 923,000 jobs. Food and agriculture represent about 22 percent of the workforce in Michigan. With more than 300

commodities, 55,000 farms and 10 million acres of farmland, Michigan also has one of the most diverse agricultural industries in the nation. The state ranks second in the U.S. in terms of its crop diversity from fruit, vegetables and soybeans to ornamental trees, livestock and fish.
Michigan farmers, ABR scientists and MSUE educators continue to be asked to accomplish more with less. Conversely, challenges with insects, plant and animal diseases, processing logistics, shifting climates and the need for consumer education have become increasingly complex and more demanding. Leveraged and external funding is more important and more competitive to secure than ever before. ABR scientists and MSUE educators and specialists continue to demonstrate flexibility, innovation and a perseverance that equips them to respond to these challenges.
The federal government's $18 million investment from the National Institute of Food and Agriculture capacity funds and associated dollars to MSU AgBioResearch and MSU Extension generated nearly $1.1 billion for Michigan residents in FY 2017-2018, according to an analysis by the MSU Center for Economic Analysis.
For every $1 the federal government invested in ABR and MSUE, the organizations also:

- LEVERAGED $10.82 of state funds, external contracts, grants and other revenues that serve Michigan residents.
- RETURNED $21 of community benefits through education programs and research.
- REPRESENTED a 58:1 BENEFIT/COST RATIO when state funds, community benefits and economic stimulus are combined, the estimated benefits to Michigan residents and the nation exceed the initial federal investment.

Key areas of interest for Extension in 2018:
Evaluation results from 2006 and 2016 Issue Identification processes that involved over 10,000 Michigan residents found current and past customers of Extension rated satisfaction high (86% in 2006 and 90% in 2016). Regression analyses found community priorities related to satisfaction, especially community development, agriculture, food safety and supply, and youth development (see https://reporting.anr.msu.edu/miprs2018/needsummary.pdf)
MSU Extension has four Institutes with work teams that build plans (see https://reporting.anr.msu.edu/miprs2018/stateplan.pdf) for team members to link to as well as identify local initiatives. In 2018, MSUE served 160,767 adults, 203,293 youth, and 17,260 volunteers.
Agriculture and Agribusiness Institute educated 54,711 adults

- 9,582 adults educated in Animal
- 1,643 adults educated in Business Management
- 5,171 adults educated in Consumer Horticulture
- 9,519 adults educated in Field Crops
- 8,109 adults educated in Fruit
- 3,494 adults educated in Ornamental Horticulture
- 5,874 adults educated in Vegetable
- 11,319 adults educated in Public Event, Breakfast on the Farm, Ag Literacy, Consumer Ed, etc.

Children and Youth Institute educated 203,293 (unduplicated) youth and 22,986 adults with 12,581 adult volunteers

- 76,541 youth trained in Animals
- 65,273 youth trained in Food and Nutrition
- 54,991 youth trained in Environmental Education/Earth Sciences
- 45,007 youth trained in Leadership and Personal Development
- 22,850 youth trained in Communication and Expressive Arts
- 26,923 youth trained in Ag in the Classroom
- 22,493 youth trained in Plant Science
- 10,304 youth trained in Community Service and Civic Engagement

- 7,077 adults trained in Child and Family Development
- 6,995 adults trained in Leadership and Civic Engagement
- 3,993 adults trained in Capacity Building
- 3,749 adults trained in Science
- 1,172 adults trained in Career Education and Workforce Preparation

Community, Food, and Environment Institute educated 41,248 adults

- 9,246 adults trained in Community Foods Systems
- 13,387 adults trained in Natural Resources Stewardship
- 6,343 adults trained in Government and Public Policy
- 1,063 adults trained in Entrepreneurship
- 6,296 adults educated in Michigan Sea Grant
- 4,292 adults educated in Finance/Homeownership
- 621 adults trained in Tourism

Health and Nutrition Institute educated 41,822 adults

- 3,737 adults trained in Disease Prevention and Management
- 5,871 adults trained in Food Safety
- 27,225 adults trained in Nutrition and Physical Activity
- 4,648 adults trained in Social and Emotional Well-Being
- 341 adults trained in Extension Health Research

Reaching underserved audiences through online education

MSU Extension offers educational content in a number of different formats, including online via webinars and online courses, which allows educators and specialists to reach underserved audiences who may not be able to attend in-person meetings.

The Beginning Farmer Webinar Series assists people interested in engaging in new or expanding agricultural enterprises. In 2018, beginning farmers were offered 15 topic-specific webinars on basic agricultural production practices, business management and marketing. This type of programming helps support the success of these small businesses that have an impact on the economic and social stability, and food security of their communities. The series resulted in 3,820 webinar views.

In 2018, MSU Extension launched a complete online course including eleven modules on Integrative Pest Management. The Desire to Learn Integrated Pest Management (IPM) Academy is an interactive, online program designed to provide a comprehensive and convenient online learning experience. This self-paced course features university experts and a full-service help center with 24/7 technical support and support materials to learn how to easily navigate the course. The course was designed for farmers and was attended by residents of Michigan as well as other states and nations. The current module topics: Introduction to IPM, IPM resources at MSU, Plant Science, Soils 101, Identifying and Conserving Natural Enemies, Conserving Pollinators, Using Enviro-weather to Assist IPM Program Decisions, Scouting in Field Crops, Scouting in Greenhouses, Scouting in Perennial Crops, and Scouting in Vegetable Crops.

Responding to stress in farm communities and throughout Michigan

To help respond to the needs of Michigan farmers and their families, MSU Extension developed the Communicating With Farmers Under Stress workshop. In spring 2016, the director of the Michigan Department of Agriculture contacted Michigan State University Extension because of an increase in Michigan dairy farmers dying by suicide. To help respond to the needs of Michigan farmers and their families, MSU Extension developed the "Communicating With Farmers Under Stress" and "Weathering the Storm: How to Cultivate a Productive Mindset" workshops designed for farmers, people who work with agricultural producers, and farm families to help them learn more about managing stress and communicating with those in need.

Key areas for AgBioResearch:

Solving critical plant agriculture problems for 20 years

For 20 years, Project GREEEN (Generating Research and Extension to meet Economic and Environmental Needs) has been a catalyst for linking researchers and Extension specialists with commodity organizations, growers and the state of Michigan to solve critical plant agriculture problems. Funding provides a launching point for innovation, from combatting disease pressures and invasive insects to promoting sustainability and environmental stewardship. Many research and Extension projects demonstrate tremendous value, leading to the leveraging of significant grants from entities such as the USDA, the National Science Foundation and the National Institutes of Health. Project GREEEN features a competitive grants process in which research and outreach specialists submit proposals to a leadership team from MSU AgBioResearch, MSU Extension and the Michigan Department of Agriculture and Rural Development. Once awarded funding, regular progress updates are required.

- Project GREEEN initiatives have bolstered Michigan's economy, with an estimated total output impact of more than $2.5 billion over the past two decades.
- More than $100 million has been allocated to Project GREEEN through mostly steady annual distributions. When adjusting for inflation, however, the program's purchasing power has more than halved.
- Outcomes from Project GREEEN research projects have assisted growers in managing issues such as spotted wing drosophila, an invasive insect of soft-fleshed fruits; emerald ash borer; downy mildew; Japanese beetle and more.

Expanding the use and impact of drone technologies

Unmanned aerial vehicles, commonly known as drones, can help increase farm efficiency and reduce labor costs on Michigan farms. Michigan State University provides a variety of educational resources to help farmers determine how and if drone technology can benefit their operations.

In the next two years, MSU will host six free two-day workshops to help growers develop an understanding of drone-based data collection specifically related to various commodities. MSU Extension, in partnership with Purdue University Extension and Ohio State University Extension, will host drone workshops covering information on drone options, software and data storage, FAA regulations, data ownership and crop scouting using precision agriculture.

During an April 2018 visit to MSU, U.S. Secretary of Agriculture Sonny Perdue was treated to a drone demonstration by MSU Foundation Professor and ABR scientist Bruno Basso, an expert in precision agriculture. Basso uses the unmanned aerial vehicles to monitor large fields and collect data on farms across the Midwest.

- At the 2018 MSU Agriculture Innovation Day, experts in remote sensing and geographic information systems educated farmers on the benefits of drones.
- MSU senior geospatial analyst Robert Goodwin demonstrated drone technology applications and explained how to determine if drone technology is right for an operation.

Supporting pollination in agriculture

Approximately one-third of agriculture in the United States depends on pollination by bees, butterflies and other insects, totaling approximately $40 billion per year. Some crops, including apples, cherries and blueberries, are approximately 90 percent dependent on pollination by bees. Use of both managed honey bee hives and natural pollinators present in the landscape are used to achieve this. New challenges, such as habitat loss and fragmentation, pesticide use and disease pressure, have caused declines in both managed and natural pollinator populations nationwide.

With support from the USDA National Institute of Food and Agriculture's Specialty Crops Research Initiative, MSU leads the Integrate Crop Pollination project, a nationwide, multi-institutional research project to investigate the performance, economics and farmer perceptions of different pollination strategies across a range of fruit and vegetable crops.

The ICP team has developed the Pollination Mapper, a free, interactive online tool that helps growers make pollination decisions by providing insight and guidance based on satellite data, habitat information, the availability of wild and managed pollinators and other data.

- The ICP team conducted a wide-ranging outreach effort, including holding talks with growers and producing informational resources freely available on the project website -- icpbees.org.
- ICP researchers determined that establishing wildflower plantings near agricultural fields provides pollinators with habitat and sustenance. Reducing mowing and tilling around the borders of fields also protects underground bee nests and allows native plants to develop.

Mitigating effects of invasive insect attacking hemlock trees

A tiny insect -- no larger than 1.5 millimeters in length - called hemlock woolly adelgid threatens more than 170 million trees in Michigan, and the cascading ecosystem effects could be catastrophic. Michigan has already experienced this with previous invasive pests, but this latest one threatens not only trees, but also the health of aquatic species and wildlife as well.

HWA preys on hemlock trees, which are vitally important to the ecological health of aquatic species and wildlife throughout Michigan. Hemlocks provide dense shade that helps to protect animals during periods of extreme weather. They typically grow along the banks of lakes and rivers, where they also help provide nutrients to soils and waterways.

- The adelgid may have been in Michigan for about 15 years, but if so, the populations stayed low and went unnoticed. Small, localized infestations near the Lake Michigan shoreline were discovered in 2015, and additional adelgid hot spots have since been found in four western Michigan counties.
- MSU researchers are working to develop a statewide hazard map that will identify where hemlock is abundant and the pest is most likely to thrive. Those areas can then be prioritized for HWA surveys and mitigation efforts to reduce impacts of the pest.

Developing strategies to prevent chronic wasting disease

A disease of the nervous system exclusive to members of the cervid family -- deer, elk, moose, caribou and other hoofed, antlered, ruminant mammals -- chronic wasting disease is a fatal disease with no known cure or vaccine. CWD spreads through direct fluid contact and the infectious protein agent is shed into the environment, where it can persist for over a decade.

Since CWD was first discovered in Michigan in 2015, MSU AgBioResearch scientists, including researcher William Porter, have begun work on a plan to identify areas of the state at high risk for CWD based on deer behavior and population dynamics. The team previously produced a similar plan in New York after CWD was first discovered there in 2005. No new cases in New York have been documented since.

The plan depends on a model that combines deer population density, proximity to bordering states with CWD problems and disease transmission to predict where the disease will likely emerge and spread.

- Since 2015, more than 60 cases of CWD have been identified in free-ranging, wild deer in Michigan. Nearly 31,000 have been tested.
- Michigan has close to 800,000 licensed hunters, 90% of whom hunt white-tailed deer.
- Deer hunting contributes over $2 billion annually to the Michigan economy.

Improving Michigan's ability to site livestock facilities

Odors from livestock production are the result of a complex set of circumstances, including location and size of the facility, species of animals, feed storage, food intake, type and size of manure storage, and odor control technologies.

The movement and dispersion of odors are heavily dependent on meteorological factors, such as wind speed and direction, as well as atmospheric stability. As livestock operations expand in Michigan due to favorable climate, population density and water resources, siting of facilities becomes critical.

No livestock odor mitigation strategy exists that can replace proper siting. Having the tools to make

proactive siting decisions is essential for both new and expanding facilities.
The Generally Accepted Agricultural and Management Practices for Site Selection and Odor Control for New and Expanding Livestock Facilities (Siting GAAMP) has been used in Michigan since 2000. A key portion of the GAAMP since 2005 was the Michigan Odor From Feedlots-Setback Estimation Tool (MI OFFSET), which provided an estimated odor footprint around an odor source location of interest. However, the original version had limitations, including a single average odor footprint for the entire state based on a small number of climatic observing sites and only 9 years of data.
ABR geography scientist Jeff Andresen and his team updated and modernized the original OFFSET scheme with a comprehensive new climatic dataset, providing detailed information that more accurately accounts for the influence of the surrounding Great Lakes on local wind and stability climatologies.
Results of the new dataset were incorporated into a new web-based decision support tool, MI OFFSET 2018, which allows users to enter their specific location and odor emission information to obtain a location-specific odor footprint. Having this information to proactively identify areas that are best suited for livestock production is essential for both new and expanding facilities, and should support the growth of the Michigan livestock industry and its contribution to the state's economy.

Estimating effects of genes: One size may not fit all
For decades, animal breeders have benefited from databases of livestock performance information on economically important traits such as milk yield or reproductive performance, along with pedigree, to accurately predict genetic merit of animals.
Genotype information using single nucleotide polymorphism (SNP) markers available within the past decade, particularly in dairy cattle, has further increased accuracy and the ability to select younger animals for breeding stock, thereby doubling genetic gain in milk yields per year.
One of the surveyors of heredity is ABR scientist Rob Tempelman, professor of quantitative genetics and animal breeding in the Michigan State University (MSU) Department of Animal Science and recipient of the 2017 Jay L. Lush Award in Animal Breeding from the American Dairy Science Association. His work enhances research reproducibility while recognizing that genetic effects and their as-sociations with economically important traits can vary widely across different environments.
For the past couple of decades, Tempelman has developed statistical models and computationally feasible algorithms to help assess the nature of this heterogeneity and the im-pacts on prediction on genetic merit of ignoring it. His current research on the use of SNP markers to predict genetic merit for complex traits, is factoring in influences such as management systems.
Feed efficiency of dairy cows is an example of an area that has benefited. Agricultural producers want to maxi-mize milk output while minimizing feed cost without jeopardizing the health of the cow. Feeds with different chemical compositions -- including, for example, energy and protein content -- are used across farms or even between seasons on the same farm, so there can be substantial heterogeneous genetic and non-genetic relationships between the various com-ponent traits of feed efficiency.
Tempelman works with a multi-institutional research team (including principal investigator Mike Vandehaar, also from MSU) funded by the USDA, that allowed him to address such issues with data from various collaborators worldwide. Some of this work also was conducted in conjunction with another USDA grant involving Juan Steibel at MSU and Tempelman's former graduate student, Nora Bello, at Kansas State. This project focused on develop-ing statistical and computational tools to model heterogeneous genetic effects across environments.
Scientists understand that factors such as milk production, body weight and dry matter intake are elements of feed efficiency. The cow itself is a key vari-able. Genetic data on the domestic cow ballooned with the sequenced genome of Bos taurus reported in 2009.
As exciting as this breakthrough was, the data are only part of the means to under-stand traits such as milk production and feed conversion. With almost 3 billion base pairs in the genome assembly, the number of markers that can help locate genes associated with a trait could be overwhelming.
The number of genetic markers in a cow's genotype is typically in the tens of thousands, yet the number of pheno-types from individual cows is compara-tively small for estimating the effects of individual SNP markers on key traits, such as milk production, in a genome-wide association (GWA) analysis. A GWA

analysis is typically a first step in identifying genes that are potentially important for the trait of interest, such as milk production or feed efficiency.
Some of the better performing statistical GWA models are based on sophisticated "hierarchical Bayesian" analyses, but require specification of the proportion of SNP markers that are believed to be as-sociated with a particular trait. In these models, such a proportion is typically referred to as a "hyperparameter." Many scientists have arbitrarily guessed these and other hyperparam-eters rather than attempting to estimate them. Tempelman has dem-onstrated that estimating these hyper-parameters is important to improving the sensitivity of GWA analyses and accuracy of predictions of genetic merit.

Continuing to bear fruit: MSU AgBioResearch scientist's blueberry varieties
The blueberry varieties developed by Michigan State University AgBioResearch fruit breeder James Hancock continue to have a significant impact on the blueberry industry in both Michigan and around the world.
Hancock developed six northern highbush blueberry cultivars - dubbed Aurora, Draper, Liberty, Huron, Calypso and Osorno - which today are grown by farmers throughout North America, South America, Korea and Europe. Aurora, Draper and Liberty, commercially released together in 2004, remain the most widely planted northern highbush blueberry varieties on Earth.
Aurora and Liberty are late-season varieties that have helped position Michigan growers favorably in the marketplace by lengthening the harvest season and outlasting blueberries from elsewhere in the country, while Draper, capable of being mechanically harvested, has helped farmers increase efficiency and reduce labor costs.
Some of the licenses for the use of Hancock's varieties were granted to other private breeding programs, which have now released their own varieties with the MSU cultivars as parents and contributing to the next generation of blueberry research.

- Blueberries contribute over $130 million to the Michigan economy.
- The MSU blueberry varieties have generated over $10 million in royalties for the university, money that has been reinvested to support further blueberry research.
- Michigan is one of the top blueberry-growing states in the nation, producing over 110 million pounds annually.

Total Actual Amount of professional FTEs/SYs for this State

Year: 2018	Extension		Research	
	1862	1890	1862	1890
Plan	190.0	0.0	65.0	0.0
Actual	203.0	0.0	115.0	0.0

II. Merit Review Process

1. The Merit Review Process that was Employed for this year

- Internal University Panel
- External University Panel
- External Non-University Panel
- Expert Peer Review

2. Brief Explanation

ABR and MSUE goals must remain fluid and flexible to meet the constant changes in the agriculture and natural resource industries. Research goals are continually evaluated for relevance and impact at local, state and regional levels. Strategic priorities address the research needs of the Michigan agriculture and natural resources industries, but are also linked to national and global goals and initiatives.

Through strategic planning with ABR-affiliated colleges, MSUE staff and key stakeholder groups, priority areas are reviewed annually. This process involves industry experts, university faculty, MSUE and ABR advisory council members and research center advisory committee members, as well as scientific review by peers (local, national and international). MSUE uses several continuous processes that assist in setting priorities and evaluating program goals and plans. At the local level, the interested public, government officials, advisory group members and industry experts are involved in broader stakeholder processes, as well as the review of individual educator plans. These goals and plans are also reviewed by state leaders and industry experts for quality and relevance and by the ABR and MSUE directors, who not only evaluate them, but use them in regional and statewide presentations to explain future plans.

Jointly, ABR and MSUE address issues of concern in communities with research and teaching by using a network of citizen advisory groups at the local and state levels. Fourteen district MSUE councils identify and prioritize issues, seek collaborations and resources and communicate to others the importance of MSUE educational programming. Citizen Advisory Councils help establish research priorities at the 13 outlying ABR centers and 18 on-campus facilities. The MSUE-ABR Council serves as liaison among district councils, research center advisory groups and state agencies and organizations.
All researchers and other personnel funded by MSU AgBioResearch are subjected to thorough annual reviews as mandated by Michigan State University. These processes are regularly reviewed to maximize effectiveness and to enhance the opportunity for employee development. For our research faculty all raises are based on merit and include reviews at both the department and college levels. In recent years these reviews have been standardized to ensure consistency and transparency both within and among our cooperating academic units. In the past two years we have added emphasis on diversity, equity and inclusion.
All AgBioResearch research project plans are peer reviewed at the department and experiment station level on a five-year renewal cycle. The alignment with the USDA Knowledge Areas has been stressed in recent years. We have also updated our guidelines for plan preparation to increase the quality and relevance of the research.
To improve the quality of the proposals submitted to competitive programs we have continued to increase our investment in our Office of Research Support. Our staff now includes 4 FTE focusing on pre-award support, 2 FTE on post-award support, and 1 FTE in program evaluation and metrics.

III. Stakeholder Input

1. Actions taken to seek stakeholder input that encouraged their participation

- Use of media to announce public meetings and listening sessions
- Targeted invitation to traditional stakeholder groups
- Targeted invitation to non-traditional stakeholder groups
- Targeted invitation to traditional stakeholder individuals
- Targeted invitation to non-traditional stakeholder individuals
- Targeted invitation to selected individuals from general public
- Survey of traditional stakeholder groups
- Survey of traditional stakeholder individuals

- Survey of the general public
- Survey of selected individuals from the general public
- Other (Conferences and meetings, social media)

Brief explanation.

On a statewide level, in 2016 MSU Extension executed an Issues Identification process, whereby an online survey and a series of statewide focus groups elicited feedback from external stakeholders. The online survey resulted in 7,180 responses from our community. Results include a ranking of statewide priorities, as well as specific programmatic feedback. There were also 52 focus groups held across Michigan, including approximately 1,200 participants, resulting in the identification of priorities by stakeholders for each MSU Extension district. The data collected from this process continues to enable MSU Extension and AgBioResearch to identify community needs, priorities for the future, and relevancy of existing programs to direct efforts for the next several years.
To address more local or district needs, MSU Extension continues to be supported by 16 district/county councils, in addition to a state level MSU Extension/AgBioResearch council. Councils provide the opportunity for a diverse group of local citizens to learn from each other about the broad impact of Extension's educational programming, help identify new partnerships and resources, assist with marketing and promotion of Extension and its programming, and advocate on Extension's behalf with key community leaders. In return council members gain valuable experiences and leadership development opportunities. Local 4-H programs also continue to utilize county expansion and review stakeholder advisory committees to guide the direction of the local 4-H program.
MSU AgBioResearch continuously gathers stakeholder input through regular interactions with commodity groups, agricultural and natural resource organizations, partner agencies and research center advisory groups. These interactions have significant impacts on our programming decisions. Of special note are Project GREEEN and the Michigan Alliance for Animal Agriculture where stakeholders submit specific prioities and participate in the project review process.

2(A). A brief statement of the process that was used by the recipient institution to identify individuals and groups stakeholders and to collect input from them

1. Method to identify individuals and groups

- Use Advisory Committees
- Use Internal Focus Groups
- Use External Focus Groups
- Open Listening Sessions
- Needs Assessments
- Use Surveys

Brief explanation.

MSU Extension and AgBioResearch's Issues Identification process utilizes statewide surveys and citizen focus groups to identify the major issues and opportunities in Michigan and assign a priority ranking to each. Also through this process, additional focus groups were held targeting underrepresented audiences in MSU Extension programming, yielding input on how future program efforts can better meet the needs of these groups.
District Extension Councils continue to provide MSU Extension a network for citizen involvement in shaping our programming and in communicating to others (including policymakers) the importance of our work in local communities. Through these councils, MSU Extension elicits feedback from and works in collaboration with a diverse group of stakeholders.

To conduct leading-edge research that results in practical solutions, ABR and MSUE rely on input from an extremely broad and long list of stakeholders and partners. Such feedback is generated by representatives in the following industries:

- Agricultural
- Food and food processing
- Natural resources
- Bioeconomy industries
- State residents
- Non-profit organizations
- Businesses
- Governmental organizations
- Universities

An emphasis is placed on keeping key internal and external stakeholders (e.g., agricultural producers, commodity groups, food processors and the tourism, fisheries and forestry industries), legislative contacts and the interested public abreast of issues, and using a blend of traditional and online platforms to reach individuals and groups and collect input from them. The Advance Michigan statewide online issues identification process that was completed in the fall 2011, the previous Strengthening Michigan's Economy comprehensive survey before it, and other ongoing outreach efforts offer multiple ways for people in various roles and locations to help identify the issues and opportunities for ABR priorities and MSUE educational programming in the years ahead.
Community-based discussions in all Michigan counties, involving local advisory committees, the MSUE-ABR councils and others are held to discern what issues and opportunities stakeholders believe should be addressed related to research and programming. Citizen focus groups are also used to identify issues and opportunities in Michigan and assign a priority ranking to each.
Community groups, commodity and producer groups and other state and local partners are periodically asked what issues and opportunities should be explored and addressed.
Faculty member focus groups, with representatives from Michigan colleges and units, are held as needed to glean perceptions on emerging Michigan issues and opportunities and to identify ways that MSU science projects and/or initiatives might address them. MSU faculty members and ABR/MSUE staff surveys are used as needed to develop a better understanding of the university's ability to respond to issues identified in faculty focus groups. County teams, including ABR center managers, synthesize and prioritize content specific program and research needs identified by the various councils and advisory committees. Working groups within each institute synthesize and prioritize content-specific program and research needs generated from the input of their advisory bodies and develop programs to meet these needs, as well as methods for evaluating their impacts. Needs are fine-tuned as additional input is received.

2(B). A brief statement of the process that was used by the recipient institution to identify individuals and groups who are stakeholders and to collect input from them

1. Methods for collecting Stakeholder Input

- Meeting with traditional Stakeholder groups
- Survey of traditional Stakeholder groups
- Meeting with traditional Stakeholder individuals
- Survey of traditional Stakeholder individuals
- Meeting with the general public (open meeting advertised to all)
- Survey of the general public
- Meeting with invited selected individuals from the general public

- Survey of selected individuals from the general public

Brief explanation.

Through the Issues Identification process, MSU Extension elicited feedback from stakeholders via online surveys and community focus groups, yielding both quantitative and qualitative data on programming priorities. To address local county or district needs, local staff regularly elicit feedback from stakeholders via open meetings, advisory committee conversations, and District Extension Council meetings.
Stakeholder input provides the foundation for the research and educational programs developed by ABR and MSUE. Stakeholders help decide the future direction for ABR through programs such as Project GREEEN, the Michigan Alliance for Animal Agriculture (M-AAA) and commodity advisory teams. There are extensive conversations and visits that also take place throughout the year with local, state and federal officials and commodity group and industry representatives from the agricultural, natural resources and renewable energy industries.
For ABR, multiple meetings were held with commodity groups, legislators and key stakeholders representing the key agricultural sectors as work continued with the consolidation of management and operations for various research centers and units. In addition to these traditional, long-standing venues, an ad hoc committee comprised of faculty members and commodity group stakeholders was established to conduct a comprehensive review of ABR centers and to provide recommendations on how to best move forward in implementing needed changes.

3. A statement of how the input will be considered

- In the Budget Process
- To Identify Emerging Issues
- Redirect Extension Programs
- Redirect Research Programs
- In the Staff Hiring Process
- In the Action Plans
- To Set Priorities

Brief explanation.

MSU Extension utilizes stakeholder input in the development of work team logic models that become the framework for individual educators and specialists to align with as well as help to identify local needs that may be specific to a certain county or district. Issues Identification survey and focus group results have been used to develop logic models for specific program priorities. At the local county level, staff utilize stakeholder input and feedback to determine the direction of local programming.
From an operational perspective, ABR has used stakeholder input to guide its decision-making process around the consolidation and restructuring of its 14 ABR centers and 18 on-campus centers. MSUE utilized the stakeholder input in forming the four institutes and the 16 work groups that guide them. The input has been useful in setting priorities and focusing on more with fewer resources.

Brief Explanation of what you learned from your Stakeholders

The following are a few of the takeaways ABR and MSUE has learned from its stakeholders:

• Food safety and security and a safe and secure water supply are critical priority areas for research activities.

• Newer technology is necessary to continue to build and maintain strong partnerships both internally and externally.
• Research and information dissemination efforts are critical to the success of the $100 billion food and agriculture industry in Michigan.
• Solutions and innovations will be even more critical in the future for residents in Michigan, the nation and the world.
• Genetic research needs to be a critical area of focus.

IV. Expenditure Summary

1. Total Actual Formula dollars Allocated (prepopulated from C-REEMS)			
Extension		Research	
Smith-Lever 3b & 3c	1890 Extension	Hatch	Evans-Allen
{No Data Entered}	{No Data Entered}	{No Data Entered}	{No Data Entered}

2. Totaled Actual dollars from Planned Programs Inputs				
	Extension		Research	
	Smith-Lever 3b & 3c	1890 Extension	Hatch	Evans-Allen
Actual Formula	9981864	0	6401963	0
Actual Matching	9981864	0	6533458	0
Actual All Other	0	0	37319374	0
Total Actual Expended	19963728	0	50254795	0

3. Amount of Above Actual Formula Dollars Expended which comes from Carryover funds from previous				
Carryover	2104840	0	0	0

V. Planned Program Table of Content

V(A). Planned Program (Summary)

Program # 1

1. Name of the Planned Program

Human Health, Environment, Family, Youth, Society and Community

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
608	Community Resource Planning and Development	5%		5%	
702	Requirements and Function of Nutrients and Other Food Components	0%		7%	
703	Nutrition Education and Behavior	20%		0%	
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources	0%		12%	
712	Protect Food from Contamination by Pathogenic Microorganisms, Parasites, and Naturally Occurring Toxins	0%		14%	
721	Insects and Other Pests Affecting Humans	0%		10%	
723	Hazards to Human Health and Safety	0%		9%	
724	Healthy Lifestyle	25%		10%	
801	Individual and Family Resource Management	10%		0%	
802	Human Development and Family Well-Being	10%		8%	
803	Sociological and Technological Change Affecting Individuals, Families, and Communities	0%		7%	
805	Community Institutions, Health, and Social Services	0%		10%	
806	Youth Development	30%		8%	
	Total	100%		100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2018	Extension		Research	
	1862	1890	1862	1890
Plan	100.7	0.0	11.5	0.0

Actual Paid	105.4	0.0	15.0	0.0
Actual Volunteer	58.0	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
4872202	0	840855	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
4872202	0	858126	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	4901649	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research programs to:

• Develop a better understanding of public benefits for policy development in recreation and tourism resource management.
• Increase understanding about how environmental pollutants, especially ozone and endocrine disruptors affect human health.
• Establish new programs and policies to help young people move successfully from foster care to independent living after they are too old for foster care.
• Analyze the relationships among social support, public policy and family characteristics and how they affect the function and well-being of rural low-income families.
• Increase understanding and develop more effective environmental management systems.
• Develop better models for the human health and human services sectors.
• Identify the nutritional determinants of allergic immune disorders.
• Develop an understanding of how n-3 polyunsaturated fatty acids affect human health and disease, especially cardiovascular disease and inflammation. ....

Educational programs to:

• Teach how to choose healthful food, physically active lifestyles and behaviors consistent with dietary guidelines.
• Teach consumers to keep their food safe by offering programs on food safety, home food preservation and healthy, hygienic food-handling practices.
• Teach people living with chronic medical conditions to manage their condition effectively.
• Teach financial literacy and prepare individuals to manage their finances in anticipation of retirement.
• Teach caregivers and parents how to prepare children for school.
• Increase access to affordable, high-quality childcare.
• Prepare communities for the health care, housing and transportation needs of seniors.
• Educate citizens and public officials about funding methods, service provision and intergovernmental cooperation.
• Provide counties and municipalities with technical assistance related to intergovernmental contracting,

consolidating services and financial and strategic planning.
- Assist government officials in leadership, conflict management, communication and engaging the public in policy development.
- Prepare youth with knowledge and skills needed for life and employment.
- Enhance the physical, social, emotional and cognitive health and well-being of youth.

2. Brief description of the target audience

Michigan private citizens, state agencies, farmers, food processors, commodity groups and agricultural industry representatives are targets of research programs. Individuals of all ages and life stages are targeted for healthy lifestyle and food-safety education programs. Human development and family well-being programs target parents and caregivers of preschool children, people living with chronic medical conditions and senior citizens. Community institutions, health and social services programs target citizens and public/government officials. Youth age 9 to 18 are targets of youth development programs.

3. How was eXtension used?

MSU Extension continues to utilize eXtension as one of the primary multi-state activities that involve contributing to Communities of Practice, responding to Ask an Expert questions, and contributing to innovation projects. One example in this area was organizing the "Communicating with Farmers Under Stress" webinar (see here: https://learn.extension.org/events/3337).

V(E). Planned Program (Outputs)

1. Standard output measures

2018	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	62888	188664	10009	20018

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year:	2018
Actual:	1

Patents listed

MICL02257, Hierarchical Genetic and Environmental Regulation of M. tuberculosis Complex Persistence. SN 62/404,492

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2018	Extension	Research	Total
Actual	6	46	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research programs on human health, environment, family, youth, society and community.

Year	Actual
2018	44

Output #2

Output Measure

- Number of adult participants trained in healthy lifestyles.

Year	Actual
2018	30962

Output #3

Output Measure

- Number of youth participants trained in healthy lifestyles.

Year	Actual
2018	72057

Output #4

Output Measure

- Number of youth participants trained in life skills.

Year	Actual
2018	5676

Output #5

Output Measure

- Number of adult participants trained in family resource management.

Year	Actual
2018	1902

Output #6

Output Measure

- Number of youth that gain knowledge in how to respond to one's own social-emotional needs and the social-emotional needs of others

Year	Actual
2018	1840

Output #7

Output Measure

- Number of adult participants trained in youth development.

Year	Actual
2018	20557

Output #8

Output Measure

- Number of adult participants trained in home ownership education and foreclosure counseling.

Year	Actual
2018	2390

Output #9

Output Measure

- Number of youth participants trained in financial literacy and money management.

Year	Actual
2018	2493

Output #10

Output Measure

- Number of adults trained in human development and family well-being.

Year	Actual
2018	7077

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of research programs to determine the relationship between family meals/lifestyle factors, education/food choices, general health and environmental influences, physical activity and general health.
2	Number of research programs to understand how environmental pollutants, especially ozone and endocrine disruptors, affect human health.
3	Number of research programs to develop better models for the human health and human services sector.
4	Number of adult participants with increased knowledge about healthy lifestyles.
5	Number of youth participants with increased knowledge about healthy lifestyles.
6	Number of adult participants with increased knowledge of human development and family well-being.
7	Number of youth participants with increased knowledge of life skills.
8	Number of adult participants with increased knowledge of youth development.
9	Number of research programs to develop more effective environmental/natural resources management systems.
10	Number of adult participants with increased knowledge of family resource management.
11	Number of research programs that study the function of nutrients and other components related to human health.
12	Number of youth that change in their ability to respond to one's own social-emotional needs and the social-emotional needs of others
13	Number of youth participants that increase knowledge in financial literacy and money management.
14	Number of adult participants with increased knowledge in home ownership education and foreclosure counseling.

Outcome #1

1. Outcome Measures

Number of research programs to determine the relationship between family meals/lifestyle factors, education/food choices, general health and environmental influences, physical activity and general health.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	9

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Worldwide, there is a movement towards incentive-based programs to promote environmental conservation,vaccination, school attendance, and other socially desirable behaviors, but most such programs are government- or donor-funded, with budgets subject to political processes and availability of funds. This makes them vulnerable to
elimination, raising the question of what will happen to behaviors afterward. Economic models that drive the design of such programs are ill-equipped to address this question. Some evidence suggests that financial incentives can undermine or "crowd out" other sources of motivation derived from social norms, but the reasons are poorly
understood. Although communication science has the potential to explain the effects of social norms and other psycho-social factors on behaviors, it has not incorporated the effects of monetary payments. Our research integrates economic models and the theories of the influence of social norms to explain and predict the ways in which monetary incentives influence social norms and behaviors. Specifically, we will use interviews and surveys with research
subjects to develop culturally specific quantitative measures of social norms and related variables. We will run a series of field experiments with them to test the causal linkages posited among communication, monetary incentives, social norms and behaviors. Finally, we will translate our theoretical and empirical results to make policy recommendations for the design of incentive-based environmental conservation programs in our study region.

What has been done
Research to: improve human, animal and plant health; understand the relationship between cancer and diet; assess allergenic potential of food; understand inflammation and the development of diabetic retinopathy; explain how diet, obesity and inflammation impact colon cancer risks; understand how diet and environment impact liver disease and heart health;

understand how incentives work to impact social norms and behavior.

Results
We developed, piloted, and implemented a culturally-derived protocol for eliciting information about social norms and the variables in our model. We trained project staff and interviewers in interviewing skills, human subjects and data protection. We completed interviews with 80 nomadic herdsmen from 4 villages on the Tibetan plateau. These interviews were transcribed and translated across 3 languages. A coding scheme was finalized, coders were trained and reliability was established. The coding and qualitative data analysis were conducted. From these data we were able to successfully design and test a
measurement tool to assess the dimensions of social norms for our population. We also piloted a methodology for doing this that can be replicated in future projects. A survey instrument was developed and most of the data were collected. This effort continued and the survey data collection was completed.

4. Associated Knowledge Areas

KA Code	Knowledge Area
703	Nutrition Education and Behavior
724	Healthy Lifestyle
802	Human Development and Family Well-Being
806	Youth Development

Outcome #2

1. Outcome Measures

Number of research programs to understand how environmental pollutants, especially ozone and endocrine disruptors, affect human health.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	3

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Carignan is an assistant professor in the MSU Department of Food Science and Human Nutrition. A significant portion of Carignan?s research focuses on PFAS, or perand polyfluoroalkyl

substances.

PFAS are manufactured chemicals used in products for stain and water resistance, as well as in foams for fighting fuel fires. They?re known as ?forever chemicals? because many do not break down in the environment and are not easily eliminated from the body.

PFAS are found both indoors and outdoors, and have contaminated the drinking water of over 6 million Americans ? including that of several communities in Michigan. PFAS exposure can cause harmful health effects in humans, and Carignan researches what those effects are.

What has been done
Research to: understand environmental chemicals and impact to reproductive and child health, understand the roll of environmental stress and human well-being ; and understand lymphoid cells in air pollutant induces asthma and rhinitis.

Results
We are currently investigating immunotoxic effects of PFAS in children exposed to contaminated drinking water and are helping create an educational resource for exposed communities. Also researchers are providing technical assistance for communities here in Michigan, as well as for the state health department.

4. Associated Knowledge Areas

KA Code	Knowledge Area
723	Hazards to Human Health and Safety
805	Community Institutions, Health, and Social Services

Outcome #3

1. Outcome Measures

Number of research programs to develop better models for the human health and human services sector.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	14

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Michigan's Upper Peninsula's (U.P.) economy is rural, remote and lagging behind the rest of the region. Furthermore, much of
the U.P. is a food desert. One project goal is to establish a teaching and learning center focused on community food systems
with a beginning farmer incubator at the U.P. Research and Extension Center. The Center will focus on providing educational
and extension programming on entrepreneurial four-season nutrient dense food production community food systems.

What has been done

Research to: transition young people who age out of foster care; develop healthcare packaging that is easier to access, particularly for aging consumers and people with disabilities; develop models for preventive and early intervention strategies for children living with a family member with a serious illness;examine the relationship between the number of foster home placements for youth and the number of community connections as emancipated adults;examine the relationships between emotion-related socialization behaviors and infants', toddlers' and preschoolers self-regulation and social-emotional competencies; and to develop models and family-based interventions that advance the well-being of National Guard soldiers and their families post-deployment to a combat zone; work to make breast cancer risk reduction messages more accessible to diverse groups.

Results

UP Food Research:
* Four workshops were held from April through October for skill seeking farmers with a combined attendance of 105
people.
1,366 independent or agency-associated individuals, including the Governor of Michigan, who were interested in learning
more about the project visited the farm throughout the period.
? 250 total students including 60 low income, 20 special needs, and 12 preschool children visited the North Farm to learn
about composting, transplant production, season extension and seed saving. The North Farm was a key partner in Start
Seeds, Save Seeds, a program that provided Superior Central School in Eben Junction and Gravaraet School and North Star
Academy in Marquette with healthy transplants for their hoop house and school garden programs. Students visited the farm to
pick up their transplants, received classroom instruction on caring for transplants, utilizing the produce, and saving seeds,
then practiced seed saving. The program culminates at a Community Seed Swap held in October, which is a partnership
between the Marquette Food Co-op, Transition Marquette, and MQT Growth.

4. Associated Knowledge Areas

KA Code	Knowledge Area
608	Community Resource Planning and Development
802	Human Development and Family Well-Being

803	Sociological and Technological Change Affecting Individuals, Families, and Communities
805	Community Institutions, Health, and Social Services
806	Youth Development

Outcome #4

1. Outcome Measures

Number of adult participants with increased knowledge about healthy lifestyles.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	23222

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Chronic diseases are among the most prevalent, costly and preventable of all health issues. Six in ten Americans live with at least one chronic health condition. Chronic diseases such as diabetes increase the financial burden on the healthcare system. Diabetes is a chronic disease of critical concern. Approximately 13% of Michigan adults have diabetes and an additional 37% have pre-diabetes. Michigan ranks 17 in the nation for prevalence of diabetes and 19th nationally for obesity, according to the latest ADA and State of Obesity data for 2018. More than 1 million Michigan adults have been diagnosed with diabetes and over 2.7 million Michigan adults are estimated to be living with un-diagnosed diabetes. Diagnosed diabetes cost approximately $9.7 billion in Michigan annually.

What has been done
Michigan State University Extension disease prevention and management programs provide participants with strategies to improve the quality of their diets, manage chronic health conditions and reduce their risk of type 2 diabetes. Access to high-quality and affordable disease prevention and management education programs such as those that MSU Extension provides is essential to saving lives, reducing disabilities and lowering the costs of everyone?s medical care.

Results
Participants in the National Diabetes Prevention Program discover how making modest lifestyle and behavior changes (such as improving food choices and increasing physical activity to at least 150 minutes a week) can help them lose 5- 7% of their body weight. Such changes reduce by 58% the risk of developing type 2 diabetes among people at high risk for the disease. MSU

Extension has assisted in these findings resulting in:

1) An average weight loss of 6.2%

2) 61% of participants met the weight loss goal of at least 5% of their body weight

3) 99.5% of participants received a weight measurement per session

4) Participants averaged 86% attendance for the program

4. Associated Knowledge Areas

KA Code	Knowledge Area
724	Healthy Lifestyle

Outcome #5

1. Outcome Measures

Number of youth participants with increased knowledge about healthy lifestyles.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	54043

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
As community gardens, farmer?s markets and home gardens become more prevalent in Michigan, so does the desire to control ingredients in foods. Consumers need accepted methods and hands-on opportunities to learn food preservation techniques to preserve foods in safe ways. Also, as school gardens, youth gardens, and farm-to-school initiatives become increasingly popular across Michigan, youth need more information and hands-on opportunities to learn proper food preservation techniques.

What has been done
MSU Extension Food Safety educators have been teaching food preservation to consumers for over 50 years. Since 2015, MSU Extension has been using the youth food preservation curriculum ?Put It Up,? developed and published by the National Center for Home Food Preservation at the University of Georgia. Put It Up is a series composed of six different food

preservation methods: boiling water canning, making jam, pickling, freezing, drying, and pressure canning. Each method is divided into a beginner-level hands-on activity and an advanced hands-on activity. Lessons can be taught as a complete series or as stand-alone lessons.

Results
In 2018, 479 youth were trained in food safety in one of four areas- jam-making, water bath canning, pickling, or freezing. Of those who completed post-program evaluations:

1) 83% of youth recognize that refrigerating and freezing food prevents the growth of microorganisms.
2) 91% of youth participants also understand that freezing and canning are ways to make food last longer.
3) 90% of youth participants reported that they would use science-based recipes when preserving food in the future.

4. Associated Knowledge Areas

KA Code	Knowledge Area
724	Healthy Lifestyle
806	Youth Development

Outcome #6

1. Outcome Measures

Number of adult participants with increased knowledge of human development and family well-being.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	5308

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Research finds that positive early experiences, support from caring adults, and the development of adaptive skills are key to building resilient children and families. Families across Michigan are facing economic hardships, placing increasing amounts of stress on parents and increasing the likelihood of adverse outcomes for children. High levels of stress on the family system, combined

with budget and programming cuts to services that support families, necessitate the development of sustainable community supports for at risk families in Michigan.

What has been done
Building Early Emotional Skills (BEES) is an 8-week parenting program for parents and caregivers of children ages birth to three years. The workshops are designed to help parents learn how their own experiences impact their parenting, encourages interactions and supports that will strengthen parent-child relationships, and supports social and emotional development. The BEES curriculum addresses four areas of parenting through hands-on sequenced activities and group discussion, including building parental awareness, listening to and interacting with child, identifying and labeling emotions and developing behavior regulation strategies. The program also provides opportunities for parents to connect with each other and build community support systems. The program specifically serves parents and caregivers reflective of a low-income, at-risk population. A version of the BEES program for child care providers, applying the same basic principles to an early childhood setting, was also recently developed and is being piloted.

Results
Since the program?s development, 264 parents have participated in the BEES workshops. Overall, parents? beliefs about emotions in their infants and toddlers and their self-reported responses to infants?/toddlers? expressions of anger, sadness, and fear were more positive after participation in the BEES program as compared to their baseline/pre assessments. Parental distress also reduced from the pre to the post assessments. Interestingly, results were stronger for parents with greater depressive symptoms and for parents who perceived their infants/toddlers as having more reactive temperaments: these parents saw greater improvements in parenting distress and reductions in uncertainty about responding to young children?s emotions as a result of participating in the program. Parents with more depressive symptoms also experienced stronger decreases in overall unsupportive responses to young children?s emotions.

4. Associated Knowledge Areas

KA Code	Knowledge Area
802	Human Development and Family Well-Being

Outcome #7

1. Outcome Measures

Number of youth participants with increased knowledge of life skills.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual

2018 4257

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
As the need for a better-educated and skilled workforce becomes widely recognized, equipping young people with the skills needed to succeed in college has become a national focus. Research shows that young people who enroll in college on time are more likely to graduate on time, making on-time college enrollment an important focus in the successful pursuit of higher education.

What has been done
As the youth development program of Michigan State University Extension, 4-H provides young people with experiences that build life skills, subsequently supporting youth in being successful in school, in college, and into adulthood. Michigan 4-H has several pre-college programs geared towards helping youth develop the social and academic skills they need for a successful transition to college. These programs all seek to increase participants? overall interest in college and to prepare youth for college by building the skills necessary for success.

Results
The Michigan 4-H Alumni College Access Project tracks college enrollment and degree attainment by submitting program alumni records to the National Student Clearinghouse, a national enrollment and degree-attainment verification system. Enrollment data show that Michigan 4-H alums are more likely to enroll in on time than other Michigan students: in 2018, 61% of Michigan 4-H alumni enrolled in college on time, while only 53% of Michigan youth overall enrolled on time. Michigan 4-H alums are also more likely than their same-age peers to have earned a college degree or certificate 6 years after high school: 40% of Michigan 4-H alums have earned a degree within 6 years of high school, compared to only 35% of Michigan youth overall. These data demonstrate that Michigan 4-H pre-college programs build life skills that support students? access to and success in college.

4. Associated Knowledge Areas

KA Code	Knowledge Area
802	Human Development and Family Well-Being
806	Youth Development

Outcome #8

1. Outcome Measures

Number of adult participants with increased knowledge of youth development.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	15418

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Young people are best able to succeed when they have reliable, supportive relationships with caring adults. There is a need to provide training for adults in 4-H programs so they have the skills and tools to recruit the best possible volunteers to work with young people.

What has been done
MSU Extension provides multiple educational opportunities for adults working with young people to best understand the strategies and content that support positive youth development. In 2018, a total of 372 adults were trained by MSU Extension staff on best practices in working with young people.

Results
Through Michigan 4-H program, in 2018 MSU Extension provided a number of different trainings on volunteer screening and recruitment. After attending a volunteer screening training, 161 attendees completed voluntary evaluations. As a result of participating in these trainings:

1) 97% know what steps they can take to obtain more information when they see potential red flags during the volunteer screening process
2) 96% have a better understanding of the importance of screening volunteers
3) 96% have a better understanding of what potential red flags to look out for when screening volunteers
4) 95% are more confident in their ability to screen volunteers appropriately

4. Associated Knowledge Areas

KA Code	Knowledge Area
802	Human Development and Family Well-Being
806	Youth Development

Outcome #9

1. Outcome Measures

Number of research programs to develop more effective environmental/natural resources management systems.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	13

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Under predicted changes in temperature and rainfall, the tree species composition of wet tropical forests also is expected to change. Predicting future species composition of the canopy remains a challenge, as it depends on the survival and growth of seedlings and their responses to climate change. The proposed study evaluates climate (rainfall and temperature) effects on tropical tree seedling production (by mature trees), and seedling growth and survival, which will determine future composition of trees in the canopy.
This topic is important because tropical forests are critical to both global carbon storage and the conservation of biological diversity. Mature tree mortality in tropical forests is generally increasing and the carbon that those dying trees contain will transfer to the atmosphere as the wood decomposes. The characteristics of the tree species that replace current and dying trees for future generations will strongly influence the capacity of tropical forests to store carbon and sequester it from the atmosphere. Tropical forests harbor approximately 2/3 of species diversity globally; human well-being depends critically on this diversity. Tropical forests are storehouses of chemicals, fibers, and genes with great potential to provide products or ideas for products that are integral to more ecologically sustainable economies.

What has been done
Research to: better understand public benefits for policy development in recreation and tourism resource management; and to better understand the current spread, historical distribution and future disease risk of Lyme disease to inform effective citizen-focused information campaigns; identify sustainable ways to enhance human well-being while reducing stresses on the environment; understand large scale biodiversity in human dominated landscapes.

Results
We have monitored the growth and survival of woody seedlings on a six week interval and have continued measurements of light availability. We continue to monitor tree flower and fruit

production. We have developed models of annual tree reproductive output. We also have compiled weather data for the field sites, which enables examining tree and seedling responses to climatic variation.

4. Associated Knowledge Areas

KA Code	Knowledge Area
608	Community Resource Planning and Development
723	Hazards to Human Health and Safety
803	Sociological and Technological Change Affecting Individuals, Families, and Communities

Outcome #10

1. Outcome Measures

Number of adult participants with increased knowledge of family resource management.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1427

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Michigan families continue to struggle with income and debt issues. Families need skills and information to manage their family finances and resources. Whether it?s handling credit card debt, investing for retirement or college funds, purchasing a new home, avoiding foreclosure, or simply wishing to have more control over personal finances, MSU Extension has expert educators located across the state that help Michigan residents in all aspects of money management.

What has been done
MSU Extension provides several money management courses that increase participants? knowledge of family resource management: Dollar Works and Money Smart (in person) and eMoney (online). Both courses cover topics like setting financial goals, creating a spending plan, using credit wisely, pumping-up savings, keeping spending records, and protecting against identity theft. Money Smart topics include making money decisions, credit use, paying off debt, spending plans, keeping records, and money issues.

Results
During 2018, MSU Extension reached 462 adults with educational programs on managing personal and household finances. Annual income was less than $18,000 for 62% of the participants. Ten percent had experienced home foreclosure in the past few years. Pre- and post-program evaluations revealed participants improved and maintained knowledge on ten learning objectives and behavioral indicators of program outcomes. As a result of the program (n=368):

1) 90% write SMART financial goals
2) 84% keep track of spending and income
3) 87% review all credit card bills and financial statements
4) 90% write out a spending plan
5) 88% save money regularly
6) 88% obtain and review credit report annually
7) 85% pay bills on time
8) 87% pay down debt or pay off new credit card charges each month
9) 88% obtain a housing payment that fits within a budget
10) 89% make choices today that will make retirement a reality
11) 87% Know how to avoid overdraft fees

4. Associated Knowledge Areas

KA Code	Knowledge Area
801	Individual and Family Resource Management

Outcome #11

1. Outcome Measures

Number of research programs that study the function of nutrients and other components related to human health.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	5

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

As the world population grows, our need for food and fuel increases. Yet the amount of arable land is limited, and often there is now a competition between food and fuel crops. In addition, changes in the global climate may impact future yields. Drought, heat and cold are abiotic stressors most commonly affecting crop yield. Pathogens infect and destroy nutritionally advanced crops. To continue to be able to provide sufficient food and fuel for an increasing world population, we need plants that show accelerated growth, have a higher grain yield, or are more resistant to stress. According to the World Resources Institute, worldwide, 1.2 billion people are facing water scarcity and 36 countries are experiencing extreme water stress.
Hence, even slight improvements in water use efficiency and drought tolerance will not only enhance yield and survival but also reduce water usage, thus ensuring water security. Our goal is to understand how we can prevent crop loss due to water stress. To accomplish this it is essential to understand the signals responsible for changes in plant development and the resulting adaptation and resistance to drought.

What has been done
Research to: improve pregnancy outcomes related to food and environment; understand the role of lipid signs; improve meat quality, safety and nutritional values; to determine the effect of selected nutrients and food components on the development of allergic airway diseases; and understand genetic and environmental components of M. tuberculosis persistence.

Results
We have characterized the effect of PLAFP on the lipid profile and the plant phenotype: PLAFP increases the phloem PA content while not modifying any other lipids. It affects plant and root growth and vascular bundle formation. PLAFP interacts with a kinase in the BRL2-signaling path that also affects vascular bundle formation. We are currently working on a manuscript to publish these data.
Plants transformed with p35S-PLAFP-HA are currently growing and await analysis

4. Associated Knowledge Areas

KA Code	Knowledge Area
702	Requirements and Function of Nutrients and Other Food Components
723	Hazards to Human Health and Safety

Outcome #12

1. Outcome Measures

Number of youth that change in their ability to respond to one's own social-emotional needs and the social-emotional needs of others

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1380

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Supporting teen mental health is a well established need across Michigan, with many communities experiencing startling suicide rates in the past three years. Young people have a strong sense that their peers are suffering and looking for support, and are interested in being equipped with the tools and resources to provide that support.

What has been done
With the support of funds from Microsoft, MSU Extension has implemented a teen mental health initiative in a local Michigan community. The goal of the initiative is to positively address the issue of teen mental health for high school students in Washtenaw County through teen-led work. The initiative utilizes a peer web of support as well as improving use of, and access to, technology resources for teens facing mental health challenges. The project has been lead, guided, and implemented by youth themselves, with participating youth identifying teen mental health as an area of need and interest. The initiative has offered both skill building for teens around mental health issues through the Natural Helpers peer-support training program, as well as leadership development opportunities across communities.

Results
Thus far 10 young people have been trained in the Natural Helpers program. After participating in the training, one young person shared her experience with others and suggested bringing the training to others in her community, resulting in a funding proposal to support the expansion of the trainings. This entire conversation was driven by a teen who also was given an opportunity to use their voice and be involved in their community in partnership with supportive adults through the library teen council. Given that the county teen suicide rate is at a 40 year high, skills built around teen mental health and community support are an important part of intervention and one of the many ways we can work together to address and impact social determinants of health within communities in Michigan and beyond.

4. Associated Knowledge Areas

KA Code	Knowledge Area
724	Healthy Lifestyle
802	Human Development and Family Well-Being
806	Youth Development

Outcome #13

1. Outcome Measures

Number of youth participants that increase knowledge in financial literacy and money management.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1870

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Youth need skills in finances and money management to help them grow and develop into productive citizens.

What has been done
MSU Extension partnered with Chemical Bank and Michigan 4-H Foundation to provide training to both youth and adults and youth on financial literacy and money management. Partnerships were utilized to help reach a variety of audiences including youth in the foster care system, juvenile transition centers, youth with special needs, mentors and their mentees, and limited income youth. Programming took place at community-based organizations, home school networks, 4-H clubs, Special Interest (SPIN) clubs, and vocational or alternative high schools. Many topics were covered including, but not limited to, budgeting simulation, stocks and investing, children?s books with money education activities, budgeting, piggy bank creating (spending/saving/investing/sharing), needs vs wants, credit and debt, check writing , savings accounts, making financial choices, money personalities, simple and compound interest, and the role of the 4-H Treasurer

Results
A total of 209 youth completed post-program evaluations.

1) 98% understand that they are responsible for their financial future.
2) 93% are confident about making future money decisions.
3) 85% feel they have the skills to successfully manage their money.
4) 85% practice self-control when making purchases.

Follow-up surveys at 6-months and 12-months demonstrate that youth continued to experience an impact from what they learned.

After 6 months (n=39):
1) 95% of youth understand that they are responsible for their financial future.
2) 95% of youth are confident about making money decisions.
3) 89% of youth say they practice self-control when making purchases
4) 77% of youth are often or always saving a portion of the money that they earn or are given.
5) 66% of youth often or always track the money they earn and spend.

After 12 months (n=23):
1) 96% of youth understand that they are responsible for their financial future.
2) 91% of youth are confident about making future money decisions.
3) 65% of youth always or often save a portion of the money they earn or are given.
4) 65% of youth track the money they earn and spend.

4. Associated Knowledge Areas

KA Code	Knowledge Area
801	Individual and Family Resource Management
806	Youth Development

Outcome #14

1. Outcome Measures

Number of adult participants with increased knowledge in home ownership education and foreclosure counseling.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1793

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Homebuyers make decisions that require them to determine their own financial situations and what financial products are available on the market. Research suggests individuals may not accurately estimate their own financial status, including information about debt and creditworthiness, which leads to less desirable financial decisions.

What has been done

The MSU Extension Homeownership Education course assists homebuyers with up to six hours of education on the advantages of homeownership and steps in the home-buying process, understanding costs of homeownership and how to maintain the investment, mortgage loan basics and why good credit is important, and how to determine how much house can be afforded. The homeownership education program hosts guest speakers from the housing industry including local realtors, lending professionals, and home inspectors to provide additional local context and perspective into the home buying process. Participants can earn a certificate of completion that is a requirement for Michigan State Housing Development Authority (MSHDA) down payment assistance programs.

Results

During 2018, MSU Extension reached nearly 1,466 adults with this programming. Most (81%) rented their current residence or lived with family (13%). Of those that do not currently own, 98% plan to buy in the next three years. Four percent had previously experienced foreclosure.
Pre- and post- program evaluations revealed participants improved knowledge and skills. As a result of this program (n=1407):

1) 87% are making changes to improve credit report and score
2) 83% save money for home ownership
3) 90% will get their home inspected by a reputable firm
4) 89% will shop around for the best home insurance coverage
5) 82% can identify best type of mortgage for needs
6) 87% can identify down payment and closing requirements of loans
7) 90% select realtor to be a buyer?s agent
8) 89% will review the closing disclosure to ensure fees are similar loan estimate
9) 83% can calculate reasonable monthly housing costs based on a budget
10) 91% pay mortgage on time every month
11) 88% set aside funds for home maintenance costs
12) 91% now understand predatory lending practices

4. Associated Knowledge Areas

KA Code	Knowledge Area
801	Individual and Family Resource Management

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Economy
- Appropriations changes

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

MSU Extension Mental Health First Aid Initiative

Issue: Many communities struggle with mental health issues. Individuals have the power to support those around them through appropriate training. Mental Health First Aid teaches participants a five-step action plan, ALGEE, to support someone developing signs and symptoms of a mental illness or in an emotional crisis:

- Assess for risk of suicide or harm
- Listen nonjudgmentally
- Give reassurance and information
- Encourage appropriate professional help
- Encourage self-help and other support strategies

Like CPR, Mental Health First Aid prepares participants to interact with a person in crisis and connect the person with help. First Aiders do not take on the role of professionals -- they do not diagnose or provide any counseling or therapy. Instead, the program offers concrete tools and answers key questions, like "what do I do?" and "where can someone find help?"

Action: Since 2017, Michigan State University Extension has trained more than 650 people in Mental Health First Aid: 527 people have been trained in adult Mental Health First Aid and 125 people have been trained in youth Mental Health First Aid.

Results: Participants in adult Mental Health First Aid noted that because of the training:

- 97% better recognize signs someone may be dealing with a mental health problem or crisis
- 92% more confident reaching out to someone who may be dealing with a mental health problem or crisis
- 96% could better actively and compassionately listen to someone in distress
- 95% could better assist a person who may be dealing with a mental health problem or crisis to seek professional help
- 93% could better assist a person who may be dealing with a mental health problem or crisis to connect with community, peer, personal supports
- 94% more aware of their own views and feelings about mental health problems and disorders
- 92% better able to recognize and correct misconceptions about mental health and mental illness

Participants in youth Mental Health First Aid noted that because of the training:

- 97% better recognize signs a young person may be dealing with a mental health problem or crisis
- 97% more confident reaching out to a young person who may be dealing with a mental health problem or crisis
- 97% could better actively and compassionately listen to a young person in distress
- 98% could better assist a young person who may be dealing with a mental health problem or crisis to seek professional help
- 98% could better assist a person who may be dealing with a mental health problem or crisis to connect with community, peer, personal supports
- 99% more aware of their own views and feelings about mental health problems and disorders

Key Items of Evaluation

AgBioResearch:

GMOs: A surrogate for the debate about agriculture?
https://www.canr.msu.edu/news/gmos-a-surrogate-for-the-debate-about-agriculture
Perceptions of the agricultural and food industries, trends in higher education, questions around research funding, political leanings and socioeconomic factors can also play a part in public concern over GMOs.
Public concern over genetically modified organisms, or GMOs, is often associated with questions over their possible effects on human health and their environmental implications. However, perceptions of the agricultural and food industries, trends in higher education, questions around how research is funded, political leanings and socioeconomic factors can also play a part.
Paul Thompson, holder of the W. K. Kellogg Chair in Agricultural Food and Community Ethics at Michigan State University (MSU), conducts research on the ethical and philosophical questions associated with agriculture and food.
"The debate over GMOs sits in a kind of strange space," said Thompson, a professor in both the colleges of Agriculture and Natural Resources (CANR), and of Arts and Letters (CAL). "There is a sense in which people learn about some pretty standard practices in agriculture through the GMO debate."
One such example is plant breeding. For thousands of years, Thompson pointed out, people have been selectively breeding plants and manipulating seeds to produce traits we find most desirable. That's genetic modification, but many don't view it as such.
"There's a kind of disconnect in terms of the way people think about agriculture, in the way they think about their food and their environment," said Thompson, who has dual appointments in the departments of Community Sustainability; Agricultural, Food and Resource Economics in CANR; and Philosophy in CAL. "I think there are issues ahead in terms of how we negotiate some of these things."
MSU alumna Elizabeth P. Ransom agrees with Thompson about the complexity of public concern surrounding GMOs. Ransom is an associate professor in the Department of Sociology and Anthropology at the University of Richmond and has research interests in the sociology of agriculture and food.
Ransom believes there needs to be more transparency in regards to GMOs --which universities and researchers could help provide to those who want to learn more about the benefits as well as the issues. The intersection of food and social issues creates an opportunity for discourse on these complex topics.
"There are going to be some unintended consequences [with GMOs]. How do we review and monitor those?" she asked. "There's a real opportunity for universities, but it does require scientists in academia to be a little more reflective [in helping the public learn about the benefits and issues related to GMOs]."

Polling Consumer Knowledge, Opinions on Food

The Michigan State University Food Literacy and Engagement Poll measures consumer knowledge and opinions on food-related issues. The poll provides an impartial and authoritative source of public perspectives to inform and guide priorities for Food@MSU, an initiative within MSU's College of Agriculture and Natural Resources that aims to give consumers tools to navigate information and misinformation about food.
The first wave of the poll was conducted in July 2017. A second wave was conducted in February 2018. Both waves asked about consumer purchasing decisions, trust and

understanding. Each version was administered to U.S. residents aged 18 and older, with figures for age, sex, race and ethnicity, education, religion and household income weighted where necessary to align with actual proportions in the population. Two waves of the poll will continue to be administered each year: one in spring, one in fall.
Key findings:

- 35% of respondents rarely seek information about their food and where it is produced.
- Respondents have a strong level of trust in academic scientists (59% trust vs. 13% do not trust) and government scientists (49% vs. 18%), but not in industry scientists (33% vs. 30%).
- 49% of households earning at least $50,000 annually believe they know more than the average person about global food systems. 28% of those earning less are as confident.

V(A). Planned Program (Summary)

Program # 2

1. Name of the Planned Program

Soil, Water and Natural Resources

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
101	Appraisal of Soil Resources	0%		5%	
102	Soil, Plant, Water, Nutrient Relationships	35%		15%	
111	Conservation and Efficient Use of Water	10%		12%	
112	Watershed Protection and Management	5%		10%	
123	Management and Sustainability of Forest Resources	5%		6%	
131	Alternative Uses of Land	10%		6%	
132	Weather and Climate	0%		12%	
133	Pollution Prevention and Mitigation	5%		10%	
134	Outdoor Recreation	0%		1%	
135	Aquatic and Terrestrial Wildlife	0%		8%	
216	Integrated Pest Management Systems	20%		15%	
806	Youth Development	10%		0%	
	Total	100%		100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2018	Extension		Research	
	1862	1890	1862	1890
Plan	14.8	0.0	11.5	0.0
Actual Paid	13.0	0.0	27.0	0.0
Actual Volunteer	24.0	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
727343	0	1242172	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
727343	0	1267686	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	7241073	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research programs and Extension activities to:

- Develop new land use models for Michigan communities.
- Offer education to planners, elected officials and citizens on how these new models will reduce sprawl and ensure that the desirable outcomes will become reality.
- Create new remediation strategies to clean up polluted soil and water. These strategies will be environmentally friendly, economically feasible and easy to implement with proper training.
- Discover new knowledge about the composition, organization and fluctuations of microbial populations in the soils.
- Develop a user-friendly computer program for nutrient management for Michigan crop and livestock producers to improve the management of fertilizer and manure nutrients on cropland to protect water resources and boost crop productivity.
- Develop management techniques for potato and vegetable growers that includes cover crops.
- Develop new nitrogen application recommendations for turf managers.
- Develop a management system for Michigan inland lakes that does not involve sampling the lakes.
- Develop Total Maximum Daily Load (TMDL) assessment tools for evaluation of Michigan watersheds.
- Determine how wildlife responds to ecosystem management decisions in forest and agricultural systems
- •Develop fish population/community computer models for species important to Michigan. These models will be used to evaluate different fishery management strategies.
- Develop web-based tools and models for natural resources managers so knowledge can be shared quickly and easily.
- Develop computer models to assess how habitat management affects species important to Michigan, including white-tailed deer, salmon, trout and perch.
- Promote and support value-added processing of forest products, including wood products, biofuels, maple syrup and other nontimber products.
- Identify, prevent and control exotic invasive pests and diseases of forests.
- Conduct educational programs to help farmers improve nutrient management and other practices to maintain and improve quality of groundwater and surface water.
- Conduct educational programs with riparians and lake users to enhance their understanding of watershed management and inland lakes water quality issues.
- Work with state agencies and local communities to encourage protection of community groundwater supplies through wellhead protection programs.
- Educate and train health officials, consultants, engineers and riparians to improve onsite and decentralized wastewater treatment and design.

2. Brief description of the target audience

Michigan farmers, natural resource managers, private citizens, agriculture and natural resources industry representatives, state agencies, riparians and foresters.

3. How was eXtension used?

MSU Extension continues to utilize eXtension as one of the primary multi-state activities that involve contributing to Communities of Practice, responding to Ask an Expert questions, and contributing to innovation projects. One example in this area was The Current Webinar: Manure, Water, and Soil Health webinar (see here: https://learn.extension.org/events/3341).

V(E). Planned Program (Outputs)

1. Standard output measures

2018	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	24854	74562	38253	76506

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year:	2018
Actual:	5

Patents listed

MICL02340, Soil Water Retention Technologies that Maximize Production and Reduce Contamination of Groundwater (SN 15/460,196), MICL02373 Development of Biodegradable and Compostable Nanocomposites (SNs 15/230,128, 62/510,563); MICL01821, Microbial Ecology and Genomics of Soil Bacteria (SN 15/417,522); MICL02478, Electrochemical Approaches for Energy Harvesting from Waste and for Pollution Mitigation (SN 15/589,950)

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2018	Extension	Research	Total
Actual	6	69	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research programs on soil, water and natural resources.

Year	Actual
2018	65

Output #2

Output Measure

- Number of adult participants trained in soil, plant, water and nutrient relationships.

Year	Actual
2018	5171

Output #3

Output Measure

- Number of adult participants trained in how human activities impact on ecosystems.

Year	Actual
2018	19683

Output #4

Output Measure

- Number of youth participants trained in how human activities impact on ecosystems.

Year	Actual
2018	38253

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of research programs to discover new knowledge about the composition, organization and fluctuations of microbial populations in the soils.
2	Number of adult participants with increased knowledge of how human activities impact ecosystem.
3	Number of research programs to determine how wildlife responds to ecosystem management decisions in natural resource and agricultural systems.
4	Number of adult participants with increased knowledge of soil, plant, water and nutrient relationships.
5	Number of research programs that deal with fish population dynamics and the management of Great Lakes fisheries.
6	Number of research programs that deal with the security, stewardship and management of Michigan's water resources.
7	Number of research programs that analyze key soil characteristics to better assess their agricultural and environmental contribution, including crop yield.
8	Number of research programs that explore the occurrence, transport and fate/effect of organic contaminants, chemicals, pesticides, pharmaceuticals and particulates in soils.
9	Number of research programs to develop new land use models for Michigan communities.

Outcome #1

1. Outcome Measures

Number of research programs to discover new knowledge about the composition, organization and fluctuations of microbial populations in the soils.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	3

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Soil harbors the greatest undiscovered microbial diversity. This diversity recycles Earth's nutrients and helps maintain our
atmosphere. This research is aimed at discovering some of that diversity, especially novel microbes that degrade chlorinated
pollutants such as PCBs, chlorinated solvents and pesticides; microbes that have unique freezing protection mechanisms, and
microbes that affect nitrogen availability for plant growth.

What has been done
Research to: understand temporal and spatial control of gene expression during development of soil bacteria; and develop new technologies to control soil-borne diseases.

Results
We continued our work on antibiotic resistance following the One-Health Initiative with a focus on the environmental and animal agriculture sources and reservoirs. Because culture-based methods are incomplete in assessing the type, quantity and fates or resistance genes and qPCR methods likely overestimate functional antibiotic resistance genes (ARGs), we have explored using long read sequencing to capture complete genes, whether ARGs are linked and whether they are on mobile genetic elements since these are all important to risk. We assessed the linkage profile of ARGs and mobile genetic elements
in a manure community enriched from Ceftiofur treated dairy cow by two long-read sequencing technologies: PacBio and Nanopore. We found many complete (potentially functional) as well as incomplete antibiotic resistance genes, the latter indicating short-read sequencing and qPCR can overestimates ARG function. Multidrug resistance genes were dominantARGs (> 62% of total antibiotic resistance genes), however, only 0.8-1.5% were associated with mobile genetic elements.

Similarly, peptide and quinolone resistance genes were detected but only small proportions of them were linked to mobile genetic elements. In contrast, Beta-lactam and macrolide resistance genes accounted for 2.3-4.6% of total ARGs and 57-71% of them were connected to mobile genetic elements. We found over 100 DNA reads with more than 10 ARGs, metal resistance genes, and mobile genetic elements in the segment (read). Both long-read sequencing technologies gave similar
results and are promising to evaluate health risk of ARGs. We also continued to evaluate N cycle relevant genes in microbial
communities of biofuel crops. Switchgrass was not responsive to N fertilization over 7 years suggesting microbes were contributing to the N economy. Three fertilizer rates (0, 56, 196 kg N ha-1) were applied annually. N2 fixation was measured in rhizosphere soil, roots and plant parts and nifH sequences were found in those samples, some similar to those found in known N2 - fixing bacteria. The N fertilization negatively affected N fixation. Furthermore, the rhizosphere bacterial and fungal community diversities, structures and compositions were affected by interactive effects of high fertilizer and low soil pH, with the low pH produced in the highest N treatment shifting the bacterial community and fungal community structures.

4. Associated Knowledge Areas

KA Code	Knowledge Area
101	Appraisal of Soil Resources
102	Soil, Plant, Water, Nutrient Relationships

Outcome #2

1. Outcome Measures

Number of adult participants with increased knowledge of how human activities impact ecosystem.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	14762

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Gardeners continue to be interested in learning and/or improving practices in which to grow their own food. Many are interested in doing the right thing as far as using environmentally friendly practices, i.e. wise use of natural resources, water conservation, and pollinator protection.

What has been done
The Smart Gardening with Vegetables 101 Webinar Series provides an educational opportunity for MI residents and others to learn how to grow their own vegetables while using more sustainable practices to positively impact the environment. The Smart Gardening with Vegetables 101 Webinar Series provides a convenient way to learn more about practices that are earth-friendly and sustainable. Participants are provided information about the importance of soil health and sustainable ways to improve it. They learn practices, which will help them make more intentional choices about use of nutrients and pesticides. Two different webinar sessions were offered in 2018. Nearly 200 participants from 49 MI Counties, as well as out of state, participated.

Results
A follow-up survey was emailed to all participants at the end of 2018 to assess their knowledge/awareness and application of practices learned in this webinar. Sixty-two (n=62) responses were received from the 198 sent out, with 93% reporting increased awareness of sustainable practices. When asked which of the following sustainable practices they used:

1) 79% plant flowers near and/or among vegetables for pollinators
2) 73% compost
3) 72% choose not to use commercial fertilizers
4) 68% plant a diversity of vegetables and herbs
5) 67% never use pesticides on open flowers to protect pollinators
6) 65% use organic mulch and crop rotation
7) 63% use efficient watering techniques
8) 60% use minimal tillage
9) 40% use IPM principles/techniques
10) 26% were able to decrease the amount of fertilizer applied

4. Associated Knowledge Areas

KA Code	Knowledge Area
112	Watershed Protection and Management
123	Management and Sustainability of Forest Resources
131	Alternative Uses of Land
132	Weather and Climate

Outcome #3

1. Outcome Measures

Number of research programs to determine how wildlife responds to ecosystem management decisions in natural resource and agricultural systems.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	10

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
With the state boasting approximately 20 million acres of woodland, Michigan?s forest products industry includes more than 800 logging and trucking companies, and over 1,000 manufacturers that depend on Michigan lumber, according to the Michigan Department of Natural Resources (MDNR). The density and diversity of those forests are dwindling, however, and a Michigan State University (MSU) AgBioResearch team is working to remedy that.

For the past half-century, the majority of Michigan?s northern hardwood forests were managed using a method called single tree selection silviculture. In this practice, emulating the dynamics of old-growth forests, loggers enter a stand of woodland every 10 to 20 years, cutting down single trees and leaving small gaps in which the ecosystem would naturally replenish itself. This should have led to diverse ages among the trees, but forest managers returning to stands over decades discovered that they remained fairly even aged. Instead of rejuvenating the stands, they were effectively thinning them out, threatening the long-term sustainability and diversity of the forests.

What has been done
Research to: understand the mechanisms of wildlife dynamics on landscape mosaics; develop a better understanding of wildlife-habitat relationships as influenced by natural and managed wildlife habitat disturbances; and uncover systematically informative morphological and molecular characteristics related to arthropods in order to revise classifications and test evolutionary hypotheses; understand wildlife responses to habitat management; and improve wildlife management.

Results
The team designed an experiment that compares single tree selection with three alternative silvicultural systems:

Seed-tree silviculture, in which all trees in a stand except a select few of diverse species are harvested. The remaining trees reseed the next generation.
Shelterwood silviculture, in which enough trees are cut to thin the canopy, allowing enough light to reach the ground for tree seedlings to grow but not so much that weeds and less desirable species flourish.
Gap-based silviculture, in which trees are harvested to leave larger multi-tree gaps of varying sizes in the forest, allowing more space for young trees to grow.
In addition to testing the effects of various harvesting methods on tree seedlings, the team is also looking at other ways to limit the impact of deer on regenerating trees

4. Associated Knowledge Areas

KA Code	Knowledge Area
123	Management and Sustainability of Forest Resources
135	Aquatic and Terrestrial Wildlife

Outcome #4

1. Outcome Measures

Number of adult participants with increased knowledge of soil, plant, water and nutrient relationships.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	3878

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The Produce Safety Rule (PSR) is part of the Food Safety Modernization Act (FSMA) that was enacted into federal law in 2011. This is the first ever mandatory rule for produce farmers that grow, harvest and sell fresh produce that is typically eaten raw. As part of the PSR, the use of biological soil amendments of animal origin are now regulated on produce farms to minimize pathogen risks. Different types of soil amendments such as manure and compost are used by produce farms across Michigan, with biological soil amendments of animal origin used more extensively on organic farms. While a beneficial product to increase soil organic matter and fertility; raw manure, unfinished compost, or compost not treated properly can pose a significant microbial risk in fresh produce which can cause illness. Due to these risks it has been recognized by the Michigan Department of Agriculture and Rural Development (MDARD) and MSU Extension that education regarding the use of these products is needed.

What has been done
A curriculum was developed in partnership with soil amendment and compost experts from Michigan Department of Agriculture and Rural Development (MDARD) and MSU Extension. This curriculum deconstructs the Produce Safety Alliance soil amendment module, provides hands on assistance with the development of Standard Operating Procedures for handling BSAAO in conjunction with the PSR.

Results

?Safe Use of Animal Based Soil Amendment? workshops were held, with 45 individuals participated in the workshops across the state. The program engaged produce growers from many different types of farms. Participating farms ranged in size from four city lots to 250 acres.The program was particularly attractive to beginning farmers, with the majority of the participants reporting 5 years or less of farming experience (58%, n=24). Program outcomes and effectiveness were be measured through a post-workshop survey instrument (n=36). 100% of participants reported gaining new information about the soil amendment requirements of the produce safety rule, and the majority of participants reported they gained ?a great deal? or ?a moderate amount? of new knowledge about how to identify and minimize potential soil amendment risks, how to keep records related to soil amendments, and where to find local resources and connections in their local food system.

4. Associated Knowledge Areas

KA Code	Knowledge Area
102	Soil, Plant, Water, Nutrient Relationships

Outcome #5

1. Outcome Measures

Number of research programs that deal with fish population dynamics and the management of Great Lakes fisheries.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	10

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Natural fish stocks are declining for several reasons including habitat loss, contaminants and excessive harvests. To these
somewhat localized pressures we must now add the specter of global climate change. For this reason, understanding how fish
adapt to different climate-induced changes in environmental conditions in natural and manipulated aquatic agroecosystems is
essential. Our previous research has established the need to investigate the effects of anthropogenic activities, principally
changes in stream flow and temperature on reproduction, survival and growth during all fish life stages.

What has been done
Research to: investigate areas of uncertainty for Great Lakes fishery management, particularly sea lamprey control and salmon stocking; determine how fish population dynamics are affected by the physical, chemical and biological environment; investigate how human activities bring about changes in aquatic habitats; develop models capable of predicting response of fish to habitat alteration; investigate the environmental effects on fish genetic diversity.

Results
We have expanded our work on fish and aquatic microbial communities to include fungi. Collaborations have led to characterizations of fungal and oomycete taxonomic diversity and relative abundance in aquatic communities and on lake sturgeon egg surfaces. Experiments have led to protocols for reducing mortality risk during early larval fish stages.
We have identified putative probiotic bacterial taxa that produce anti-fungal and anti-oomycete chemicals that retard fungal/oomycete growth for species of aquaculture importance. We have also quantified the effects of chemicals commonly used in aquaculture on fish gut microbiome diversity.

4. Associated Knowledge Areas

KA Code	Knowledge Area
112	Watershed Protection and Management
134	Outdoor Recreation
135	Aquatic and Terrestrial Wildlife

Outcome #6

1. Outcome Measures

Number of research programs that deal with the security, stewardship and management of Michigan's water resources.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	15

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The invasive sea lamprey remains the most significant source of mortality for many large fishes of

the Great Lakes and represents one of the greatest impediments to the restoration of the native food web and the many economic opportunities and ecosystem functions it provides to human society. The financial cost of applying pesticides to sea lamprey-producing streams across the Great Lakes basin is substantial, averaging $10-18 million per year and requiring the application of as much as 70,000 kg of lampricide. These costs constrain the contrl program to treatment of no more than approx. 100 streams per year of the 485 known infested streams (21%), and likely underlie the programs failure to achieve suppression targets.
?In the Great Lakes, the invasive sea lamprey remains the most significant source of mortality for many large fishes. The sea
lamprey is currently controlled by the application of pesticides to larvae that reside in as many as 500 unblocked river
systems in any given year. The pesticide program costs U.S. and Canadian governments $18-22 million per year. Although effective, there is growing concern over the economic and environmental viability of maintaining a large-scale pesticide application program. These challenges have motivated the Great Lakes Fishery Commission (GLFC) to make the pursuit of novel tactics for reducing reproductive success and improving the efficacy of the pesticide program a central focus of its efforts.

What has been done
Research to: enhance the current water resources management structure through the ecosystems approach, development of a system to help create sustainable water resource management, understand how anthropogenic actions can affect food web structure and function, address critical questions that have relevance to specific problems in Michigan inland lake and Great Lakes integrity; help develop dynamic, interactive computer interfaces in resource-based recreation management; construct and evaluate a knowledge management system in resource-based recreation management; develop a landscape-based ecosystem management framework that integrates landscape ecology with natural resource policy and management; determine why sport fish populations, fish assemblages and lake food webs, and their response to perturbation vary among lakes; determine if pheromones can be used to control sea lamprey in streams, with a view to developing a viable new control strategy; to improve design of engineered phytoecosystems for treatment of wastewaters and stormwaters; assess the value of ecosystem services from inland waterways; and understand sustainable water use of both natural and agriculture systems.

Results
Over the last five years, this project has focused on generating the knowledge necessary to engineer new control tactics that:
1) substantially improve the efficacy of the pesticide program whilst simultaneously holding costs at the current level; and/or,
2) introduce new non-pesticidal approaches to improve the success of integrated pest management for the sea lamprey based on behavioral manipulation during the reproductive migration. Behavioral manipulation refers to a type of integrated pest management tactic that relies on exploiting an animal's innate responses to environmental information.

We carried out three years of field study to determine how sea lamprey would return to the coast, encounter rivers in the Great Lakes and to ascertain the functional role of the full larval odor, as well as to specifically test three larval odor compounds in attracting and retaining migratory lampreys at river mouths. The movements of sea lamprey were captured with fixed acoustic telemetry both on the coast in front of a river, and offshore, over 3 km from the coast. Before the telemetry data could be used we had to develop a framework for describing animal behavior from telemetered observations (Gurarie et

al. 2015) and develop a standardized approach for assessing and filtering the fixed acoustic telemetry known as the VEMCO
Positioning System (VPS) (Meckley et. al. 2014). A two-year major field experiment designed to record sea lamprey behavior in and near the Ocqueoc River plume revealed that, upon reaching a coastline, sea lampreys move parallel to shore. Encounter with river water appears to trigger localized search, regardless of larval odor content. However, when larval odor was abundant, the migrant was more likely to enter the river. Whether a migrant enters a river, is modulated by the presence of detectable larval odor, manipulation of river selection by invasive sea lamprey for management is viable in rivers with high
encounter rates.

4. Associated Knowledge Areas

KA Code	Knowledge Area
102	Soil, Plant, Water, Nutrient Relationships
111	Conservation and Efficient Use of Water
112	Watershed Protection and Management
133	Pollution Prevention and Mitigation

Outcome #7

1. Outcome Measures

Number of research programs that analyze key soil characteristics to better assess their agricultural and environmental contribution, including crop yield.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	7

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Soil and water contamination by many inorganic and organic contaminants pose potential risks to ecosystem and human health,
and agricultural food production. The impacts of emerging contaminants such as pharmaceuticals (e.g., antibiotics), engineered nanoparticles (ENPs), antibiotic resistant bacteria (ARB) and genes (ARGs), and emergent microbial pathogens to environmental and human health as well as food quality and safety are little known.

What has been done
Research to: study herbivore suppression of cyanobacteria and total phytoplankton biomass; effectiveness of nitrogen rates on soil quality and plant nutrition; study the characteristics of high content soil blends used in athletic fields and golf putting greens and how the properties of these soils change with time and use; and to explore diversification with cover crops to enhance nutrient cycling efficiency and rhizosphere traits for resilient, productive row crop systems.

Results
In last year, we investigated the pharmaceutical residues, bacterial communities and antibiotic resistance genes (ARGs) in lettuce and soil under irrigating with pharmaceuticals-contaminated waters. Our prior results have shown that pharmaceutical exposure will change bacterial communities in soils and lettuce. Thus, we are currently assessing whether pharmaceutical exposure through soils and irrigation water could influence the survival of human pathogens in vegetables, due to competition between native bacteria and invading pathogens. We started investigating the contribution of stomata to the internalization of
ENPs into plant leaves. We established the cultivation of four Arabidopsis thaliana types (two ecotypes ler and col-7 and their
respective mutants ost1-2 and scord7) in growth chambers. The Arabidopsis mutants are defective in the abscisic acid (ABA)-
regulated stomata closure. The stomata images in the presence and absence of ABA were captured by confocal laser scanning microscope, from which the stomata aperture was measured. The stomata aperture of Arabidopsis ecotypes and mutants agreed with the expected responses of these plants to the ABA exposure. The kinetic and equilibrium sorption ofnano-Ag to the Arabidopsis leaves was investigated with and without ABA. The results will allow us indisputably demonstrate the role of stomata in the internalization of ENPs. Finally, we continued collaboration with Chinese scientists in fundamental scientific research on several topics including the role of extraceullar DNA on contaminant sorption to clays, and the metaanalysis of antibiotics in China's major rivers and seas (2005-2016). The international research aimed to increase communication in basic agricultural and environmental science, and encourage international cooperation.

4. Associated Knowledge Areas

KA Code	Knowledge Area
101	Appraisal of Soil Resources
102	Soil, Plant, Water, Nutrient Relationships
111	Conservation and Efficient Use of Water
133	Pollution Prevention and Mitigation

Outcome #8

1. Outcome Measures

Number of research programs that explore the occurrence, transport and fate/effect of organic contaminants, chemicals, pesticides, pharmaceuticals and particulates in soils.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	7

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Manures and biosolids typically contain antibiotics that, when applied to soils, exert a selective pressure on soil bacteria to mutate and become resistant to the antibiotics. This is a potential threat to human and animal health because antibiotic resistance genes that are induced in this manner are thought to be transferrable to pathogens, which places
at risk many of the antibiotic medicines that we take for granted in fighting infections. This project tries to understand and potentially mitigate that risk by learning how properties of the soil system (pH, metals, clays, organic matter) affect the uptake of antibiotics by bacteria. This is important research because antibiotics only exert selective pressure and cause antibiotic resistance to spread when antibiotics are taken up by bacteria. Thus, by defining the conditions under which antibiotics are NOT taken up, we should be able to define management strategies that minimize the risks associated with applying manures and biosolids to soil.

What has been done
Research to: investigate the transport of a group of engineered nanomaterials in the soil and water environments and develop an understanding of their interactions with other elements; evaluate the occurrence and human health risks of historic pesticide contamination of agricultural soils; understand the mechanisms by which chronic estrogen exposure brings about reproductive failure; determine the mechanistic functions and contributions of soil humus and clays to the immobilization of pesticides and POPs found in soils; evaluate the occurrence of antibiotics in animal farms and their mobility; to control and convert rural waste to resources; and to understand adaption for ecosystem responses.

Results
Leveraging four external competitive grants, two from NSF and two from NIH. We made progress during 2018 on all seven objectives of the
project. In each case, goals are to demonstrate mechanisms of interaction, because such knowledge enables rational management of agro-environmental-research systems. a) Identify the predominant
tetracycline species in water that optimizes bacterial uptake and activation of antibiotic resistance genes, b) Evaluate the
bioavailabilities of tetracycline sorbed to whole soils and soil components (soil organic matter and clay minerals), and c)
Determine the expression of antibiotic resistance evoked by sorbed tetracycline as functions of soil water content, biofilm
formation on geosorbent surfaces, and internalized ultrafine sorbent particles in bacterial cells.

One paper was published from
this grant in 2018 and another is currently in review. The USDA grant has a paper in press. In addition, we published three
other papers in 2018 (both by Shuai Zhang et al.) on mechanisms and energetics for sorption of small organic molecules onto
clay mineral surfaces.

4. Associated Knowledge Areas

KA Code	Knowledge Area
101	Appraisal of Soil Resources
102	Soil, Plant, Water, Nutrient Relationships
111	Conservation and Efficient Use of Water
112	Watershed Protection and Management
132	Weather and Climate
133	Pollution Prevention and Mitigation
216	Integrated Pest Management Systems

Outcome #9

1. Outcome Measures

Number of research programs to develop new land use models for Michigan communities.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	13

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Land cover- (plants, waters or constructed items) and land use-, by humans and other creatures, change (LCLUC) is one of the great areas of interest to scientists involved in Global Change studies. Because agriculture, by nature, involves changing the land cover, it plays a large role in these studies. As agriculture adapts to changing populations and their needs, changes in agricultural lands--either through expansion, intensification or even abandonment--will have significant consequences for the economy and food security.
However the change occurs, agricultural land use change also imposes significant environmental

consequences. This may include increases in soil erosion, enhanced nutrient leaching from fertilizers that pollutes aquatic environments and degrades water quality, reduced water availability for other ecological uses by wildlife, and changes in biogeochemical processes such as greenhouse gas emissions and carbon sequestration. Recent studies show that large-scale agricultural land use changes can alter regional climate patterns.

What has been done

Research to: better understand how regional and continental processes affect local processes; increase management capacities among agencies to better integrate biological and human dimensions of management in dealing with wicked problems, such as wildlife health; and to help develop sustainable agro-ecosystems that protect public health, environmental quality and promote efficient and profitable resource use.

Results

This project created a rich knowledge on the food security and land use under a changing climate. The publications generated through this project presents rich information and methodology on ways climate change and land management affect food production and thus food security at large scales. The research demonstrated that satellite images and geospatial tools and modeling are critically important in the assessment of large-scale land use change, food production and societal implications.

The following are some major conclusion statements:

1. Climate change, particularly climate variability has significant impacts on ecosystem productivity, including croplands and grasslands. The impacts are spatially heterogeneous thus requires a geospatial tools and technologies to mitigate climate impacts.
2. Land use, the way human manage lands and other ecosystems, has significant implications to food security and environment, including productivity of forage and crops, as well as greenhouse gas emissions that further promote climate change.
3. Urban land expansion imposes a great threat to agricultural lands and, thus, food security.
4. Through human interventions, land can be managed effectively to achieve food security while preserving the environment.

4. Associated Knowledge Areas

KA Code	Knowledge Area
102	Soil, Plant, Water, Nutrient Relationships
112	Watershed Protection and Management
123	Management and Sustainability of Forest Resources
131	Alternative Uses of Land
135	Aquatic and Terrestrial Wildlife

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

MSU Extension World Food Prize Michigan Youth Institute

Issue: Ending poverty and hunger are the some of the greatest challenges we face on the planet today. The WFPMIYI is an exemplary model of how Michigan State University engages and empowers Michigan youth as global citizens addressing these and other critical global challenges, while also highlighting a few of the many ways that MSU faculty, staff and students, as well as community partners, are working to address the topic in Michigan communities and around the world. The WFPMIYI seeks to create opportunities for dialog and conversation between food "experts" and members of the community (in this case, youth) in order to advance the public's understanding of food and its impact on people and our planet. Participating in the WFPMIYI empowers, motivates and advances Michigan youth as the newest contributors towards efforts within Michigan to provide members of our local communities, and the world, a healthy, nutritious, adequate and sustainable diet.

Action: In 2018, 261 youth from 11 counties participated in the program in their school or local community, and 54 of those youth registered and participated in the World Food Prize Michigan Youth Institute on May 10 in East Lansing or Chatham.

Result: Youth participants completed a post-program evaluation survey at the end of the program. 40 youth submitted post- program evaluations.

- 96% of youth feel more knowledgeable about career opportunities that I can pursue in the future.
- 96% of youth can connect their interests and skills to career opportunities.
- 93% of youth can weigh the pros and cons of future career options.
- 79% of youth have a better idea of what they might do after high school.

Select comments from youth participants: Because of my participation in the 2018 WFPMIYI, I learned...

- "[that I can affect the world. Awareness and education is key to fixing world problems. There are so many possibilities for improvement. Things are getting better."
- "a lot about Michigan State as well as the different problems and possible solutions facing countries around the world."
- "about hunger-related problems and discussed awesome solutions. I also learned more about the role different cultures play in food production and consumption"
- "leadership, responsibility and I made new friends."
- "that we are pretty privileged and we should be thankful for what we are given."

Key Items of Evaluation

Developing strategies to prevent chronic wasting disease

A disease of the nervous system exclusive to members of the cervid family -- deer, elk, moose, caribou and other hoofed, antlered, ruminant mammals -- chronic wasting disease is a fatal disease with no known cure or vaccine. CWD spreads through direct fluid contact and the infectious protein agent is shed into the environment, where it can persist for over a decade.

Since CWD was first discovered in Michigan in 2015, MSU AgBioResearch scientists, including researcher William Porter, have begun work on a plan to identify areas of the state at high risk for CWD based on deer behavior and population dynamics. The team previously

produced a similar plan in New York after CWD was first discovered there in 2005. No new cases in New York have been documented since then.
The plan depends on a model that combines deer population density, proximity to bordering states with CWD problems and disease transmission to predict where CWD will likely emerge and spread.

- Since 2015, more than 60 cases of CWD have been identified in free-ranging, wild deer in Michigan out of nearly 31,000 that have been tested.
- Michigan has nearly 800,000 licensed hunters, 90% of whom hunt white-tailed deer.
- Deer hunting contributes over $2 billion annually to the Michigan economy.

Solving the phosphorous pollution puzzle to improve water quality in the Great Lakes region
https://www.canr.msu.edu/news/solving-the-phosphorous-pollution-puzzle-to-improve-water-quality-in-the-great-lakes-region
When fertilizers run off into nearby streams, rivers and lakes, phosphorus in the fertilizer can degrade water quality, promote harmful algal blooms and, in extreme cases, cause massive fish kills. These effects also have impacts on recreational activities such as swimming as well as industries such as fishing.
The state of Ohio and countless other stakeholders around the Great Lakes are working to stop the flow of fertilizer into the water. Included in that group are researchers at Michigan State University (MSU), who are implementing strategies that start at the source of the issue -- farmers' decision making on fertilizer use. Cloé Garnache, assistant professor in the MSU Department of Agricultural, Food and Resource Economics, is the lead researcher in two nationally funded grants to understand why and how farmers decide how much fertilizer to use on their crops.
The first grant, co-sponsored by the Economic Research Service (ERS) and the National Institute of Food and Agriculture (NIFA), aims to understand the source of the algae problem by using insights from psychology and behavioral economics to test whether farmers could be nudged into applying less fertilizer. The second grant, funded by NIFA, looks at how all aspects of the phosphorus problem are connected to help identify the most cost-effective policies.
"If we want to understand how water quality is impacted by agricultural runoff, we have to think about all the pieces of the puzzle," Garnache said. "And the first piece is farmer behavior."
Hired as a part of the MSU Global Water Initiative, Garnache and her team of economists and crop scientists are focusing on understanding how farmers make decisions. The key questions are why some farmers use more fertilizer than necessary to maximize crop growth, and whether social comparisons could persuade farmers to apply less fertilizer.

V(A). Planned Program (Summary)

Program # 3

1. Name of the Planned Program

Plant Sciences

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
201	Plant Genome, Genetics, and Genetic Mechanisms	0%		17%	
202	Plant Genetic Resources	0%		3%	
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants	0%		13%	
204	Plant Product Quality and Utility (Preharvest)	0%		5%	
205	Plant Management Systems	80%		12%	
206	Basic Plant Biology	0%		10%	
211	Insects, Mites, and Other Arthropods Affecting Plants	0%		12%	
212	Pathogens and Nematodes Affecting Plants	0%		12%	
215	Biological Control of Pests Affecting Plants	0%		5%	
216	Integrated Pest Management Systems	10%		11%	
806	Youth Development	10%		0%	
	Total	100%		100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2018	Extension		Research	
	1862	1890	1862	1890
Plan	28.1	0.0	20.0	0.0
Actual Paid	34.0	0.0	37.0	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
1733630	0	2140358	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
1733630	0	2184320	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	12476925	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research programs to:

• Develop improved varieties of dry beans, tart and sweet cherries, potatoes, wheat, rice, soybeans, oats, barley, canola, turfgrass, apples, strawberries, blueberries, floriculture crops, chestnuts, vegetable crops, and conifers for Michigan growers.
• Continue to identify genes and genetic pathways that control plant response to environmental stresses and develop techniques to insert these pathways into at-risk plants.
• Identify and isolate novel genes, markers and genetic pathways that can benefit crops important to Michigan agriculture through higher yields, improved quality, and better insect and disease resistance.
• Identify and isolate novel genes, enzymes and other phytochemicals that may have benefits for human health and determine how these beneficial compounds can be made available to people.
• Develop integrated management strategies and provide education programs for producers of fruit, field, vegetable, floriculture, Christmas tree and forestry crops that use the lowest possible inputs of resources and improve yield and quality, while minimizing environmental effects, such as leaching and run-off.
• Develop cultural, management and insect and disease control strategies for crops that meet USDA certified organic standards so Michigan growers can take advantage of this growing market, if they choose to do so.
• Continue to develop biological controls for pest insects and diseases to minimize effects on the environment.
• Continue variety trials for crops important to Michigan, including wheat, corn, soybeans and forages.
Extension activities to:

• Conduct educational programs to help farm producers control weeds and more effectively manage high-cost fertilizer inputs while optimizing crop production.
• Develop plant disease prediction models.
• Conduct educational programs to help plant producers control disease caused by pathogens and nematodes and teach integrated pest management methods.
• Provide green industry professionals and homeowners with scientifically sound information to enable them to safely and effectively manage their turf, landscapes and gardens, improving efficiency of resources and controlling pests, while reducing pesticide and fertilizer use.
• Train Native American adults in sustainable agriculture.

2. Brief description of the target audience

Michigan growers (traditional and organic), commodity groups, agriculture and natural resources industry representatives (including herbicide, pesticide and insecticide suppliers), green industry/landscape/turf professionals, state agricultural agencies, Native American growers and the interested public.

3. How was eXtension used?

MSU Extension continues to utilize eXtension as one of the primary multi-state activities that involve contributing to Communities of Practice, responding to Ask an Expert questions, and contributing to innovation projects. One example in this area was conducting a webinar series on using solar enegry in agricultural settings (see https://learn.extension.org/events/3221).

V(E). Planned Program (Outputs)

1. Standard output measures

2018	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	24537	73611	22493	44986

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year:	2018
Actual:	24

Patents listed

MICL02303, Improved Pretreatments and Enzymes for biomass Deconstruction (SN 15/437,359; 62/491,632); MICL02456 Genetic Improvement of Beans (Phaseolus vulgaris L.) for Yield, Pest Resistance, and Food Value (SN 201700006, 201700007, PV201700125); MICL02315, Exploring Sporulation and Spore Dispersal in Fungal Pathogens (SN 15/316,647); MICL02332,Genetic Improvement of Sour Cherry and Cherry Rootstocks (SN 15/330,731, 15/330,732, 15/330,737, 15/330,730, 15/330,734); MICL02166, Chemical Catalysis and Processing for Advanced Biofuels and Biochemicals (SN 15/359,735); MICL02357, Regulation of Lipid Metabolism in Plants and Algae (SN 15/487,063, 15/627,006, 62/479,599); MICL02462, Physiology and Biochemistry of Potato Tuber Disease Resistance (SN 15/502,553); MICL02368, Understanding Spatial and Temporal Variability of Crop Yield, Water and Nutrient Fluxes by Integrating Precision Agriculture with Crop Modeling (SN 15/612,442, 62/411,976); MICL02278, Molecular Genetics of Plant Defense Against Insects (SN 62/359,293, 62/379,773); MICL02384, Probing the Structural Basis of Cyanobacterial Photoprotection and CO2 Fixation (SN 62/378,979, 62/438,655); MICL02416, Root-Associated Fungi in Agriculture and Forestry (SN 62/458,236); MICL02347, Genetic Engineering of Oilseed Crops (SN BR102016015577-0)

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2018	Extension	Research	Total
Actual	8	118	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research projects on plant sciences.

Year	Actual
2018	112

Output #2

Output Measure

- Number of adult participants trained in plant management systems.

Year	Actual
2018	23502

Output #3

Output Measure

- Number of youth participants trained in plant management systems.

Year	Actual
2018	22493

Output #4

Output Measure

- Number of adult participants trained in integrated pest management (IPM).

Year	Actual
2018	1035

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of adult participants with increased knowledge of integrated pest management (IPM).
2	Number of research programs to develop insect and disease control and/or cultural and management strategies for organic crops.
3	Number of research programs to develop biological controls for pest insects and diseases to minimize any effects on the environment.
4	Number of research programs to develop integrated management strategies for fruit, field, vegetable, floriculture and forestry crops that use the lowest amounts of nutrients possible and improve yield and quality.
5	Number of research programs to identify and isolate novel genes, markers and genetic pathways that can benefit crops important to Michigan agriculture through higher yields, improved quality, and better insect and disease resistance.
6	Number of research programs to identify genes and genetic pathways that control plant response to environmental stresses and develop techniques to insert these pathways into at-risk plants.
7	Number of research programs to develop improved varieties of economically important crops for Michigan and the region.
8	Number of adult participants with increased knowledge of plant management systems.
9	Number of research programs to develop weed control methodologies, protocols and practices.
10	Number of research programs to develop controls for pathogens and nematodes affecting plants.
11	Number of research programs to develop production protocols and environmental and cultural strategies for the floriculture/nursery industry.
12	Number of research programs to develop more effective post-harvest protocols and practices to minimize loss and enhance quality.

Outcome #1

1. Outcome Measures

Number of adult participants with increased knowledge of integrated pest management (IPM).

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	776

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The Drosophila suzukii (SWD) continues to create havoc in Michigan?s berry industry. In 2012, blueberry growers reported multi-million dollar losses to SWD, and in 2014, some Latino and African American growers lost more than 58% of their income due to this pest. Also, expenses of managing SWD increased from $150 per acre in 2012 to $372 per acre in 2013 (AABI 2016). In 2016, 100% of surveyed growers signaled SWD as the major source of economic losses at their farms. To comply with the industry ?zero? tolerance for insects in blueberries, growers need to spray insecticides numerous times. This increased the risk of exceeding maximum residue limits (MRLs) and caused loss of revenues due to increased pest control expenses and/or fruit rejected/downgraded. As a result, the Michigan Blueberry Advisory Committee (MBBAC) has maintained the SWD as one of its top priorities for research and extension.

What has been done
Controlling the SWD requires a deep understanding of IPM tactics, strategies and tools, and reeducation of growers; especially those located in regions isolated from major berry production areas receiving regular attention from MSU Extension. In 2014, growers indicated that their major obstacles for integrating the SWD management into current IPM programs was lack of knowledge and understanding of: ?how insecticide applications should be adjusted to account for pest behavior, crop conditions, insecticide chemistry and behavior on the crops, weather conditions and sprayer equipment?. They were taking insecticide application recommendations as ?prescriptions? rather than dynamic recommendations needing adjustments to account for the effect of environmental factors on pest, host and insecticides performance. Thus, based on research results obtained at MSU and other collaboration institutions we develop a SWD IPM training program to teach growers to manage the SWD under a Systems Science Approach to Pest Management model. Training approach was curriculum-based with classroom and hands-on training. Major components of the model are the pest biology and behavior, plant phenology, recommended insecticides chemistry and behavior, and current and forecasted weather

conditions at the target site.

Results

After training, growers successfully reduced crop losses and decreased pest control expenses. For the last three years since the implementation of this new approach to SWD management, growers participating in the training program reported the following: 69% reported no crop losses; 76% no fruit downgrading, and pest management costs decreased to an average of $178 per acre, $194 less than in 2013. The System Approach to SWD Management model helped growers to reduce the number of insecticide applications made in blueberries by at least one spray compared with 2013. These results indicate that timely, cost-effective and reliable management of SWD is of high importance to Michigan blueberry growers to maintain their livelihood and employment. MSU Extension efforts are contributing to help Michigan blueberry growers to remain competitive, maintain employment and preserve the livelihood of small fruit growers, especially of underserved and minority growers.

4. Associated Knowledge Areas

KA Code	Knowledge Area
205	Plant Management Systems
216	Integrated Pest Management Systems

Outcome #2

1. Outcome Measures

Number of research programs to develop insect and disease control and/or cultural and management strategies for organic crops.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

The high value of organically produced fruit as well as the significant use of pesticides in tree and small fruits translates to
significant economic and environmental impact of this umbrella project. Michigan's unique

geographic location and diverse
microclimates provide significant natural advantages for the production and marketing of organic foods at local and regional
level (Bingen et al. 2007). However, the organic agricultural community within Michigan has been traditionally underserved, to a
large extent because of incompatibilities between organic certification requirements and the research emphasis of the land
grant system (i.e. GMO's, synthetic fertilizers, and synthetic organic pesticides).

What has been done
Research to: increase the production and use of thermophilic compost and vermicompost as important tools for organic and sustainable production and management of vegetable transplants and year round vegetable production and marketing on rural and urban farms using greenhouses; studies addressing the behavior and ecology of crop, pest, and beneficial organisms were continued.

Results
studies addressing the behavior and ecology of crop, pest, and beneficial organisms were continued. Projects included: 1) Demonstration of attract and kill techniques for Japanese beetle, 2) development of a solid set canopy delivery system (SSCDS) for the delivery of chemical inputs to apples, grapes and berry crops, 3) evaluation of floor management targeting apple scab and 5) a multistate project researching NOP compliant management techniques for spotted wing Drosophila. All of the current projects are funded at least in part by external grants from USDA competitive programs, MSU
internal programs, and grants from MI commodity groups. Over the course of 2017-2018, one MSU GREEEN, one commodity group and one NIFA proposals were funded. Data from ongoing and completed studies were presented at 25+ extension talks, posters, and invited and submitted formal research talks. Information was also disseminated via online media and through grower trade publications.

4. Associated Knowledge Areas

KA Code	Knowledge Area
205	Plant Management Systems
211	Insects, Mites, and Other Arthropods Affecting Plants
212	Pathogens and Nematodes Affecting Plants
215	Biological Control of Pests Affecting Plants
216	Integrated Pest Management Systems

Outcome #3

1. Outcome Measures

Number of research programs to develop biological controls for pest insects and diseases to minimize any effects on the environment.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	22

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Tiny but mighty pollinators are an essential contributor to many of Michigan?s high-value fruits and vegetables. In the past 10 winters, however, American beekeepers have lost a high proportion of their colonies, with some of the biggest losses recorded in the Midwest. At the same time, some wild bee species once common in the Great Lakes region, such as the rusty-patched bumble bee, have become extremely rare. Even the iconic monarch butterfly is less common because of the many challenges facing pollinators, such as habitat reduction, pathogens, parasites and pesticide exposure.

What has been done
Research to: develop and deliver Integrated Pest Management strategies for insects in Michigan vegetable crops; develop stable, sustainable management strategies for vegetable insect pests; determine the effectiveness of currently registered and experimental products for control of insect pests in small fruit crops; improve control of moth pests by pheromone disruption; increase knowledge about mode of actions or effects of pests and diseases on honey bees to achieve better control and to gain increased honey production and more effective pollination of agricultural crops; to develop biological and cultural tactics based on vegetation management; to increase knowledge about the plant defense genetics; and to use new pest controls for tree fruit production

Results
In response, over the past decade Michigan State University (MSU) has been bolstering its pollinator expertise in the Department of Entomology. This past summer, the department launched a new $1 million project funded by the U.S. Department of Agriculture National Institute for Food and Agriculture aimed at improving Great Lakes landscapes to support healthy pollinators. Led by entomology professor and extension specialist Rufus Isaacs, the team is building on previous work to explore the complexities of poor pollinator health.

?The challenges faced by honeybees, wild bees and other flower-visiting insects threaten our food security,? Isaacs said. ?Addressing this in Michigan is of particular importance. We have a significant honeybee industry that provides local and national pollination services and honey production, and Michigan is a leader in growing fruits and vegetables that depend on these insects for pollination.?

https://www.canr.msu.edu/news/enhancing-great-lakes-landscapes-for-healthy-pollinators

4. Associated Knowledge Areas

KA Code	Knowledge Area
205	Plant Management Systems
212	Pathogens and Nematodes Affecting Plants
215	Biological Control of Pests Affecting Plants
216	Integrated Pest Management Systems

Outcome #4

1. Outcome Measures

Number of research programs to develop integrated management strategies for fruit, field, vegetable, floriculture and forestry crops that use the lowest amounts of nutrients possible and improve yield and quality.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	21

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Michigan vegetable producers are facing an increased incidence of extreme weather events ? such as drought, heat and heavy rainfall ? that place extreme stress on crops. New cropping systems are needed to help reduce the risks associated with these events.

Daniel Brainard, associate professor in the Michigan State University (MSU) Department of Horticulture, is undertaking a range of research projects to build resiliency in vegetable crops. He is looking at reducing tillage and maintaining crop residues on the soil surface, two principles basic to conservation agriculture.

What has been done
Research to: identify and characterize phloem-associated lipids and lipid-binding proteins and identify their role in plant development and pathogen defense response; optimize protocols for honeycrisp storage in air and in controlled atmospheres; utilize and integrate physiological, genetic and horticultural approaches for understanding and improving Great Lakes region high value fruit production; decrease reliance on conventional crop protection practices by using low environmental impact fungicides in combination with host resistance; and to improve row crop nitrogen management to optimize economic returns and reduce environmental impacts

Results
Current projects include several long-term trials exploring the best way to implement strip tillage systems to build soil health, increase moisture retention and protect tender crops, and develop new irrigation systems to reduce heat and drought stress for historically nonirrigated Michigan vegetables.

Strip tillage involves tilling fields in straight lines separated by a strip of untilled soil where a cover crop may be planted. For some crops, such as carrots, the cover crop strip can protect the cash crop when plants are small and vulnerable. When the cover crop dies and is left on the soil surface, it acts as mulch and helps to preserve soil moisture and prevent erosion.

With support from other MSU specialists and MSU Extension educators, Brainard?s long-term strip tillage trials have shown beneficial increases in soil organic matter and improvements in soil moisture under drought conditions, along with reduced labor and fuel costs for tillage. https://www.canr.msu.edu/news/developing-new-cropping-systems-to-help-michigan-vegetables-survive-extreme-weather

4. Associated Knowledge Areas

KA Code	Knowledge Area
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems
206	Basic Plant Biology

Outcome #5

1. Outcome Measures

Number of research programs to identify and isolate novel genes, markers and genetic pathways that can benefit crops important to Michigan agriculture through higher yields, improved quality, and better insect and disease resistance.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	22

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Fleshy fruits are an essential component of the human diet, providing sources of carbohydrates, vitamins, minerals, antioxidants, and fiber. A diet rich in the consumption of fruits and vegetables reduces the likelihood of obesity and the incidence of disease. Therefore, research into the biology of fruit development and ripening, together with production and postharvest strategies, is of significant importance to food and nutritional security, both within the US and globally. Generating a mechanistic understanding of the genes and processes required for the development and ripening of fleshy fruits, including those that influence their nutritional content, will create fundamental knowledge that can be utilized to infer targets for incorporation into breeding programs, leading to improved crop varieties. The research outlined in this project will utilize tomato
as a model crop plant to identify and characterize genes that influence fruit development and ripening.

What has been done

Research to: identify and characterize phloem-associated lipids and lipid-binding proteins and identify their role in plant development and pathogen defense response; optimize protocols for honeycrisp storage in air and in controlled atmospheres; utilize and integrate physiological, genetic and horticultural approaches for understanding and improving Great Lakes region high value fruit production; decrease reliance on conventional crop protection practices by using low environmental impact fungicides in combination with host resistance; and to improve row crop nitrogen management to optimize economic returns and reduce environmental impacts

Results

Tropane alkaloids are synthesized by several plant families and in the Solanaceae, are particularly abundant in the Atropa, Hyoscyamus, and Datura genera, which synthesize diverse tropanes, including the pharmaceutically important compounds, hyoscyamine and scopolamine. In the Solanaceae, tropanes are synthesized in the roots and are subsequently transported to the aerial tissues. The root-specific synthesis of tropanes in the Solanaceae was exploited to identify root-preferentially expressed candidate genes from a multi-tissue transcriptome assembly of Atropa belladonna (Deadly Nightshade) that are potentially involved in tropane biosynthesis. The function of candidate genes was tested by virus-induced gene silencing in the roots of Atropa belladonna, followed by liquid-chromatography mass-spectrometry based metabolite profiling of tropane alkaloids and selected precursor compounds. This strategy has led to the identification of several candidate genes encoding enzymes, transcription factors, and transporters that are potentially involved in tropane biosynthesis. Under this project, five enzymes that catalyze steps in the biosynthesis of tropane alkaloids were characterized, including a type III polyketide synthase and a cytochrome P450 that are required for the synthesis of tropinone, the first metabolite in the tropane pathway with the characteristic 8-azabicyclo[3.2.1]octane core bicyclic structure of all tropanes (manuscript under revision). In addition, a UDP-glucosyltransferase and a serine carboxypeptidase-like acyltransferase required for the synthesis of the aromatic tropane ester, littorine, the immediate precursor of hyoscyamine and scopolamine were characterized (manuscript under revision). An aromatic amino acid aminotransferase that channels L-phenylalanine into the tropane pathway to provide the
phenylllactic acid moiety of littorine was also characterized (manuscript published in 2014). These studies have provided significant insight into the biosynthesis of tropane alkaloids, and have developed knowledge that will be useful for future studies investigating the function of these metabolites in planta, together with metabolic engineering strategies to boost their production.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
205	Plant Management Systems
206	Basic Plant Biology

Outcome #6

1. Outcome Measures

Number of research programs to identify genes and genetic pathways that control plant response to environmental stresses and develop techniques to insert these pathways into at-risk plants.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	13

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Strawberries and blueberries are among the most widely enjoyed fruits in the United States. Each year farmers produce 3 billion pounds of strawberries and 690 million pounds of blueberries.

While the nutritional value and sweet taste of these fruits are widely cherished, their origins remain a bit of a mystery. Humans and most other animals have diploid genomes, meaning they inherit one set of chromosomes from each of two parents that determine their genetic characteristics.

Strawberries, blueberries and many other plants are polyploids, however, which means they have three or more sets of chromosomes. Polyploidy can take two different forms ? autopolyploidy, in which the chromosomes are copies of genetic material from a single progentior species, and allopolyploidy, in which each chromosome comes from a different ancestral species.

What has been done
Research to: identify molecular markers for traits that are important in highbush blueberries; identify high-yielding oat, barley and canola cultivars for Michigan; provide guidance on disease control and crop health to the Christmas tree and chestnut industries; determine the biochemical mechanisms involved in turfgrass disease control; develop production methods to increase net

returns to Michigan berry producers; elucidate molecular and biochemical mechanisms of plant resistance to arthropod herbivores; determination of how to better control for fungal and bacterial diseases of plants; and to develop improved analytical methods for the profiling of metabolites to assist in comprehensive measurements of biomarkers related to plant and animal health.

Results
?By disentangling each of the progenitor species that gave rise to crops like blueberries and strawberries, we can understand how their genomes are formed and use that to breed better cultivars for growers,? Edger, assistant professor in the MSU Department of Horticulture, said. ?Many genes that encode favorable traits were unintentionally lost during domestication and modern crop improvement efforts. My team is identifying the valuable genes from the original sources ? the wild progenitor species ? and reintroducing them into our breeding programs.?

Traditional plant breeding is a lengthy process in which scientists crossbreed parent plants with promising, advantageous characteristics ? such as higher yields, resistance to pests or diseases, and drought resilience. They wait for the plants to mature, then select the most promising of those with which to repeat the process, often for many generations.

Recent years have seen great strides in plant breeding, with new molecular technology emerging to allow researchers to identify which offspring possess the genes for desired traits when they are still seeds. This has the potential to eliminate much of the most time-consuming aspect of plant breeding, because researchers can grow only the most promising offspring, without having to cultivate an entire generation in search of the desired traits.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
206	Basic Plant Biology
216	Integrated Pest Management Systems

Outcome #7

1. Outcome Measures

Number of research programs to develop improved varieties of economically important crops for Michigan and the region.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	18

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Michigan is the third most diverse agricultural production system in the U.S. Field crops are the most important commodity group in the state in terms of total crop acreage (at 6.5 million acres, 97% of the total), number of growers, and farm income, contributing over $4 billion in production value. Eight of the top ten commodities in Michigan are field crops, or dependent on field crops (livestock, egg production). Corn is the leading crop in the state in acreage (2.5 million acres) and cash value, followed by soybean (1.9 million acres). Unlike neighboring corn-belt states driven by corn and beans, Michigan grows a diversity of field crops, ranking first in several types of dry beans and fourth in sugarbeets. Other field crops include alfalfa,pasture, and other forages; small grains such as wheat, barley, oats, and rye. With the global demand for grain for direct consumption and livestock feed, as well as for biofuels, crop prices are at a high and field crop acreage is expanding in the state. Invasive species were and continue to be a major problem in the U.S. Michigan is a potential hot-spot for insect introductions, home to Great Lakes shipping ports, airports in Detroit and Chicago with non-stop flights to Asia, and a diverse crop base vulnerable to colonization by many species. Other invaders, foreign and native, are expanding in their range into Michigan. Thus producers are presented with new challenges from both foreign-invasive and native-invasive species that increase in pest status or range. Established and new insect invaders are now responsible for the majority of insect-caused
yield and quality loss in Michigan field crops, influencing pest management decisions, driving insecticide use and reducing profitability. Tied in with invasive species is the issue of climate change. For some field crop insect pests, damage is getting worse and the damage period is growing longer during the season. A reality in field crop production is the use of biotechnology, specifically genetically modified crops with herbicide resistance or Bt insecticide toxin. According to the USDA Economic Research Service, 86% of the corn, and 91% of the soybean, acres in Michigan were transgenic in the 2012 planting season. Because universities have little role in the development of this technology, land grant entomologists are viewed as neutral observers and thus have an important role to play in education and making public statements.

What has been done

Research to: identify the genes critical for the replication and repair of chloroplast DNA; understand the patterns of evolution of flora forms that contributes to the reproduction and persistence of Michigan plants; increase the environmental and economic sustainability of small fruit production through management of diseases in Michigan; understand the central plant metabolism and transport in plant systems well enough to rationally manage and engineer them for human benefit; develop a data-driven protocol for culture of juice grape cultivars as well as fruit plant canopies and management systems that fit into these advances to achieve maximum efficiency; and to discover genes that are co-expressed with genes known for amino acid biosynthetic and catabolic enzymes.

Results

Understand the impact of pest insects in Michigan field crops, aspects of their life history and ecology that
contribute to these impacts, and crop/pest interactions that affect yield. *In soybean, aphid

numbers remained very low in
Michigan during the entire project. A regional suction trap was maintained on the Michigan State University campus each
summer, and it documented low flights. A suite of predators and parasitoids contributed to aphid management in Michigan.
Three parasitoid species were identified from samples. While Aphelinus certus and Lysiphlebus testaceipes are common on
soybean aphid, Aphidius colemani is apparently rarely found. However, this species is found in southern Ontario, and
Michigan shares insect populations across the border. More and diverse of parasitoid species could partially explain the low
aphid levels in the eastern cornbelt compared to Iowa and Minnesota. Michigan joined nine other states in a collaborative
project to determine stink bug species composition and best sampling practices in the Midwest. Stink bug species were
cataloged from Michigan fields sampled weekly over the course of several seasons. One-spotted stink bug was the most common species collected in Michigan, making up >80% of captures. The invasive brown marmorated stink bug was approximately 10% of the catch, but it was found only in fields closer to built environments. Michigan data was pooled with that from other locations in the North Central region, and analyzed to determine spatial patterns of insects in field. Not surprisingly, stink bugs were spatially aggregated, but the aggregation varied by species, life stage, and location in the
Midwest. Stink bug numbers averaged one to three per 25 sweeps in Michigan in R-stage beans. An annual survey to estimate insect losses and insecticide inputs in soybean, conducted in seven southern states since 2004, was expanded nationally to 16 states (including Michigan) representing 32.6 million acres of production. The survey, led by Mississippi State, provides a valuable perspective on changes in insect pressure and management over time. With the addition of more states,there was a regional pattern of higher management cost and loss in the southern states compared to northern states. This survey allows the soybean industry to identify and document long-term trends and changes in insecticide use, yield impacts, and key soybean pests. Scientists, regulators, and commodity groups can use the survey to prioritize areas for research,extension programming, and funding. The expansion into northern states, like Michigan, makes the survey useful to a growing number of people. * In corn, to address the increase in ear feeding in corn, a project on western bean cutworm and ear mold
was begun, in conjunction with the MSU Agronomy program. Replicated plots of Bt hybrids differing in Bt trait and ear mold susceptibility were planted across Michigan. The plots were scouted for cutworm, evaluated for ear mold, and grain samples were pulled for mycotoxin analysis. There was a positive correlation between insect feeding, ear mold, and toxins. Even a small amount of ear feeding predisposed grain to mycotoxins. This work is in progress to provide growers with a better understanding of the risk of ear feeding insects on mycotoxins in grain.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems
206	Basic Plant Biology

Outcome #8

1. Outcome Measures

Number of adult participants with increased knowledge of plant management systems.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	17627

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Weed control in soybean continues to be challenging in Michigan as herbicide-resistant populations of horseweed and other species become more commonplace. New herbicide-tolerant varieties of soybean have been developed in the last decade, but many growers have not had experience growing them and working through the challenges associated with their production. Local demonstrations and dissemination of information will be important as more growers adopt these technologies.

What has been done
MSU Extension's educational weed control programs consisted of field demonstrations highlighting two different herbicide tolerant technologies: LibertyLink and Xtend soybeans. Working with local agrochemical retailers, crop consultants, regional agrochemical representatives, and MSU Extension's Weed Guide, MSU Extension educators delivered several herbicide programs at different price points that could be used in each of these technologies/systems. In replicated on-farm trials, MSU Extension educators applied herbicide treatments and then monitored weed control throughout the growing season via aerial imagery and ground-level scouting.

Results
Field demonstrations were attended by 59 Michigan residents. Of those who completed post-program evaluations, all said their knowledge of the subject matter increased and 50% of respondents indicated they planned to change some aspect of their business or farm operation based on information presented. They estimated that these changes would impact 2,400 acres and increase net income by $16,400.

4. Associated Knowledge Areas

KA Code	Knowledge Area
205	Plant Management Systems

Outcome #9

1. Outcome Measures

Number of research programs to develop weed control methodologies, protocols and practices.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	4

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The old adage ?what doesn?t kill you makes you stronger,? can be applied to weeds, insects and diseases developing resistance to pesticides.

For centuries, farmers have combated pests in a number of ways, embracing technological advances such as cultivation, chemicals, data-driven scouting, integrated pest management and genetic modification of crops as they became available.

What has been done
Research to: add to the body of knowledge on the influence of perennial crops, cover crops, and soil amendments on weed seed survival in cropping systems; to explore multiple strategies that manipulate and manage weeds in agronomic systems.

Results
Resistance is not a new phenomenon, nor is it a direct result of the introduction of genetically modified organisms (GMO), according to Michigan State University (MSU) researchers. Rather it?s a natural process that happens over time as pests that are already resistant to a certain type of removal mechanism find ways to survive and reproduce.

?In weeds, what resistance comes down to is just the overuse of a particular herbicide that functions at the same place in the plants,? said Christy Sprague, MSU weed scientist.

Sprague is quick to point out that the herbicides themselves don?t make a plant resistant; instead, a small percentage of plants are just naturally resistant to any given herbicide. What?s happening is called selection pressure, caused by applying the same herbicide over and over again, and it has occurred in crops for nearly half a century.

?Once those resistant plants grow and they don?t die, they produce more seed and suddenly the [resistant] population expands,? Sprague said. ?One of the first weeds identified in Michigan that was resistant was atrazine-resistant common lambsquarters back in the early ?70s. Since then, we?ve seen multiple weed species that have become resistant to herbicides.?

Even though fungicides used to combat plant diseases are generally applied less often than herbicides used to fight weeds are, selection pressure may still occur.
https://www.canr.msu.edu/news/resistance-yesterday-today-tomorrow

4. Associated Knowledge Areas

KA Code	Knowledge Area
205	Plant Management Systems
216	Integrated Pest Management Systems

Outcome #10

1. Outcome Measures

Number of research programs to develop controls for pathogens and nematodes affecting plants.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	4

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
There are nearly endless phenotypic variations in size and shape of both sexual and asexual spores. And yet spore size and
shape are not haphazard, and these factors are integral to survival and dispersal of the fungal species. Different fungal niches
will require different approaches to dispersal. Aquatic fresh water fungi are frequently star-shaped, to facilitate being tangled in

the organic debris of a stream, whereas marine fungi frequently exhibit mucilaginous appendages for attaching to floating
debris. On land, for aerial dispersal, spores need to break free of the boundary layer of still air that surrounds all surfaces. This
layer can be 1 meter on a forest floor or a few millimeters in an open agricultural field on a windy day. Many of the Ascomycota
have fruiting bodies that contain asci that shoot spores out of the boundary layer of still air into the breeze to be carried away.
These spores may be very small, designed to ride the wind for some distance, or may be larger, and held together by mucilage,
to generate the momentum to land closer to their place of origin. Asexual spores also have great diversity in size and shape,
but all spores have evolved to maximize their chances of landing in an environment in which they can successfully establish and
reproduce.
Understanding spore diversity, spore dispersal mechanisms and the initial establishment of spores in new territory will
provide better manage strategies for both the beneficial and harmful effects these fungi in areas of food safety, sustainable
agriculture, and the health of the planet and ourselves.

What has been done
Research to facilitate the development of integrated tools that will lead to transformative approaches of soil ecosystem management and improve land use, food security, and loss of habitat and biodiversity; to increase the capacity of risk assessment to evaluate specific risk management strategies related to (I) Agriculture - Food, Feed and Fiber; (II) Environment; and (III) Food and Health; provide better manage strategies for both the beneficial and harmful effects these fungi in areas of food safety, sustainable agriculture, and the health of the planet and ourselves.

Results
Dr. Haiyan Sun came over from Nanjing Agriculturall University to work with us and to learn microscopy and cell biology techniques. Our goal is to generate a model for the mechanism of forcible discharge of ascospores from asci and use the model to identify the biological elements that function to fire spores. The mechanism of ascus firing is not well understood. By harnessing the expertise of a biophysicist and two engineers, we will model the process of spore firing and from that determine the genes involved. Since dissemination of ascospores is often the first step in disease initiation in an agricultural field, a knowledge of this process will provide important insight into developing methods to inhibit this initial spore release.

4. Associated Knowledge Areas

KA Code	Knowledge Area
205	Plant Management Systems
206	Basic Plant Biology
212	Pathogens and Nematodes Affecting Plants
215	Biological Control of Pests Affecting Plants
216	Integrated Pest Management Systems

Outcome #11

1. Outcome Measures

Number of research programs to develop production protocols and environmental and cultural strategies for the floriculture/nursery industry.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	3

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

The U.S. green industry experienced unprecedented growth, innovation, and change from 1980 to 2010. Recently, however, slower sales growth and reduced profit margins indicate the market is maturing. Prices usually decline and competition intensifies in mature markets, challenging all firms to become more effective with their resources to best connect with customers, generating revenue and profits. Michigan ranks among the top three states for floriculture crops and among the top 10 states in nursery plant production. Like the national trend, Michigan plant producers are experiencing a similar pattern of
slowing demand. While the horticulture industry's outlook may be somewhat uncertain, it is clear that innovativeness will continue to be a requisite skill in ensuring the survivability and profitability of green industry firms in the future. Whether producer or retailer, some business effort must be focused on enhancing the value proposition offered by firms. Businesses can improve their value proposition by emphasizing the economic, social (e.g., health and well-being), and environmental benefits (e.g., energy/water saving production methods, or use of recyclable/compostable containers) that green industry products and services offer end consumers (Hall and Dickson, 2011) over price, which is emphasized in undifferentiated
commodity sales. Still, reaching customers with value-added propositions will only be successful if the messages are conveyed in a meaningful way.

What has been done

Research to: provide nursery managers, landscape contractors, and urban foresters with additional tools to improve the long-term success of landscape and street tree plantings; improve signage at the point of purchase (short term) and help firms enhance their value proposition by more effectively providing timely, useful, and pertinent information to customers; create a new model for science education; enable greenhouse growers to reduce energy costs for heating and light

Results

We observed consistency across the various experiments with regard to the type of cue utilized by subjects. Subjects scoring high in involvement (interest) used signage information faster and for a longer period of time compared to subjects with low involvement scores. However, subjects scoring high on the expertise scale used signage information faster and for a longer period of time compared to individuals who scored low on the expertise scale. Thus, we found evidence to support H1-H3. We conclude that high involvement or high expertise leads consumers to seek more information about the plant. This is information they cannot readily ascertain simply by looking at the plant (e.g. that it was grown with water consering practices).
we also found an impact on visual cues for branded (versus unbranded) plants. We found that for 28% of the subjects, branded plants (although digitally identical) were perceived as having higher quality compared to unbranded plants, supporting H4. We did not find evidence to support H5 (novice consumers or those with low expertise scores) would evaluate branded plants as having higher quality. Nor did we find evidence to support H6 that novice consumer would use more intrinsic visual cues. In fact, both high involvement or high
expertise consumers used more visual cues (in support of H7) compared to low involvement or low expertise consumers. For a substantial segment of the market (nearly one-third) brands on plants signal higher quality and are an important visual cue in the purchase decision.

4. Associated Knowledge Areas

KA Code	Knowledge Area
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems

Outcome #12

1. Outcome Measures

Number of research programs to develop more effective post-harvest protocols and practices to minimize loss and enhance quality.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	3

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Postharvest food losses are inevitable. However, to some extent most losses can be minimized and this tenet is evident in several of the focus areas of the USDA under Topic V, "Food and Non-Food Products: Development, Processing, Quality and Delivery", in Knowledge Area 503 (Quality Maintenance in Storing and Marketing Food Products). The application of modified atmospheres is an important storage technology; however, some apple varieties, such as Honeycrisp, Empire and McIntosh suffer from sensitivities to the low temperatures and altered atmospheres typically used for extending storage and providing a year-round supply of apple fruit. We intend to improve our understanding of the root causes of CA injury in Honeycrisp and other sensitive apple varieties and develop recommendations to our apple industry that will be useful in maintaining the value of these important varieties. In addition, we will continue to improve our understanding of the biology of aroma compound biosynthesis in apples. We would like to learn more about the fundamentals of the biochemistry and biology of fruity flavors produced by apples and clarify how best to control their synthesis through cultural means (i.e., harvest timing, storage management techniques, and the use of growth regulators).

What has been done

Research to: Improve orchard and vineyard postharvest technologies and postharvest recovery of sugars and pectic polysaccharides from plants; to test and recommend a series of vineyard management strategies that can hasten fruit development and maturation for improved and more consistent high quality grape production in a highly variable climate year to year; determine storage regimens for Honeycrisp and other apples prone to CA injury.

Results

Multiple (1.5-month intervals) 1-methylcyclopropene (1-MCP) exposures were used in combination with air storage to avoid the use of controlled atmospheres for Honeycrisp apple storage. This was the second year we evaluated these treatments. Further, we examined the impact of multiple applications of 1-MCP to avoid CA storage and CA injury of Honeycrisp apple. We found multiple applications improved the quality of air-stored Honeycrisp apple fruit when applied at 15-day intervals at 3 °C, longer intervals were not effective at suppressing ripening.

We have begun to evaluate the genetic basis of the regulation of the formation of branchedchain ester biosynthesis. We have collected tissues from over 40 apple lines varying in their production of the percent of the total esters involving branched-chain precursors (esters of 2-methylbutanoate and 2-methylbutanol). We are using a new analytical technique known as 'nanopore' technology to evaluate allelic differences in the upstream regulatory regions, introns and exons of citramalate synthase genes. Sequence data has been generated and analyses are underway. Tissue is being collected for gene expression analyses. Additional work is in progress sequencing isopropylmalate synthase and acetolactate synthase in green and ripe banana fruit.

4. Associated Knowledge Areas

KA Code	Knowledge Area
205	Plant Management Systems

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

MSU Extension Online IPM Academy

Issue: Integrated Pest Management (IPM) education is crucial for Michigan's agricultural system.
Action: In late 2017, MSU Extension launched the online IPM academy, an interactive program designed to provide a comprehensive and convenient online learning experience. This self-paced course features university experts and a full-service help center with 24/7 technical support and support materials to learn how to easily navigate the course. Current topics include:

- An Introduction to IPM
- IPM Resources at MSU
- Plant Science
- Soils 101
- Identifying and Conserving Natural Enemies
- Conserving Pollinators
- Using Enviroweather to Assist IPM Program Decisions
- Scouting in Greenhouses
- Scouting in Perennial Crops
- Scouting in Vegetable Crops

The course is a combination of videos, resources and interactive content. To participate, a computer with an updated web browser, speakers and internet access are required. Users can complete a systems check to determine if their computer is capable of running the course.
Result: Since going live in fall of 2017, the course has had 167 people register for the course and in 2018, 56 completed all of the course content. Participants who completed the course (N=56, n=48) represent 17,044 acres of ag production and 3,250 sqft of greenhouse production. Sixty-six participants have requested pesticide recertification credits within the state of Michigan (some of those in late 2017). Respondents reported the following improvements and intended changes:

- 77% plan to access MSU IPM resources online (Digests, Scounting reports, pesticide guides, etc.)
- 79% plan to reference weather modeling to make management decisions (e.g. Enviroweather)

- 69% plan to only treat for pests when the economic threshold is reached, as applicable
- 75% plan to support beneficial insect habitat to promote pest control via natural enemies
- 73% plan to select of pest resistant varieties or cultivars
- 67% plan to implement sanitation practices (removal of inoculum, sterilizing implements etc.)
- 79% plan to utilize the least biologically impactful pesticide when management is needed
- 77% plan to protect native pollinators (mowing before spraying, spraying at night, etc.)

Key Items of Evaluation

Synthetic biology may hold key to answering some of the most difficult science questions
https://www.canr.msu.edu/news/synthetic-biology-may-hold-key-to-answering-some-of-the-most-difficult-science-questions
An emerging field -- synthetic biology -- is attempting to broadly address the need for more nutritious food, improved prevention and treatment of diseases, renewable energy sources and protection for the environment.
The scientific community spends much of its time on the challenges surrounding food, health, energy and the environment. The specific problems may differ by location, but the basics are universal: society needs more nutritious food, improved prevention and treatment of diseases, renewable energy sources and protection for the environment.
With a global population estimated to exceed 9 billion by 2050, that's no small task.
One emerging field -- synthetic biology -- is attempting to broadly address these categories, starting at the most foundational of levels.
Synthetic biology has a variety of components, but at its core is understanding the biological functions of molecules to improve or construct new processes. Putting this understanding to work can take the form of developing high-value molecules that perform any number of designated jobs. Implications of synthetic biology advances include breakthroughs in medicine, biofuels, food production and much more.
At Michigan State University (MSU), Bjoern Hamberger is spearheading the charge by taking advantage of expertise across campus.
"'Synthetic biology' is a fairly new term used to describe a very broad discipline that takes principles from many areas of science," said Hamberger, an assistant professor in the MSU Department of Biochemistry and Molecular Biology. "This is all new ground that we're breaking. We have much to learn, but the possibilities are almost limitless. MSU has experts in plant science, human health, engineering -- all areas that advance our understanding and improve synthetic biology."
His team is focused on plants and their specialized metabolites -- compounds synthesized by plants that perform a complexity of functions ranging from growth to defense.
Researchers have identified the diverse utility of metabolites but know relatively little about the processes that yield them. By determining how plants develop substances to defend themselves, for instance, scientists can better understand how to replicate or enhance production of valuable compounds in synthetic systems.

V(A). Planned Program (Summary)

Program # 4

1. Name of the Planned Program

Economics, Marketing and Policy

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
601	Economics of Agricultural Production and Farm Management	35%		10%	
602	Business Management, Finance, and Taxation	40%		7%	
603	Market Economics	0%		10%	
604	Marketing and Distribution Practices	5%		9%	
605	Natural Resource and Environmental Economics	0%		12%	
606	International Trade and Development	0%		11%	
608	Community Resource Planning and Development	20%		10%	
609	Economic Theory and Methods	0%		12%	
610	Domestic Policy Analysis	0%		11%	
611	Foreign Policy and Programs	0%		8%	
	Total	100%		100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2018	Extension		Research	
	1862	1890	1862	1890
Plan	27.2	0.0	7.0	0.0
Actual Paid	28.9	0.0	14.0	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
1510427	0	859965	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
1510427	0	877629	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	5013050	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research programs to:

- Identify current and emerging key public policy issues on trade, environmental, agricultural and food issues important to Michigan and analyze responses.
- Conduct research and education to improve the operations, business and financial management skills of Michigan producers so they can make decisions that are more sound financially and environmentally.
- Evaluate the competitiveness and marketing strategies of Michigan farm markets, greenhouses and other green industry retailers.
- Develop a framework to understand and analyze domestic and international trade policies and assess their impact on Michigan.
- Evaluate how Michigan citizens use the Internet when searching for information about a vacation destination or planning a vacation.
- Determine rationale for farmland preservation choices and how changes will affect the Michigan tax base.
- Develop models to estimate the demand for and value of recreational fisheries and wildlife resources.
- Identify and evaluate the policy, technology and marketing issues faced by Michigan organic growers and develop responses.

Extension program activities to:

- Teach financial management skills, business organization, estate planning, management information systems, strategic management, alternative sustainable production and marketing systems to agriculture and natural resources producers and businesses.
- Assist agencies, organizations, local governmental units and individuals in pursuing a cultural economic development strategy.
- Offer business retention and expansion support.
- Help people recognize, understand and appreciate multicultural differences.
- Provide entrepreneurship education to a broad audience, including individuals, business owners, youth and communities.
- Offer communities consultative, diagnostic and educational assistance in planning and zoning to meet community land use goals.

2. Brief description of the target audience

Agriculture and natural resources producers and industry representatives; tourism industry

representatives; state agency representatives; private citizens; school administrators; local, state and federal elected officials and policymakers.

3. How was eXtension used?

MSU Extension continues to utilize eXtension as one of the primary multi-state activities that involve contributing to Communities of Practice, responding to Ask an Expert questions, and contributing to innovation projects. One example in this area was MSU Extension staff's participation in the Financial Security for All Community of Practice.

V(E). Planned Program (Outputs)

1. Standard output measures

2018	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	11612	34836	1168	2336

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year:	2018
Actual:	0

Patents listed

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2018	Extension	Research	Total
Actual	1	48	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research programs on economics, marketing and policy.

Year	Actual
2018	45

Output #2

Output Measure

- Number of adult participants trained in economics of agricultural production and farm management.

Year	Actual
2018	1643

Output #3

Output Measure

- Number of adult participants trained in business management and finance.

Year	Actual
2018	2360

Output #4

Output Measure

- Number of adult participants trained in community resource planning and development.

Year	Actual
2018	7609

Output #5

Output Measure

- Number of youth participants trained in entrepreneurship.

Year	Actual
2018	1168

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of adult participants with increased knowledge in economics of agricultural production and farm management.
2	Number of adult participants with increased knowledge in business management, finance and taxation.
3	Number of adult participants with increased knowledge in community resource planning and development.
4	Number of research programs to identify current and emerging key public policy issues on trade, environmental, agricultural and food issues important to Michigan and analyze responses.
5	Number of research programs to improve the operations, business and financial management skills for Michigan producers so they can make decisions that are more sound financially and environmentally.
6	Number of research programs to evaluate the competitiveness and marketing strategies and human resources management practices of Michigan farm markets, greenhouses and other green industry retailers.
7	Number of research programs to develop a framework to understand and analyze domestic and international trade policies and assess their impact on Michigan.
8	Number of research programs to develop models to estimate the demand for and value of recreational fisheries and wildlife resources.
9	Number of youth with increased knowledge in entrepreneurship.

Outcome #1

1. Outcome Measures

Number of adult participants with increased knowledge in economics of agricultural production and farm management.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1232

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Many farm business owners struggle with understanding exactly where the business financially stands. Huge production swings, volatile prices, timing of sales and inputs, and changes in inventories, prepaid expenses and unpaid bills make it difficult to get a good measure of actual profitability in an effective structure that not only communicates efficiently to business owners but also to outside appropriate people including consultants, lenders and others. In addition, tight or negative profit margins, changing markets, the ag industry changing structures, new technological advances, have contributed to enhanced need for financial analysis, projections and comparative financial studies to enable producers to make informed logical decisions.

What has been done
MSU Extension provides technical assistance and consultation to farmers and producers to respond specifically to their needs. Services have included financial analyses & projections. Many of these analysis and projections are used to secure operating debts and loan restructures. In 2018, 77 FINANs, 18 FINLRB and 11 FINFLO analysis and/or financial projections were completed with individual personal educational consultations.

Results
Three business expansions were made, resulting in $1,091,001 capital investment stimulating additional ripple effect long-term economic growth. $575,000 is the expected annual increase in revenue. Other farms secured operating capital by securing loans and restructuring debt. Supporting Agriculture families to maintain competitiveness, viability and growth is important for local communities and the state of Michigan. Agriculture is the state?s second largest primary industry. Without primary industries, there is no need for secondary attendant industries such as government, schools, infrastructure, banking and other services.

4. Associated Knowledge Areas

KA Code	Knowledge Area
601	Economics of Agricultural Production and Farm Management
602	Business Management, Finance, and Taxation

Outcome #2

1. Outcome Measures

Number of adult participants with increased knowledge in business management, finance and taxation.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1770

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Small business operations and especially farmers on cash accounting systems for income tax have the ability to strategies when to sell products, buy products and buy capital items to take advantage of financial and production benefits. This has major tax implications from the exposed taxable income. Income tax management goal is to get the maximum income through the tax system as possible, at the lowest cost possible, over time. The overtime part is especially difficult with agricultural operations because of the extremely variable yields, prices and input cost. A farmer has more variability in net income from year to year than nearly any other businesses. Tax professionals often do not have a good sense of probable future earnings.

What has been done
Farm producers enrolled in the MSU Extension Telfarm Record system meet with Extension professionals before the end of the tax year, to manage their taxable income. Fifty-Five (55) mid-Michigan farm families (96 people) met individually to develop their business?s tax management strategy for the current year. An excel spreadsheet is utilized to help people develop their plan. Another Excel Spreadsheet is used to help people target their optimal income. A third Excel file calculates the appropriate starting points for withholdings for the Payroll Program

Results
On average, the tax savings was $34,061 per family totaling $1,873,362 total benefit for the effort. Such savings support farm families and the agriculture industry to be financially strong,

competitive, and keeping these dollars at home has significant economic impact to Michigan and local economies.

4. Associated Knowledge Areas

KA Code	Knowledge Area
601	Economics of Agricultural Production and Farm Management
602	Business Management, Finance, and Taxation

Outcome #3

1. Outcome Measures

Number of adult participants with increased knowledge in community resource planning and development.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	5707

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Different strategies are needed for community success in the demographic and economic realities of today. The challenge for communities is to change perspectives to think about unique regional assets, and develop plans and ordinances that capitalize on those assets. Natural resources, arts and culture, parks and recreational facilities, agriculture, civic organizations, schools, access to health care and an entrepreneurial spirit are all important amenities that a community might leverage as a New Economy asset. Needed now are strategies to make communities more competitive in the New Economy, where talented people, entrepreneurs, and other knowledge workers are the drivers of economic performance. Recognizing the need for new strategies is one thing, but undertaking the needed master plan updates, zoning ordinance amendments, and Placemaking initiatives is a difficult task.

What has been done
The Citizen Planner program helps local planning officials prepare their communities to face the unique challenges of the New Economy. Citizen Planner prepares planning officials by providing a solid foundation in the basics of planning and zoning, and advanced innovative techniques. Topics include Understanding the Planning and Zoning Context, Planning for the Future of Your Community, Implementing the Plan with Zoning, Making Zoning Decisions, Using Innovative Planning and Zoning, and Successfully Fulfilling your Role. In 2018, the Citizen Planner

classroom program was offered at 6 different locations statewide with 134 total participants.

Results
Participants completed post-event evaluations (n=104):

1) 91% reported feeling more confident or much more confident to use their knowledge and skills to be a more effective planning official.
2) 88% reported feeling more confident or much more confident to refer to and find information in their zoning ordinance or master plan.
3) 83% reported feeling more confident or much more confident to suggest new or improved operating procedures or processes for their board or commission?
4) 81% reported feeling more confident or much more confident to answer questions from other members on their board or commission based on their planning and zoning knowledge.
5) 78% reported feeling more confident or much more confident to successfully complete their current term as an appointed or elected official.
6) 72% reported feeling more confident or much more confident to read and understand the information in their packet before the meeting.
7) 69% reported feeling more confident or much more confident to rely on their knowledge rather than depending on planning staff.
8) 67% reported feeling more confident or much more confident to speak up during meetings by asking questions and making comment.

4. Associated Knowledge Areas

KA Code	Knowledge Area
608	Community Resource Planning and Development

Outcome #4

1. Outcome Measures

Number of research programs to identify current and emerging key public policy issues on trade, environmental, agricultural and food issues important to Michigan and analyze responses.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	16

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Our current way of life is heavily dependent on fossil energy use, particularly petroleum. World petroleum production peaked in about 2005 and is set to decline over the next few decades. If we are to maintain the wealth and other benefits that petroleum use has brought to us over the past 100 years or so, we will have to conceptualize, design and build out large scale renewable energy systems, also over the next few decades. Bioenergy and biofuels (liquid fuels made from plant matter) are an essential, "non negotiable" part of a sustainable energy system. The system must be evaluated on its overall performance, not just one or two parts of the system.

What has been done

Research to: develop a dynamic model to analyze the long-run impacts of renewable energy development on fossil fuel supply; provide a more comprehensive understanding of tourist preferences for tourism management and development; provide information that can contribute to better design and better use incentive-based conservation; develop rural Latino communities in Michigan; develop environmentally benign bioprocesses to effectively utilize various renewable resources; visually characterize changes in food and agricultural systems examine the implications of sustainability principles for U.S. agriculture; elucidate the role of economics and law on environmental management; develop, extend and apply economic and ecological theory to analyze economic and ecological trade-offs associated with ecological problems; and to better understand impacts of climate change on crops; sustainable bioenergy systems; telecoupling food security and land use; and integrated farm-based refining for chemical and bio-fuel production.

Results

In 2017, we coauthored a paper with leaders of the CIB that used a marginal analysis approach to estimate the life cycle greenhouse gas emissions (GHGs) of electricity and biomethane produced by four currently operating Italian biogas plants. The biogas is burned on-farm to generate electricity that is then exported to the grid. The marginal lifecycle GHGs of this farm-produced electricity range from -335 to 25 grams CO2 per kilowatt hour (kWh). By comparison, the marginal GHGs of electricity generated by fossil fuels in the European Union (EU) is 752 grams CO2 per kWh. The biogas might also be upgraded to produce pipeline-quality biomethane, a direct substitute for natural gas. The marginal lifecycle GHGs of biomethane potentially produced from the Biogasdoneright? plants range from 10 to -36 grams CO2 per megajoule (MJ) while the corresponding figure for a conventional biogas plant is 27 grams CO2 per MJ. Natural gas in the EU produces 72 grams CO2 per MJ and marginal fossil fuel in the EU generates 115 grams CO2 per MJ. Negative GHG emissions arise largely from avoided emissions of agricultural effluents and residues. We have now involved other colleagues at Michigan State University (eg, Dr. Wei Liao and Dr. Kurt Thelan) and elsewhere (eg, Dr. Tom Richard at Pennsylvania State University) with the CIB and are continuing our efforts to understand and advance farm-based bioenergy systems, including biogas/biomethane and bioethanol. The current status and future directions of these and other sustainable bioenergy modeling efforts are described in our umbrella project renewal application entitled "Sustainable Agroenergy Systems: Understanding and Advancing Three "Win=Win" Examples." We have identified three "win-win" system-level approaches to sustainable bioenergy production, including
biogas/biomethane and bioethanol. These farm/regional approaches economically benefit agriculture and agricultural communities while simultaneously contributing to the solution of other large societal concerns. These concerns include: feeding a growing world population, providing large amounts of renewable, low-carbon energy, reducing greenhouse gas emissions, increasing

soil fertility, increasing wildlife habitat and improving water quality.

4. Associated Knowledge Areas

KA Code	Knowledge Area
601	Economics of Agricultural Production and Farm Management
605	Natural Resource and Environmental Economics
608	Community Resource Planning and Development
610	Domestic Policy Analysis

Outcome #5

1. Outcome Measures

Number of research programs to improve the operations, business and financial management skills for Michigan producers so they can make decisions that are more sound financially and environmentally.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	17

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Natural resource management involves making decisions in the face of both conflicting objectives and great uncertainty about the outcome of those decisions. Two critical shortcomings of historical decision making involving natural resources have been (1) inadequate or inappropriate consideration of uncertainty; and (2) a failure to effectively engage stakeholders in the decision-making process. Decisions made without appropriate recognition of uncertainty have often been based on optimistic judgments of the effects of management decisions because the risks of undesirable consequences are not
properly considered. Many natural resource management "failures", such as commercial fishery collapses, have resulted from this failure to recognize the risks associated with management decisions. There are many examples worldwide of failures to protect stocks from collapse due to overfishing and of unsuccessful, and sometimes costly, attempts to rehabilitate degraded fish populations. Conversely, arbitrary yet conservative adjustments to management strategies to qualitatively account for risk can limit opportunities for socially and economically beneficial uses of

natural resources.

Natural resource management agencies have traditionally involved stakeholders in the decision-making process primarily after the decision problem has been analyzed and a possible solution or decision has been identified. More recently stakeholder groups have been invited to provide input at the start of a decision-making process, but then left out of the analytical steps that lead to the recommendation decision. This approach to engagement lacks transparency, and combined with the, at best, mixed track record of natural resource decision-making, has led to a serious erosion of trust among many stakeholders. Consequently, stakeholders have begun to demand a greater degree of involvement in the management process.

What has been done
Research to: explore, analyze and evaluate the dynamics and economic impact of entrepreneurial activity within the context of MI and global agrifood systems; further the understanding of coupled human and natural systems and sustainability; more broadly develop conceptual and analytically frameworks for understanding, assessing and empirically studying effective innovation in the agriculture, food and natural resource sectors; examine the causes and consequences of Michigan state and local government fiscal challenges; to discern the relationship between entrepreneurship and the Michigan agrifood sector; to develop sustainable energy and business systems; understand agricultural production economics in an environmentally conscious manner; to improve the quality of natural resource management.

Results
During this reporting period we focused on publishing our research on invasive crayfish risk assessment for the State of Michigan, use of otolith microchemistry to inform Chinook salmon movements between Lakes Huron and Michigan, and an assessment of the risks and feasibility of developing and using genetic options to control sea lamprey in the Great Lakes. For these projects we have one paper accepted and four in review. Our work with Lake Erie percid fishery stakeholders continues. Our focus during the reporting period was on refining and running Management Strategy Evaluation simulations for Lake Erie Yellow Perch to assess the expected performance of
candidate harvest policies for this highly valuable commercial and recreational fishery. We have met twice with our stakeholder advisory group and will be presenting our simulation results to them for discussion during summer 2018.

We have begun work with fishery management groups on Lake Huron to guide decision making about lake whitefish, walleye and hatchery-supported salmon fisheries. We will be using a Structured Decision Making approach to facilitate engagement between decision makers and stakeholders and thereby foster a more transparent management process.
Our research on subsistence salmon fisheries in western Alaska continued during the reporting period. We hosted four workshops to discuss trade-offs among competing objectives for salmon fisheries and opportunities for community-based monitoring programs to address critical information needs for salmon fisheries. We also concluded a project to update and apply a stock-assessment and management model for the Canadian-origin component of the Yukon River Chinook salmon
fishery.

4. Associated Knowledge Areas

KA Code	Knowledge Area
601	Economics of Agricultural Production and Farm Management

602 Business Management, Finance, and Taxation
604 Marketing and Distribution Practices

Outcome #6

1. Outcome Measures

Number of research programs to evaluate the competitiveness and marketing strategies and human resources management practices of Michigan farm markets, greenhouses and other green industry retailers.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Tourism is one of the largest industries in Michigan and offers a viable and growing alternative to manufacturing throughout the state. Much of Michigan's tourism industry is directly or indirectly dependent upon outdoor recreation and associated outdoor settings. Full realization of tourism's potential as a form of economic and community development will require both the strengthening of Michigan's existing tourism product as well as the provision of appropriate new product that appeals to today's traveler. Michigan is blessed with a diversity of natural and cultural landscapes and attractions; the project proposed will investigate ways in which to capitalize upon these resources while minimizing negative impacts on their availability and quality, thereby maintaining the image on which the multiple-award winning "Pure Michigan" tourism marketing campaign continues to be built.

What has been done
Research to:investigate ways in which to capitalize upon resources while minimizing negative impacts on their availability and quality,thereby maintaining the image on which the multiple-award winning "Pure Michigan" tourism marketing campaign continues to be built.

Results
Numerous activities contributed to improved understanding of the importance of tourism - as well as the importance of specific natural
resource-based tourism assets such as water and trails - among community members (including the tourism industry, elected officials, economic development and planning staff, and residents).

Such efforts encourage both increased/improved (i.e., more effective) marketing of these assets, as well as increased awareness of the need to protect their integrity and quality. Other activities contributed to the development and application of new methods to natural resource/environment-related issues, in particular their more effective planning and management. With respect to the second goal, focusing on international students: A journal article related to this topic was accepted for publication with an expected publication date in 2017 (Nicholls, S. (forthcoming). Influences on International Student Choice of Study Site: Evidence from the United States. Accepted for publication in Journal of International Students in January 2017).

4. Associated Knowledge Areas

KA Code	Knowledge Area
602	Business Management, Finance, and Taxation
603	Market Economics
604	Marketing and Distribution Practices
608	Community Resource Planning and Development
609	Economic Theory and Methods

Outcome #7

1. Outcome Measures

Number of research programs to develop a framework to understand and analyze domestic and international trade policies and assess their impact on Michigan.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	8

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The world population is growing and is expected to reach 9 Billion by the year 2050.The food and nutritional security will become a critical global issue. With the emerging trends of globalization, agriculture has become a global sector.Our food systems and agribusinesses are global and international trade is increasing each year.Private sector is expected to play a vital role and public-private sector partnerships (PPPs) are growing.

International collaboration and cooperation is a hallmark of Michigan State University (MSU). MSU continues to play a pivotal role in international agricultural research and development through collaborative research, education, and outreach programs throughout the world. The College of Agriculture and Natural Resources (CANR) at MSU has had a long history of internal agriculture development. Numerous scientists associated with MSU AgBioResearch are actively engaged in collaborative research programs. MSU laboratories are becoming "global laboratories." Developing countries are becoming countries of opportunities.
Agriculture is global and there are opportunities for MSU scientists to collaborate with international scientists to solve some of the most important and pressing issues/problems in food and agriculture. Global collaboration is essential for a productive Michigan agriculture. All of our genetic diversity is from collaboration with international scientists since the USA does not have any genetic diversity for most of our major food crops. In addition to the genetic diversity, collaboration with international scientists allows our scientists to develop and test their theories in many diverse microclimates. Collaboration with international scientists will help MSU scientists identify technologies that will help make Michigan's agriculture more sustainable and profitable.

What has been done
Research to: provide economic analysis of agricultural production technologies and management practices related to the many agricultural enterprises important to Michigan farmers; better understand the supply chains of various horticultural products; and identify ethical issues in agriculture; and increase innovation, entrepreneurship and sustainability in MI and globally in agri-food and value chains; and global partnership for food security and economic growth.

Results
The World Technology Access (WorldTAP) Program Team continues to identify and facilitate international transfer of MSU AgBioResearch generated and other relevant technologies that have potential and need further in-depth research and market analysis for piloting, scaling-up and commercialization in emerging international markets for mutual benefits. These technologies include:
1. DNA-based Rapid Plant Pathogen/Plant Disease Diagnostic Kits for Small-holder Farmers, Extension Services, Private Companies, Ports, and Health Departments - Dr. Brad Day and Dr. Dave Kramer
2. Solar Powered Cooling Chambers for Storage of Perishable Food Products in Developing Countries (fresh fruits and vegetables, seeds and planting materials) - Dr. Randy Beaudry
3. AFEX Technology - Use of Crop/Plant Residue for Animal Feed and Alternative Energy Source - MBI/MSU Technology - Dr. Bobby Bringi - MSU College of Engineering and Michigan Biotechnology Institute (MBI)
4. Crop Varieties and germplasm developed by MSU Plant Breeders including Soybean and Potato Varieties - Dr. DeChun Wang, Dr. David Douches.
5. Biological Control Technology for the control of Malaria Vector using Wolbachia Bacteria - Dr. Zhiyong Xi

4. Associated Knowledge Areas

KA Code	Knowledge Area
601	Economics of Agricultural Production and Farm Management
605	Natural Resource and Environmental Economics
606	International Trade and Development
610	Domestic Policy Analysis

611 Foreign Policy and Programs

Outcome #8

1. Outcome Measures

Number of research programs to develop models to estimate the demand for and value of recreational fisheries and wildlife resources.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

The contributions of Michigan's natural resources to the State's economic health are widely cited. Land, water, forest resources, fish and wildlife and associated habitat, and ecosystem functions and services are but a few of the critical resources that play a significant role in numerous sectors of Michigan's economy. While discussions of sustaining a sufficient quantity of these critical resources are common, debate has tended to focus on how much of the resource can or should be used in total, with less direct attention to questions raised by competition for the resource. While resource users express concerns about the quality and quantity of the state's natural resources, state policy has not kept pace with the resource competition and resource degradation concerns, nor the restoration and regeneration needs, evidenced by the state's natural resource issues. One example lies in Michigan's statutory framework for managing water use within the context of the Great Lakes - St. Lawrence River Basin Water Resources Compact (the Compact). While Michigan's program provides for monitoring large extractions of water resources, it does not account for return flows of water withdrawn into affected watersheds or large clusters of small, individual withdrawals. Nor has its proposed process for managing competition and conflict been tested.

Innate inconsistencies between the state's common law for water use and state statutes developed in 2008 will create additional challenges for water resource management in Michigan. Reconciling the statute and common law as water scarcity arises in some watersheds will prove challenging, and involvement of large-quantity water users (and others) in decisions about how scarce water resources will be allocated is envisioned by statutes as a way to ameliorate such conflicts. However, water users in Michigan have little experience in collaborative governance and resource management, and challenges are inevitable.

What has been done
Research to: identify and evaluate natural resource governance models for effective policy and management of local, regional and state-level natural resource problems in Michigan.

Results
Research on irrigation water demand in regions where irrigation
water is supplemental to rainfall is very limited. Results indicate that irrigation water demand is sensitive to temperature and preciptation levels, which suggests increased demand as a result of climate change impacts. Irrigation water demand is also sensitive to the cost of energy used to pump water (where energy cost is a proxy for water price in a region where users do not pay for the water itself). Collaboration among water users in the interest of negotiating over water allocations in water-scarce management areas
has not materialized. However, research is ongoing, and work is underway to assess where in MI the kind of conflict that could lead to a desire for collaboration is most likely to occur. Research results indicate that those who spend more time in outdoor activities are more concerned about climate change impacts and the associated effects on natural resources and outdoor activities. This information is useful to local governments as they work toward climate change adaptation programs and policies.

4. Associated Knowledge Areas

KA Code	Knowledge Area
603	Market Economics
605	Natural Resource and Environmental Economics

Outcome #9

1. Outcome Measures

Number of youth with increased knowledge in entrepreneurship.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	876

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Youth need information and opportunities to explore their future careers and interests, and build entrepreneurship skills.

What has been done

MSU Extension 4-H programs are youth focused and designed to increase life skills and leadership skills, increase leadership and employability skills, and engage youth as active citizens and the leaders of today. One example is the Generation E Program, which is an intensive youth entrepreneurship program. In this program, young people create, develop, and sell a product. Each business starts with an idea for a product or service, and develops a prototype while figuring out the cost to produce the product. The students then develop a pricing strategy, marketing plan, and find venues to sell their products. Participants work through the development of their business plan and complete their financials to determine their profits. Business plans are then submitted for the statewide Generation E Youth Business Showcase held in Battle Creek. Seventeen youth from Delta County participated in the Generation E Entrepreneurship program developing five businesses.

Results

Youth participating in all long term Michigan 4-H entrepreneurship programs (N=93) were evaluated. As a result of participating in a 4-H entrepreneurship program:

1) 95% of participants agree or strongly agree that they understand what it means to be an entrepreneur.
2) 95% of participants agree or strongly agree that they know how to effectively communicate with customers.
3) 95% of participants agree or strongly agree that are aware of the finances involved in running a business.
4) 95% of participants agree or strongly agree that they understand how to use marketing strategies.
5) 93% of participants agree or strongly agree that they can identify resources needed to develop a business.
6) 96% of participants agree or strongly agree that they aware of how they could use their skills to become an entrepreneur.
7) 85% of participants plan to pursue further education about business/entrepreneurship.
8) 93% of participants plan to use their entrepreneurial skills in the future.
9) 75% of participants plan to start their own business.

4. Associated Knowledge Areas

KA Code	Knowledge Area
602	Business Management, Finance, and Taxation

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Competing Public priorities
- Competing Programmatic Challenges
- Populations changes (immigration, new cultural groupings, etc.)

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Beginning Farmer Webinar Series

Issue: Michigan citizens interested in engaging in new agricultural enterprises sometimes lack knowledge, experience and technical support to get started. Extension educators and specialists receive numerous contacts from such people seeking basic, start-up information. The Michigan State University Extension Beginning Farmer Webinar Series was developed in response to this need.

Action: The 2018 series featured fifteen evening webinars from January 17 through April 25 on topics of interest to beginning farmers. Webinar length was shortened from 2 hours in past years, to 30 - 60 minutes based on clientele input. Seventeen presenters, including fourteen MSU staff and three private or agency people were involved. Three hundred three participants registered for 3,820 webinar views, including two hundred fifty six people from sixty one Michigan counties and sixty one people from fourteen other states and seven other countries.

Results: A follow-up on-line evaluation was conducted using Survey Monkey after the series was completed. One hundred eleven responses were collected for a response rate of 33%. The total amount of agricultural land which 91 respondents indicated is, or will be, influenced by what they learned from webinars is roughly 3,816 acres, with a median response of 2-4 acres and a mean response of roughly 42 acres.

- As a result of the series, 85% plan to use the MSU Extension Beginning Farmer Webinar Series website, 84% plan to use the MSU Extension website, 67% plan to use MSU Extension print bulletins, 61% plan to utilize MSUE educators and offices, 59% plan to use other materials mentioned
- Respondents indicated that they have, or will, diversify or expand a farm or other ag business (44%), begin cultivating a crop in Michigan (23%), start up a new business (26%), purchase farm equipment (20%), begin a new livestock or poultry enterprise (23%), improve their standing at a current job or apply for a new job (11%), decide not to cultivate a crop in Michigan (5%), and establish new business partners (3%)
- Fifteen respondents indicated that the series resulted in creation of new jobs (15 new

jobs).
New and expanding farm businesses provide jobs, income, increased economic and social stability, and increased food security to rural and other communities. Providing basic, practical information on sound production practices, business management and marketing to people interested in, or already engaging in, new and expanding farm enterprises of any size helps these small businesses succeed.

Key Items of Evaluation

Growing new soybeans for Uganda
https://www.canr.msu.edu/news/growing-new-soybeans-for-uganda
Long before people started keeping agricultural records, they were growing soybeans. Archaeological digs in East Asia have revealed that domestication of the crop stretches back almost 9,000 years. Since then, soybean cultivation has expanded to nearly every corner of the globe.
Though raw soybeans are toxic to most mammals, including humans, cooked soybeans are an excellent source of essential nutrients such as protein, dietary fiber, iron, manganese, phosphorus and vitamin B.
Soybean oil plays an important role in cooking, baking and food processing, as well as in biodiesel production and other industrial applications. Soymeal - the plant matter left over once the oil has been extracted - is a reliable source of livestock feed throughout the world. Like other legumes, soybeans also function as nitrogen-fixers, improving soil health by restoring the nitrogen lost during the cultivation of other major crops such as corn.
Phinehas Tukamuhabwa, director of the Makerere University Agricultural Research Institute in Uganda, has been studying and breeding soybean varieties that meet Ugandan farmers' needs since 1990.
In 2015, Tukamuhabwa attended a workshop in Brazil for African scientists and policymakers. The gathering was coordinated by the African Biosafety Network of Expertise, a network launched in 2008 through a partnership between Michigan State University (MSU) and the New Partnership for Africa's Development. The network works to help African nations improve their decision-making capacity on biosafety and biotechnology topics.
While in Brazil, Tukamuhabwa observed genetically modified soybeans growing in the field. During a subsequent visit to MSU, he met Karim Maredia, professor in the MSU Department of Entomology and director of the World Technology Access Program, or WorldTAP.
"Karim and I discussed soybeans and issues farmers in Uganda face while growing them," Tukamuhabwa explained. "He put me in touch with the researchers at MSU, and through them we were able to acquire new soybean varieties with traits that could make a tremendous impact on our soybean industry."
Through Maredia, Tukamuhabwa met MSU AgBioResearch soybean geneticist Dechun Wang, who used soybeans featuring a genetically modified trait that rendered them resistant to glyphosate herbicides, namely Roundup, in his soybean breeding program. Common in agriculture in the United States, glyphosate-resistant soybeans allow farmers to spray their fields with highly effective glyphosate herbicides, wiping out weeds quickly, efficiently and cost-effectively, without damaging their crops.

V(A). Planned Program (Summary)

Program # 5

1. Name of the Planned Program

Animal Production and Protection

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
301	Reproductive Performance of Animals	0%		14%	
302	Nutrient Utilization in Animals	0%		10%	
303	Genetic Improvement of Animals	0%		10%	
304	Animal Genome	0%		10%	
305	Animal Physiological Processes	0%		9%	
307	Animal Management Systems	80%		10%	
308	Improved Animal Products (Before Harvest)	0%		3%	
311	Animal Diseases	10%		13%	
314	Toxic Chemicals, Poisonous Plants, Naturally Occurring Toxins, and Other Hazards Affecting Animals	0%		2%	
315	Animal Welfare/Well-Being and Protection	0%		11%	
605	Natural Resource and Environmental Economics	5%		8%	
806	Youth Development	5%		0%	
	Total	100%		100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2018	Extension		Research	
	1862	1890	1862	1890
Plan	14.1	0.0	9.0	0.0
Actual Paid	17.7	0.0	13.0	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
930683	0	783524	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
930683	0	799617	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	4567446	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research programs to:

- Understand the processes that control/influence reproduction at the molecular and genetic level.
- Develop and test new cropping, grazing and feeding strategies for food animals.
- Develop and evaluate management/training strategies for race horses to reduce injuries.
- Add to the understanding of various food animal genomes by improving and integrating genetic maps.
- Understanding of the genetic and molecular processes that control/influence the immune system in food animals to create new disease detection and tracking technologies.
- Develop and evaluate new tools and strategies to detect, prevent and control emerging and reemerging livestock and poultry diseases.
- Understanding of the environmental fate and biological effects of vaccines, steroids and other drugs fed to animals.

Extension activities to:

- Assist beef producers with implementing the mandatory electronic identification system and demonstrate methods to use the system to sharpen management skills.
- Provide livestock producers with knowledge and skills to develop and maintain herd-health systems.
- Provide animal industry with up-to-date animal health information.
- Improve farm-specific environmental stewardship related to manure management, including developing whole-farm nutrient management plans, manure value, land use and neighbor relations.

2. Brief description of the target audience

Michigan animal producers, agriculture and natural resources industry representatives, animal pharmaceutical industry, animal welfare organizations, state agency representatives, state and local elected officials and the interested public.

3. How was eXtension used?

MSU Extension continues to utilize eXtension as one of the primary multi-state activities that involve contributing to Communities of Practice, responding to Ask an Expert questions, and contributing to innovation projects. One example in this area was MSU Extension staff participating in the "Livestock and Poultry Environmental Learning Center" Community of Practice.

V(E). Planned Program (Outputs)

1. Standard output measures

2018	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	9582	28746	76541	153082

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year: 2018

Actual: 2

Patents listed

MICL02434, Mechanism of Cellular Reprogramming During Somatic Cell Nuclear Transfer (SN 15/326,863); MICL02470, Molecular Mechanisms Associated with Turkey Skeletal Muscle Growth and Meat Quality (SN 62/443,998)

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2018	Extension	Research	Total
Actual	5	43	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research programs on animal production and protection.

Year	Actual
2018	43

Output #2

Output Measure

- Number of adult participants trained in animal management systems.

Year	Actual
2018	9582

Output #3

Output Measure

- Number of youth participants trained in animal management systems.

Year	Actual
2018	76541

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of adult participants with increased knowledge about animal management systems.
2	Number of youth participants with increased knowledge about animal management systems.
3	Number of research programs to understand the processes that control/influence reproduction at the molecular and genetic level.
4	Number of research programs to add to the understanding of various food animal genomes by improving and integrating genetic maps.
5	Number of research programs to develop and evaluate new tools and strategies to detect, prevent and control emerging and reemerging livestock and poultry diseases.
6	Number of research programs to understand the environmental fate and biological effects of vaccines, steroids and other substances fed to animals.
7	Number of research programs to develop and evaluate management/training strategies for horses to reduce injuries.
8	Number of research programs to add to the understanding of animal behavior and welfare.
9	Number of research programs to test new cropping, grazing and feeding strategies for food animals.

Outcome #1

1. Outcome Measures

Number of adult participants with increased knowledge about animal management systems.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	7187

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
In early 2018, Cargill Inc. and Tyson Foods announced that they would require producers be certified in the Beef Quality Assurance (BQA) program in order for them to buy cattle from those producers. Cargill and Tyson are make up a major part of the finished beef cattle harvest capacity in the United States. Producers that eliminate them from the bidding pool are likely to receive severe discounts for their finished cattle. The BQA program has been instrumental in improving beef quality in the United States since its inception over 45 years ago. However, while producers have learned much of the BQA concepts through an educational process, relatively few producers have actually taken the time and effort to become certified.

What has been done
MSU Extension educators and specialists conducted 13 certification programs across Michigan in 2018. Each session consisted of a two hour presentation followed a 15 question test. Producers needed to obtain 80% correct to achieve certification. Certified producers received a unique certification number and certificate. Their certification credentials were passed onto sale barns if they so desire. Producers failing the test on first attempt were offered another short presentation and allowed to retake the test. Initial passing rate was at 97% with 100% passing on the second attempt.

Results
In 2018, 1441 beef producers obtained BQA certification through MSU Extension trainings, 757 with in-person meetings and 684 online. Recent reports from Michigan auction yards indicate that producers who are not BQA certified are experiencing lower sales values compared to cattle being sold by certified producers. Consequently, Michigan producers are finding important economic value to the certification program and likely more producers will be seeking certification programs in the near future.

4. Associated Knowledge Areas

KA Code	Knowledge Area
307	Animal Management Systems
311	Animal Diseases

Outcome #2

1. Outcome Measures

Number of youth participants with increased knowledge about animal management systems.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	57406

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Youth need opportunities and information to learn about animal management systems and related science that will lead to improved life skills and help in exploring new careers.

What has been done
One example is MSUE hosted the Michigan 4-H Dairy Conference for youth and adults with the following objectives:

1) Provide 4-H youth and adult leaders the opportunity to learn more about the Michigan dairy industry.
2) Teach skills in areas of dairy science and management.
3) To give conference participants opportunities to explore new ideas in-depth and get hands-on experience.

The attendees spent 3 days exploring ideas, research and hands-on activities relating to dairy science and biology. Youth and adult participants were given the opportunity to participate in a variety of sessions, including: comparative anatomy dissection of sheep, cattle, and pig eyes; learning about mating strategies to improve herd health, BLV, calf respiratory health, winter animal management, sire selection, career exploration, dairy communication, and dairy judging.

Results
Forty-one youth (62% of participants) voluntarily submitted a retrospective post-then-pre evaluation of their experience at the conference.

1) 92% of respondents indicated an interest and engagement in science after the conference compared to 87% before the conference.
2) 79% of youth indicated positive attitudes and aspirations towards science after the conference compared to 69% before the conference.
3) 77% of youth demonstrated a capacity for science process skills after the conference compared to 75% before the conference.
4) 84% of youth demonstrated the ability to think critically and understand informed decision making after the conference compared to 80% before the conference.
5) 92% of youth were felt more knowledgeable about entrepreneurship and career opportunities in science-related fields compared to 75% before the conference.

4. Associated Knowledge Areas

KA Code	Knowledge Area
307	Animal Management Systems
311	Animal Diseases
806	Youth Development

Outcome #3

1. Outcome Measures

Number of research programs to understand the processes that control/influence reproduction at the molecular and genetic level.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	11

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Reproductive efficiency is a major determinant of the economic success of beef and dairy operations. For example, in the dairy industry, conception rates in lactating cows have decreased

from 66% in 1951, to a less desirable level of 35% or less today. Poor conception rates have a detrimental impact on days open and increase reproductive culls form the herd Thus, total reproductive inefficiencies from culling and lost milk due to extended calving intervals account for significant economic loss to dairy producers (> $90 per cow) of over $2.4 billion annually. In domestic ruminants, embryonic and fetal death may account for up to 75% of all reproductive loss following a single breeding. The causes of infertility in beef and dairy cattle remain poorly understood but may be attributable in part to ovulation of eggs (oocytes) of poor developmental competence. Poor oocyte competence is also the major factor limiting efficiency of reproductive biotechnologies (in vitro embryo production and nuclear transfer/cloning) in bovine species. Acquisition of oocyte competence is controlled by the interaction of genetics, the hormonal environment and the intrafollicular microenvironment. Despite decades of research, the fundamental questions remain of what makes an egg good or bad and how to improve egg quality in a laboratory setting or on farm.

What has been done

Research to: understand the impact of animal agriculture on the modern society; develop new methods to improve fertility and reproductive efficiency in livestock; investigate potential effects of exposure to environmental contaminants in humans and animals, with an emphasis on reproductive performance; develop a local/regional pasture-based beef production system encompassing the entire beef production chain; and to assess the impact of Ovsynch on conception rates of lactating dairy cows.

Results

Caudal-type homeobox transcription factor 2 (CDX2) plays a crucial role in formation and maintenance of trophectoderm in preimplantation embryos. We previously established that exogenous follistatin supplementation during the initial 72h of in vitro culture of bovine embryos results in a significant increase in blastocyst development, CDX2 expression and trophectoderm cell numbers. We have also found similar effects of follistatin supplementation on somatic cell nuclear transfer (SCNT) embryos. However, the mechanisms by which follistatin augments CDX2 expression and embryo development are not fully understood. The current study investigated whether stimulatory effects of follistatin are linked to a loss of DNA methylation within key regulatory regions of the CDX2 gene in d7 bovine SCNT blastocysts. SCNT zygotes were cultured in the presence of 0 or 10 ng/ml of recombinant human follistatin for 72h, then washed and cultured in fresh culture media until d7 when blastocysts were collected (n = 15 blastocysts/pool; n = 6 replicates) and subjected to CDX2 mRNA analysis and bisulfite sequencing. CpG island prediction for the bovine CDX2 gene sequence (GenBank: AM293662) demonstrated multiple CpG islands upstream and downstream of the transcription start site. Two different fragments within the promoter region (fragment P1; -1180 to -1760; P2, -241 to -745) were selected for bisulfite-sequencing analysis. Consistent with our previous results, follistatin supplementation triggered a significant increase in blastocyst rates (31.34 Vs 20.04 % for follistatin treated versus control respectively) and CDX2 mRNA expression. A differentially methylated pattern on specific CpG sites was revealed for fragments P1 and P2 in response to follistatin supplementation. There was a positive effect of follistatin treatment on hypomethylation of a subset of the DNA fragments. For example, the overall methylation of fragment P1 in SCNT control group was 1.9 % vs 0.4 % for follistatin treated group with a single CPG site that was hypomethylated in follistatin treated
group. For Frag P2, the overall methylation in SCNT embryos was 4.4 and 3.6% for control and follistatin treated group respectively. Analysis of CPG methylation revealed 7 potential differentially methylated sites, 4 CPG site were hypomethylated and 3 were hypermethylated in

follistatin treated group. Analysis of transcription factor binding sites using MatInspector (Genomatix) combined with a literature search revealed a potential association between differentially methylated CpG sites and binding sites for numerous transcription factors that regulate and (or) are regulated by the TGFβ superfamily. These transcription factors include, but are not limited to homeodomain transcription factors (HOMF), E2F transcription factors, and Activating protein 2 (AP2).

4. Associated Knowledge Areas

KA Code	Knowledge Area
301	Reproductive Performance of Animals
303	Genetic Improvement of Animals
304	Animal Genome
305	Animal Physiological Processes
314	Toxic Chemicals, Poisonous Plants, Naturally Occurring Toxins, and Other Hazards Affecting Animals

Outcome #4

1. Outcome Measures

Number of research programs to add to the understanding of various food animal genomes by improving and integrating genetic maps.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Improvements in productivity and efficiency are critical for maintaining profitability of the US pork industry. However, increases
in lean growth rate are frequently associated with higher incidences of inferior quality meat. Differences in gene expression account in large part for the variation observed in animal growth and meat quality. The project objectives are to: 1) Conduct an analysis to identify locations in the pig genome corresponding to expression of genes from skeletal muscle of pigs from the Michigan State University Duroc x Pietrain resource population; 2) Determine gene regulatory networks controlling growth, carcass merit and meat quality phenotypes; 3) Verify the functional roles of candidate genes in cultured muscle cells; and 4) Evaluate the genomes and transcriptomes of

pigs to reveal RNA editing events in a range of tissues including brain, heart, skeletal muscle, adipose, kidney, lung and liver. Expected results of this project will increase knowledge of genetic mechanisms and identify genes controlling variation in muscle growth, carcass composition and pork quality. This fundamental knowledge
will lead to new strategies for enhancing efficiency of lean growth, and improving quality and consistency of pork in swine breeding programs.

What has been done
Research to: develop a new set of tools and reagents to study autologous cell therapy using a new large animal model; enhancing efficiency of lean growth, and improving quality and consistency of pork in swine breeding programs

Results
We have used the Michigan State University three-generation F2 Duroc-Pietrain resource population to identify expression quantitative loci (eQTL). Single nucleotide polymorphism (SNP) marker genotypes were previously obtained for the F0, F1, and a portion of the F2 pigs using the Illumina SNP60 BeadChip. For this project, total RNA from longissiums dorsi (LD) muscle samples from 176 F2 pigs was used to obtain transcriptional profiles for both mRNA and mircoRNA, and the SNP and transcript data were combined for genetical genomics analyses. For microRNA analyses, target genes for 15 miR-eQTL were identified. Target genes negatively correlated (FDR<0.05) with their associated miRNA's expression were co-localized with phenotypic QTL (pQTL), yielding three miR-eQTL miRNAs with 29 total target genes overlapping pQTL. For mRNA eQTL analyses, we mapped a total of 334 eQTL (FDR<0.01) with 187 exhibiting local acting regulation. Joint association of eQTL
with pQTL segregating in our population revealed 16 genes significantly associated with 17 pQTL for meat quality, carcass composition and growth traits. This dataset was also used to evaluate allele-specific expression (ASE). We tested for ASE in 69,502 coding SNP (cSNP) called directly from the longissimus muscle transcriptomes. A total of 18,234 cSNP with significant ASE were identified (FDR<0.01), corresponding to 4,170 genes with significant allele-specific effects (FDR<0.01). Another project initiated in the past year involved determination of changes in CpG methylation status (whole-genome bisultife sequencing, WGBS) and transcript abundance (RNAseq and miRNAseq) in LD muscle samples from pigs at 41 days of
gestation and 70 days of gestation (n=3 per stage). We identified 17,710 differentially methylated (DM) regions (3,518 hypermethylated and 14,192 hypomethylated at 70dg versus 41dg), which were enriched among gene promoters. Differentially expressed genes (895 upregulated and 718 downregulated, FDR<0.05) were enriched among 3,911 DM genes.

4. Associated Knowledge Areas

KA Code	Knowledge Area
304	Animal Genome
305	Animal Physiological Processes

Outcome #5

1. Outcome Measures

Number of research programs to develop and evaluate new tools and strategies to detect, prevent and control emerging and reemerging livestock and poultry diseases.

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	11

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Johnes disease (JD) is a chronic bacterial disease of wild and domestic animals, including sheep, cattle, deer, and goats. Animals with clinical Johnes disease typically have persistent diarrhea, progressive weight loss, and eventually die due largely to inflammation in the small intestine. The symptoms of clinical JD are very similar to human Crohns disease. In fact, the bacteria that causes JD, mycobacterium paratuberculosis or MAP, is suspected as a cause of some cases of human Crohns disease. JD currently ranks as one of the most costly and widespread diseases of dairy cattle, costing the industry as much as $1.5 billion per year. There are no cost-effective therapies for JD and vaccines, which are currently not used in the U.S., do not prevent infection and spread to other animals. JD thus represents a significant threat to our US dairy industry, may have important food safety implications, and reduces overall animal health and welfare. Our long-term objective in this project is to
use the tools of modern genetics and immunology to understand why only some cattle get sick following infection with MAP, and if it is possible to breed cattle more resistant to the devastating effects of clinical JD. Our project is unique in several ways: First and foremost, the new Translational Genomics Program from USDA-NIFA has provided a funding source with enough time and enough funds to allow us to track animals over a long period of time. This is critical in JD research since the disease can take 2 to 5 years to develop following initial infection. Second, the tests used to determine if an animal is infected are not very sensitive and the response to each test can vary with time. In our new program, we will be testing the same animals repeatedly over several years at regular intervals to ensure our results are as accurate as possible. In addition, we will be introducing new testing techniques based on our prior knowledge of how the immune system of cows responds to infection with MAP (studies
that were also supported through USDA-NIFA). Third, because our work will enhance knowledge of basic immune responses in cattle, this project will enhance knowledge across many different diseases in cattle. Finally, funding from this program will provide detailed genetic information on a

large number of cattle that will be useful well beyond our own research. Through existing collaborations, our resources will advance research in nutrition, reproduction, and other diseases. In our final objective, we will work with dairy producers and breeders to ensure our results are used in the industry to breed cattle that are highly resistant to JD, improving profitability, animal welfare, and the overall safety of our food supply.

What has been done

Research to: derive useful information on emerging infectious diseases; develop new interventions to reduce antimicrobial resistance when treating animals with antimicrobial drugs and develop a new non-antibiotic treatment option for mastitis in dairy cows; dissect the mechanism of representative members of enzymes; determine if discontinuing the use of milk replacer medicated with antibiotics results in increased antimicrobial susceptibility in enteric organisms; to elucidate the molecular mechanisms that control phenotypic variation in economically important pig production and meat quality traits; and understand the role of bovine leukemia virus (BLV)infection on progression of clinical Johnes disease.

Results

Bovine Leukemia Virus (BLV) is a disease of growing concern in the dairy industry. BLV is a delta-retrovirus, similar in structure to human immunodeficiency virus (HIV). BLV can cause lymphocytosis through unregulated proliferation of B-cells. The prevalence of BLV has grown over the years with 83% of US dairy herds containing infected cows. BLV is transmitted horizontally through bodily fluids, likely by veterinary practices. BLV causes decreased milk production and increased risk of infected cows being culled, possibly due to reduced immune function. This results in large economic losses for producers. Our previous results established that BLV infection reduced total and antigen specific IgM levels in serum in infected cows, relative to uninfected herdmates. Our goal in these studies was to determine if BLV infection also altered antibody levels in the milk
and saliva of infected cows.

Methods

Using Enzyme Linked Immunosorbent Assay (ELISA) paired samples were tested for total antibody levels in BLV+ and BLVcows in serum (n= 34+,15-), milk (n=71+, 54-), and saliva (n=10+,10-). Dilutions of milk, serum, and saliva were previously determined experimentally and designed to fall within the linear range of a standard curve generated as recommended by the manufacturer.

Results

We noted a significant ($p<0.05$) decrease in total IgM concentration in milk from BLV+ cows, compared to BLV- cows. In contrast, there was a significant ($p<0.05$) increase in IgA concentration in serum from BLV+ cows, compared to BLVcows. Total antibody levels show considerable variability in saliva and are currently being normalized by using total protein concentrations.We leveraged samples from a USDA sponsored Johne's disease immunity study to investigate associations between BLV status and alterations in various T cell parameters. Differences in percentage of cell types were evaluated using a linear
model including fixed effects of farm, age, JD and BLV testing status. Analyses were carried out using the stats package in R. As expected, we observed a dramatic increase in the percent of B cells in PBMCs from BLV+ cows, relative to BLV- cows. There were significant concomitant reductions in percentage of CD4+, CD8+, and gamma-delta(gd) T cells. Both CD4+ and CD8+ cell populations from BLV+ cows contained more cells expressing the CD25 (IL-2R) activation marker than similar populations from BLV- cows. Stimulation with MAP antigens or PWM did not change this pattern, although the overall CD25+
populations increased, as expected. In contrast, gdT cell populations in PBMCs from BLV+ and BLV- cows expressed similar levels of CD25. Another gdT cell activation marker, MHCII, was

expressed on significantly more cells in PBMCs from BLV+cows than from BLV- cow cells. We conclude that BLV infection has several significant effects on T cells in PBMCs from infected cows. CD4+, CD8+ and gdT cell populations all appear to contain increased numbers of activated cells based on CD25 expression for CD4+ and CD8+ and MHCII for gdT cells. In all cases, these cells are capable of responding to mitogenic stimulation, but differences between cells from BLV+ and BLV- cows remain during this response. Mechanisms behind the effects of BLV will be subject to further study.

4. Associated Knowledge Areas

KA Code	Knowledge Area
303	Genetic Improvement of Animals
305	Animal Physiological Processes
308	Improved Animal Products (Before Harvest)
311	Animal Diseases
315	Animal Welfare/Well-Being and Protection

Outcome #6

1. Outcome Measures

Number of research programs to understand the environmental fate and biological effects of vaccines, steroids and other substances fed to animals.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Antimicrobial resistance bacteria (AMRB) is increasing globally and poses a serious threat to human and animal health (Roca et al., 2015). AMRB is recognized as one of the greatest threats to human and animal health worldwide (Llor & Bjerrum, 2014). Just one organism, methicillin-resistant Staphylococcus aureus (MRSA), kills more Americans every year than emphysema, HIV/AIDS, Parkinson's disease and homicide combined (Infectious Diseases Society of America, 2011). Globally, 20% and 3.7% of new cases of previously treated cases of tuberculosis are estimated to be caused by strains that are resistant. For decades, these antituberculosis drugs were effective against

tuberculosis, but today the effect is insufficient. Currently, only one-half of multidrug-resistant tuberculosis is effectively treated
with the existing drugs (World Health Organization, 2014). Extensively drug-resistant tuberculosis has been identified in 84 countries globally. There is a striking lack of development of new drugs active against these multidrug-resistant Gram-negative bacteria, particularly those producing carbapenemases and none of the antibiotics currently available are now effective (Boucher et al., 2013). This increase in resistance is believed to be caused by a wide range factors (Ventola, 2015); however, the linkages between the hypothesized root causes and observed increase in AMRB is not well understood and the parameter
space must be defined and measured (Martínez & Baquero, 2014). The lack of understanding is due to the highly complex nature of AMRB and is likely due to multiple interacting and synergistic factors:
? within the AMRB microbiome;
? within AMRB disease hosts;
? the selection pressure being applied to bacterial species by humans via the use various antimicrobials in humans and livestock;
? the environmental persistence of antimicrobial compounds in human engineered and natural environments (e.g., healthcare settings, farms, food processing facilities);
? the environmental persistence of AMRB in engineered environments and in nature;
? the persistence of AMRB in wildlife, humans, and livestock; and,
? the transmission dynamics between all living organisms.

What has been done
Research to: develop models that better reflect the heterogeneity in effects of causal variants and their associations with high density genetic markers across the genome; describe, measure, and model antimicrobial resistant bacteria transmission dynamics to
determine potential means of retarding AMRB emergence

Results
This project aims to understand what types of AMRB are present on dairy farms and where they are present. This project hypothesizes that the environment contains AMRB and serves as a reservoir for AMRB exposures to wildlife, humans, and dairy cattle, and that different locations of the environment pose different levels of risk to AMRB transmission between species. This project also aims to understand the levels of AMRB present spatially to determine if spatial proximity contributes to AMRB transmission in wildlife, humans, and livestock. Finally, this project aims to understand the types of resistance
present and describe the threats to food production and human health.

4. Associated Knowledge Areas

KA Code	Knowledge Area
307	Animal Management Systems
314	Toxic Chemicals, Poisonous Plants, Naturally Occurring Toxins, and Other Hazards Affecting Animals
315	Animal Welfare/Well-Being and Protection

Outcome #7

1. Outcome Measures

Number of research programs to develop and evaluate management/training strategies for horses to reduce injuries.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Performance horses routinely experience career-ending or career-altering injuries. Rossdale et al. (1985) determined that lameness was the most common reason for racehorses to miss training. Johnson (1993) reported that, of horses necropsied as a result of death at a California racetrack, 84.6% had injuries to the musculoskeletal system. In addition, a British survey showed that 58.1% of two-year-olds became lame at some time during training (Jones, 1989). In the U.S., the problem encountered by young horses may be even greater. This is due to one of the more frequently witnessed disorders of young
racehorses -- the bucked shin complex. Veterinarians working in the U.S. reported a 70% incidence of bucked shins in twoyear-old Thoroughbred racehorses (Norwood, 1978) and an incidence rate in two-year-old racing Quarter Horses of up to 50% has been reported by Goodman (1987). Another common problem that can affect any athletic horse, including racing, dressage, jumping or roping horses, is degenerative joint disease (Smith, 1991). Degeneration of the articular cartilage results from excessive stress that accompanies many equine athletic events (Baxter, 1992). The ensuing lameness can result in reduced performance and possibly even permanent joint dysfunction.

What has been done
Research to: examine whether omeprazole administration will alter calcium absorption, markers associated with bone mineral turnover, and health in athletic horses.

Results
A project was completed examining whether omeprazole interferes with mineral absorption and potentially plays a role in skeletal injuries in performances horses. The results from that project were invited for presentation at the Recent Advances in Animal Nutrition Australia Conference and a manuscript was published in Animal Production Science as of October 2017. Results showed omeprazole administration was not deleterious to equine skeletal health.

A project examining how many times per week is sprint work needed to improve skeletal strength was completed. Results showed that only one 72-m sprint is needed per week to increase the fracture force of the lower limb compared to calves not allowed to sprint. The results confirm the importance of high-speed exercise to bone strength and provide guidance as to the management of animals to sustain or improve skeletal health.

4. Associated Knowledge Areas

KA Code	Knowledge Area
307	Animal Management Systems
315	Animal Welfare/Well-Being and Protection

Outcome #8

1. Outcome Measures

Number of research programs to add to the understanding of animal behavior and welfare.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	13

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The susceptibility to adult onset of chronic, debilitating gastrointestinal diseases and reduced feed efficiency in agricultural
animals is profoundly influenced by environmental influences occurring early in life. We will study the mechanisms by which early life stress triggers in pigs causes long-lasting defects in intestinal epithelial barrier function, a primary causative factor in the development of GI diseases. These studies have the potential to unravel the mechanisms of early life stress-induced GI disorders leading to the identification of novel therapeutic targets for the prevention and treatment of a number of GI diseases of humans and animals.

What has been done
Research to: maintain and improve skeletal health in livestock and companion animals; identify management practices and environmental conditions, particularly for young animals, that allow expression of positive natural behaviors while improving animal welfare in the context of environmentally sustainable production systems; and to examine ethical issues in agriculture.

Results
We will utilize in vivo approaches, ex vivo electro-physiologic assays, and confocal imaging of the porcine intestine to test our working hypothesis that early intestinal inflammatory pathways alter development of intestinal cholinergic neurons leading to increased activity and long-term intestinal barrier dysfunction. Upon completion of this objective, we expect to have a fundamental understanding of how stress impacts enteric nervous system development and how this modulates key aspects of intestinal epithelial function, including intestinal barrier function and intestinal absorptive and secretory mechanisms. These findings are directly translatable to growth and feed efficiency and disease resistance in agricultural animals such as the pig.
Results: Results revealed the cholinergic protein expression is upregulated early after weaning stress with a rapid upregulation of choline acetyltransferase at 8 hours in ileal and colonic mucosa and mesenteric lymph nodes. ChAT staining revealed a marked upregulation in the ileal epithelium overlying the Peyer's pathches. Pigs challenged with Salmonella Typhimurium exhibited upregulated ChAT staining in the Peyer's patch epithelium.

4. Associated Knowledge Areas

KA Code	Knowledge Area
307	Animal Management Systems
315	Animal Welfare/Well-Being and Protection

Outcome #9

1. Outcome Measures

Number of research programs to test new cropping, grazing and feeding strategies for food animals.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	1

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Michigan's beef operations. All options; exit the business, downsize, remain the same, and expansion, will be in play for operators. For those that choose to remain in the business, increased production and economic efficiency will be imperative. The environmental footprint and consumer acceptance of production practices will be a huge factor in survivability. Operators will need to massage production practices to enhance returns while minimizing negative impacts on

the environment. Altering the diets fed, manure management, and reducing pathogen load are three areas to address these concerns.

The increased cost of traditional feed resources such as grains and hay has forced cattle feeders to consider alternative feeds or feeding only homegrown feedstuffs. Several feedstuffs potentially available are distiller's grain with soluble, glycerin, pressed beet pulp, whole sugar beets, corn stover and condensed distiller's soluble to name a few. The challenge is to determine which feedstuffs can be blended with minimal amounts of corn and still produce beef that is acceptable to the consumer, profitable and environmentally friendly. Distiller's grain with soluble and glycerin are two co-products that are drastically changing in nutrient content with the implementation of new processing technologies to extract more value at the processing plant. Additionally, new technology has renewed interest in processing crop residues to enhance the nutrient availability for growing-finishing cattle.

We propose to develop feeding strategies to optimize use of home-grown feeds and co-products to produce wholesome beef that minimizes the impact on the environment and provides maximum beef produced per acre.
Another area of concern is the infrequent role pathogens play in wholesomeness of beef. The two primary pathogens are Salmonella and E. coli. The origin of these pathogens is generally from the cattle entering the harvest facilities. Strategies to eliminate the pathogen load in cattle prior to harvest would be beneficial for the industry. A team of scientists on campus have developed a project to characterize the shedding of E. coli O157:H7 and other pathogenic strains in the dairy and beef cattle.

What has been done
Research to: develop a local/regional pasture-based beef production system encompassing the entire beef production chain; investigate strategies to maximize milk production output and ecosystem functions in grazing dairy systems; mitigate the environmental footprint of animal systems; develop a local/regional pasture-based beef production system encompassing the entire beef production chain; investigate strategies to maximize production output (milk)and ecosystem functions (processes and services) in grazing systems managed under various scenarios for the optimization of automatic milking and pasture systems; better understand the mineral needs of the pig; and to evaluate the effectiveness of mannaniligosaccharides on egg production, egg weight and bird livability of laying hens

Results
The QScout technology was developed to provide a chute-side white blood cell (WBC) count of each animal during processing, providing a quantifiable estimate of their immune status. If cattle exhibit abnormal levels of neutrophils or lymphocytes based on a scan of a blood sample, it is expected that the animal is immunocompromised and would benefit from antimicrobial treatment. The premise of this strategy is to identify highest risk animals that are most likely to benefit from antibiotic treatment. We hypothesize this strategy will result in a more effective and judicious use of antibiotics as indicated by morbidity and mortality rates, while saving producers from costs associated with unnecessarily treating healthy cattle. Two
hundred eighty Holstein cattle with an average weight of 405 lb were purchased by the Lewis farm and enrolled in the BRD QScout study from April 2 - August 31, 2018. These animals were purchased from sale barns from across the state of Michigan. Upon processing, the cattle all undergo hormone implantation, deworming, and vaccination and are then subjected to two sorting procedures, the first based on rectal temperature (>103°F = TRT 0). Cattle with rectal temperature <103°F are randomly sorted into three antibiotic treatment groups: TRT 1 = no treatment, TRT 2 = all treated, TRT 3 = selective treatment
based on QScout scanning.

4. Associated Knowledge Areas

KA Code	Knowledge Area
302	Nutrient Utilization in Animals
307	Animal Management Systems
308	Improved Animal Products (Before Harvest)

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

MSU Extension Beef Cattle Ultrasound Program

Issue (who cares and why)? Michigan has only one beef cattle ultrasound technician. I serve this role representing the MSU Beef Team and provide this valuable service for carcass data collections for the beef industry.

What has been done? In 2018, there were scanned 473 purebred cattle and 105 market steers for carcass contests for a total 578 head. This number is similar to last year. A total of $9137.12 in gross income was generated in 2018 to support the program.

Results/Impact? Results from each scanned animal allow purebred breeders gain valuable carcass data for contemporary groups within their individual herds. In addition, individual carcass data influences animal EPS values within the breed registry. This allows for keep/cull, mating and marketing decisions for breeders.

On the youth side, carcass contests at local county fairs provide a window into carcass value of each animal without measuring actual carcasses on the rail. This allow all participants to gain valuable information on market readiness for their project and provides USDA grid pricing education and rankings for participating youth.

What difference did it make - public value? The use of ultrasound technology and subsequent data collection allows Michigan beef producers to stay on the cutting edge of genetic advancement for carcass quality and value. Youth education also benefits the next generation of beef producers by advancing their knowledge of carcass evaluation and pricing relative to our current USDA grid pricing system.

Key Items of Evaluation

Using dietary strategies to improve dairy cattle health and productivity

Michigan's 1,500 dairy farms produced more than 11 billion pounds of milk in 2017, placing the state fifth in the nation in milk production. Adam Lock, an associate professor in the Michigan State University Department of Animal Science, is working to help producers increase the value of their product amidst currently suppressed milk prices.

Supplementing diets with fat is a common practice on dairy farms to support milk production. With assistance from several grants from the Michigan Alliance for Animal Agriculture (M-AAA), Lock has pursued a better understanding of the types of fatty acids that would be the most effective. He is also delving into the uncharted territory of evaluating the long-term effects of palmitic acid supplements on dairy cattle health and productivity, hoping to determine the potential role of supplemental fatty acids in very early lactation.

"The dairy industry has deep roots in Michigan agriculture, and my research is trying to continue this tradition through maintaining and enhancing its economic viability," Lock said. "Dairy producers and their nutritionists are highly engaged in the research, and that makes for a great partnership."

The objective of his first M-AAA project was to determine the effects of three commercially available fat supplements on the yield of milk and milk components, and feed efficiency. Lock observed that a diet supplemented with a palmitic acid-enriched fat increased the yield of milk fat and protein, while a diet supplemented with a fat containing a mixture of palmitic and oleic acids increased body weight gain.

Based on 2016 Michigan milk prices, feeding a palmitic acid-supplemented diet would increase gross income by 81 cents per cow, per day. After accounting for the price of the supplement, this would translate to an increase in income of over $75,000 per year on a 500-cow dairy farm.

In a 2017 project, Lock began to look at developing effective strategies to maximize the yield and efficiency of milk production while optimizing body fat reserves. This promotes cow health and reproductive performance, as well as increasing milk income and farm profitability.

The goal was to determine the long-term effects of palmitic acid supplements on the yield of milk and milk components, nutrient digestibility, energy intake, body weight, feed efficiency, adipose tissue composition and indicators of inflammation.

Lock observed that production responses of dairy cows to palmitic acid supplementation were consistent throughout the 10-week treatment period and had carryover effects on the yield of milk fat. Overall, the palmitic acid supplement improved digestibility, milk yield, milk fat yield and feed efficiency in mid-lactation dairy cows.

"Our results had immediate impact on dairy industry recommendations and strategies to increase milk component yields, and will enable us to positively influence dairy cattle production efficiency and farm income," Lock said. "We have already engaged with on-farm nutritionists and technical consultants with results being communicated at local, regional and national dairy nutrition consultant and farmer meetings."

V(A). Planned Program (Summary)

Program # 6

1. Name of the Planned Program

Food and Non-Food Quality, Nutrition, Engineering and Processing

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
205	Plant Management Systems	0%		12%	
402	Engineering Systems and Equipment	0%		12%	
501	New and Improved Food Processing Technologies	0%		10%	
502	New and Improved Food Products	0%		10%	
503	Quality Maintenance in Storing and Marketing Food Products	0%		14%	
504	Home and Commercial Food Service	0%		10%	
511	New and Improved Non-Food Products and Processes	20%		12%	
712	Protect Food from Contamination by Pathogenic Microorganisms, Parasites, and Naturally Occurring Toxins	80%		20%	
	Total	100%		100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2018	Extension		Research	
	1862	1890	1862	1890
Plan	4.9	0.0	6.0	0.0
Actual Paid	4.1	0.0	9.0	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

2. Actual dollars expended in this Program (includes Carryover Funds from previous years)

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
207579	0	535089	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
207579	0	546080	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	3119231	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Activities will be undertaken to:

- Connect Michigan industries with the research, education and entreprenuerial activity needed in the basic sciences, engineering, plant science and agriculture to provide the state with a foundation for the vigorous development of a strong biobased economic sector.
- Identify and isolate beneficial plant compounds and develop technologies and processes to make new functional foods.
- Develop new biosensors and DNA chips that can rapidly and accurately detect a broad spectrum of harmful organisms in food and water.
- Identify breeding and genetic improvements related to food quality, nutrition and processing.
- Develop packaging systems to enhance food quality and shelf life.

2. Brief description of the target audience

Agriculture and natural resources industry representatives, biotechnology company representatives, food industry representatives,state agency representatives, private citizens, entreprenuers, native American growers.

3. How was eXtension used?

MSU Extension continues to utilize eXtension as one of the primary multi-state activities that involve contributing to Communities of Practice, responding to Ask an Expert questions, and contributing to innovation projects. One example in this area was MSU Extension staff participating in the "Encourage Kids to Eat Healthy Foods" content group.

V(E). Planned Program (Outputs)

1. Standard output measures

2018	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	5871	17613	0	0

2. Number of Patent Applications Submitted (Standard Research Output)

Patent Applications Submitted

Year:	2018
Actual:	3

Patents listed

MICL02007, Field-Operable Nano-Biosensors for Global Health, Biodefense, Food Safety, and Water Quality (SN 62/381,979); MICL02291 Bioreactor Engineering for Gas-Intensive Fermentations to Produce Biobased Fuels and Chemicals (SN 15/383,320); MICL02308, Improving biofuel crops by targeting biosynthesis and storage of mixed-linkage glucan in stem parenchyma tissue of model grasses (SN 15/237,331)

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2018	Extension	Research	Total
Actual	2	30	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research projects focusing on food quality, nutrition, engineering and processing.

Year	Actual
2018	28

Output #2

Output Measure

- Number of adults trained on new and improved non-food and bioeconomy related products and processes.
  Not reporting on this Output for this Annual Report

Output #3

Output Measure

- Number of food handlers that increase their knowledge about food safety.

Year	Actual
2018	5871

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of research programs to identify and isolate plant compounds and/or develop processes and technologies to manufacture functional foods.
2	Number of research programs to develop new biosensors and DNA chips that can rapidly and accurately detect a broad spectrum of harmful organisms in food and water.
3	Number of research programs to identify breeding and genetic improvement related to food quality, nutrition and processing.
4	Number of research programs to develop packaging systems to enhance food quality and shelf life.
5	Number of research programs to connect Michigan industries with research, education and entrepreneurial activity needed in the basic sciences, engineering and plant science and agriculture to provide the state with a foundation for vigorous development of a strong biobased economic sector.
6	Number of food handlers that increased their knowledge about food safety.

Outcome #1

1. Outcome Measures

Number of research programs to identify and isolate plant compounds and/or develop processes and technologies to manufacture functional foods.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	3

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

While significant progress has been made in combating world hunger, there is still many millions of hungry or ill fed people. Most of these people are in sub-Saharan Africa or southeast Asia. The purpose of this project is to increase the ability of institutions in developing countries to find local solutions to problems that lead to malnutrition. These institutions include universities, research organizations and ministries of agriculture. With the help of the US Agency for International Development (USAID) we visit affected countries and identify institutions that may help alleviate hunger in the country. We then visit these institutions and identify specific training requirements that they have. Gaps in knowledge may be in areas of agricultural economics, agribusiness, plant breeding, nutrition, food science, agronomy, or soil science. We then identify talented scientists in these areas and assess their suitability for training at the MS or PhD level. We then match suitable candidates to US or regional universities that are strong in these particular areas. Armed with graduate degrees, trainees return to their countries
and spend a lifetime contributing to fighting hunger. We don't restrict our work to training people. We also try to strengthen
institutions in the region by helping them improve their functionality. This work may include teaching grant writing, or curriculum development, or, as in the case of our large project in Afghanistan, help the Ministry of agriculture development of research
program with the aim of increasing wheat production. Thus, through human and institutional capacity development, we aim to
decrease hunger and malnutrition in developing countries. The benefit of this activity is not only for the hungry people directly
affected. Reducing hunger also decreases the tendency of people to be radicalized thereby decreasing the chance of armed conflict, and increasing the chance of world peace.

What has been done

Research to: identify, develop means to potentially increase labor efficiency or reduce labor requirements; to more consciously utilize and protect natural resources; and to maximize quality and consistency of product through development and implementation of sensing and automation technology and through effective harvest and post harvest handling methods in the fruit, vegetable, and chestnut industries; provide comprehensive, well designed, scientifically sound studies that compare organic milk to conventional milk by tracking milk production from comparable farms, processed under similar conditions, and handled similarly until it reaches the consumer.

Results

? Over 200 BHEARD scholars are now enroled in graduate programs in the US, Ghana, Kenya, and South Africa. Seven GRAIN scholars have started their graduate program in India.
? Monitoring, evaluation, and analysis has resulted in the creation of innovative models of graduate education such as
South South programs. Institutional capacity development activities to improve curriculums have also been instituted.
? Institutional capacity in Afghanistan has been enhaced by the development of a data management system and a small
grants program.

4. Associated Knowledge Areas

KA Code	Knowledge Area
501	New and Improved Food Processing Technologies
502	New and Improved Food Products
503	Quality Maintenance in Storing and Marketing Food Products

Outcome #2

1. Outcome Measures

Number of research programs to develop new biosensors and DNA chips that can rapidly and accurately detect a broad spectrum of harmful organisms in food and water.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	3

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The rapid detection of harmful organisms and disease-causing agents in food and water, and the ability to track and trace sources is critical to human health. In the food safety arena, it is estimated that 48 million food-borne illnesses occur each year in the U.S., accounting for 128,000 hospitalizations and more than 3,000 deaths. Biosensors can play a key role in food safety by quickly identifying contaminants in water supplies, food processing and assembly lines, raw food materials and food products before they cause problems further up the food chain.

What has been done
Research to: develop novel field-operable biosensors for rapid detection of bacterial pathogens of concern to global health, biodefense, food safety, and water quality; understand newly identified mechanisms by which foodborne toxins disrupt normal function of specialized hormone-secreting cells in the gut and elicit anorexia and vomiting.

Results
Synthesized and characterized functionalized magnetic nanoparticles (MNP) for rapid extraction and capture of bacterial contaminants in food and water. We have also synthesized gold nanoparticles for signal generation in biosensor devices.These MNPs were used to extract different types of bacteria, such E. coli, Salmonella, Listeria, Bacillus, and Vibrio in phosphate buffer and in complex food matrices. The food matrices included milk (whole, 2%, 1%, and skim), egg, egg yolk, mayonnaise, apple juice, lettuce, sprouts, and fish.

4. Associated Knowledge Areas

KA Code	Knowledge Area
402	Engineering Systems and Equipment
503	Quality Maintenance in Storing and Marketing Food Products

Outcome #3

1. Outcome Measures

Number of research programs to identify breeding and genetic improvement related to food quality, nutrition and processing.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual

2018 7

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

There is a lack of information aimed at understanding the effects of functional compounds (dietary fibers and resistant starch) in wheat flours on end-product qualities, and the retention of these compounds when undergoing processing such as baking and extrusion. In addition, it is increasingly recognized that wheat allergy is a growing public health problem. The specific objectives of this project are to identify and quantify the functional compounds of a group of selected wheat flours, evaluate effects of the compounds on baked and extruded products, and determine how cooking processing (baking and extrusion) affects the retention of these compounds; and to identify, in a wheat breeding program, wheat lines with various degrees of allergenic
properties. The long-term objectives of this project are to identify markers of dietary fibers and resistant starch in wheat lines and develop processing procedures for retaining these functional compounds in end-products, and to be able to screen wheat varieties for hypo/non-allergenic properties. The ultimate goals are to maintain and improve (by breeding, by selection, and by processing) the quality of US wheat and to be able to provide wheat products for wheat-allergic consumers to enjoy.

What has been done

Research to: determine the impact of heat stress on meat quality; help address the detection and diagnostic challenges in global health, biodefense and food/water safety; assess the risk of humans to mycotoxins via food-borne and air-borne exposure and develop appropriate mitigation strategies; understand the process of E. coli chromosomal DNA replication and its regulation at the biochemical level; identify protein markers that are indicators for soft wheat processing quality; limit human exposure to aflatoxin in food to help prevent liver cancer; characterize the role of hypoxia in metal-induced toxicity; and to develop innovative processing that adds value to fresh or processed meat products.

Results

I. During the reporting period, our laboratory continued coordinating the wheat quality testing program of MSU advanced wheat lines for the Michigan wheat industry and evaluating the milling and baking qualities of the wheat lines. A 36-page report was published and data were shared with the Michigan wheat industry at the Michigan State Millers' Association Annual meeting in January 2018.

II. In the past, we reported starch contents of straight-grade flour samples of a selected group of Michigan grown wheats; these ranged from 50.5 to 74.5% (dry basis). The isolated starches of the studied varieties had wide ranges of rapidly digestible starch (RDS) contents from 19.4% to 38.8%, slowly digestible starch (SDS) contents from 42.9% to 64.5%, and resistant starch (RS) contents from 9.1% to 34.4%.

Information on starch digestibility is important especially to the diabetic population, who need to prevent excess rises in their
blood glucose and insulin levels. The higher the content of RDS in a food, the higher the insulin response upon ingestion of food. The starch digestibility analyses in the above project were conducted on raw isolated starch, i.e., uncooked starch. In general, food is cooked first prior to consumption, e.g., cookies and bread, and one would expect the distribution of RDS, SDS and RS to be different in a cooked product as compared to their raw counterparts.

Cookies made from a soft wheat variety (Aubrey) were evaluated for their starch digestibility and compared with cookies made from bean powder blended with corn starch. The retention of SDS and RS in wheat cookies were 69.9% and 19.7%, respectively, while cookies made with bean powder blended with corn starch had much higher retentions of SDS and RS, 71.8 to 96.1% and 88.5 to 126%, respectively. It is clear that wheat starches had much lower retention of SDS and RS in cookies as compared with bean-corn starch in cookies. Furthermore, it appeared that food processing (i.e., baking in this case) could also increase RS in the end product (e.g., over 100% retention in some bean-based cookies). These experiments provided opportunities for identifying unique wheat starches in wheat varieties within a breeding program that could potentially retain higher amounts of SDS and RS in cooked products.
III. Our initial study of identifying hypo/non-allergenic wheat lines was methodology development. A mouse model was developed to study hypersensitivity responses to salt-soluble wheat proteins (SSWPs). SSWPs were extracted from variety Carpio and injected into female BALB/cJ mice. Injection with SSWPs resulted in time-dependent SIgE antibody responses associated with the elevation of TIgE concentration. Challenge with SSWPs elicited severe HSR that correlated with a significant elevation of plasma mMCP-1 levels. Sensitized mice developed facial dermatitis associated with mast cell degranulation. The developed model is currently being used to conduct research in our laboratories on wheat allergy.

4. Associated Knowledge Areas

KA Code	Knowledge Area
501	New and Improved Food Processing Technologies
502	New and Improved Food Products

Outcome #4

1. Outcome Measures

Number of research programs to develop packaging systems to enhance food quality and shelf life.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	6

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
? Reduce medication errors
The Institute of Medicine (IoM) has reported medication errors as the 8th leading cause of death

in the US,resulting in 44,000-98,000 deaths annually. While many contributing factors have been identified, drug name confusion and confusion relating to packaging and labeling are commonly indicated as inciting factors.

? Enhance patient adherence to medical regimens

Why? It has been suggested that 50% of medications taken for chronic disease are not taken as prescribed and that non adherence rates are even higher in developing nations. These incidents are exacerbated by global trends such as: the aging of the population, and increasing complexity of medical regimen. This has led researchers and the World Health Organization (WHO) to report, "Increasing the effectiveness of adherence interventions may have a far greater impact on the health of the population than any improvement in specific medical treatments."

? Reduce hospital/healthcare acquired infections (HAIs)

Why? HAIs, or infections acquired while an individual is a patient at a hospital that was neither present nor incubating in the patient prior to receiving service there, have been referred to as "one of the most serious patient safety issues in healthcare today." Stone estimates that the overall annual direct costs to US hospitals alone resulting from HAIs to be between $28- 45 Billion. The problem has been predicted to grow in future years, "HAIs have increased by 36% in the last 20 years and are consuming more health care dollars each year" due to an increase in invasive procedures and growing resistance to antibiotics.

? Induce healthier food selections

Why? Current trends predict that over 86% of US adults will be overweight or obese by 2030. Given the increased rates of morbidity, mortality and health costs associated with obesity, creative approaches to curb this epidemic are needed.

Although packaging may not be the most obvious response to these issues, it has the potential to favorably impact them. It is for this reason that it is a rich area for investigation. Few have focused on packaging as a way to mitigate the impacts related to these issues.

What has been done

Research to: Promote functional and sustainable packaging systems that optimize the utilization of raw materials; to develop and use new types of packaging systems for fruits and vegetables; use nanoparticles in active packaging; and improve health through packaging.

Results

For most of the reporting period, we concentrated much of our efforts on the areas of reducing medication errors and enhancing patient adherence to medical regimens. The work objectively investigates how varied labeling strategies impact both attention to and use of critcial information needed for the safe and effective use of OTCs with particular emphasis on older consumers, who are at higher risk for adverse drug reactions (ADRs) than their younger counterparts. Specifically, we conducted pilot work (supported by two internal grants) with the goal of submitting an R01 in the Fall of 2017. The
application was successfully submitted and has been awarded.

We propose to adapt a Front of Pack (FOP) labeling strategy, demonstrated as effective for food labels, for use with over-thecounter (OTC) medications in an attempt to reduce Adverse Drug Reactions (ADRs). We will empirically determine whether such a technique is effective for older adults, an at risk population. Information deemed most critical to mitigating the likelihood of ADR will be informed by a national survey of pharmacists. Efficacy of the developed label strategies will be tested using a series of six experiments that apply methods from basic research on visual cognition (change detection, a speeded decision task, a cross product comparison task, and eye tracking) to directly measure attention to label information and how attending to that information impacts decision making by older adults.

4. Associated Knowledge Areas

KA Code	Knowledge Area
402	Engineering Systems and Equipment
503	Quality Maintenance in Storing and Marketing Food Products

Outcome #5

1. Outcome Measures

Number of research programs to connect Michigan industries with research, education and entrepreneurial activity needed in the basic sciences, engineering and plant science and agriculture to provide the state with a foundation for vigorous development of a strong biobased economic sector.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	9

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Plants are currently the only renewable source of carbon capable of displacing significant quantities of fossil fuels. However, the amount of plant matter expected to be available by the year 2030 is insufficient to displace even half of the current petroleum usage in the U.S., notwithstanding coal usage. Therefore, technologies that efficiently transform carbon into energy products are necessary. Biomass pyrolysis offers such an approach as both the carbohydrate and lignin fractions of biomass are converted to the liquid fuel intermediate known as bio-oil. As bio-oil bulk and energy densities are significantly greater than raw biomass, the decentralization of bioenergy systems using pyrolysis offers many advantages. However, bio-oil is characterized by reactive instability and corrosiveness which pose major barriers to adopting pyrolysis. At MSU, the subsequent use of electrocatalysis has been studies to transform the reactive chemical species in bio-oil into stable forms. In so doing, bio-oil becomes less corrosive and hence more compatible with metal storage tanks and pipe networks. Transporting stable bio-oil to centralized refineries for more rigorous hydroprocessing to liquid hydrocarbon fuels then becomes feasible. The net outcome of this research is a carbon and energy efficient, liquid fuel bioenergy system, based on pyrolysis and electrocatalysis at regional depots followed by high temperature and pressure upgrading at centralized refineries.

What has been done

Research to: develop innovative bioelectrocatalytic converters that achieve mediated electron transfer to dehydrogenases and optimize the reactor's performance for coupled bioconversions having commercialization potential; and to facilitate the development of bio-derived fuels and chemicals through property characterization

Results
Solid fuel production from biomass was investigated to provide a renewable replacement for coal in power plants. Biomass torrefaction, a mild heat treatment that creates a renewable solid fuel with coal-like properties, was investigated as a pretreatment for making industrial chemicals and as a renewable competitor to wind energy. Unlike wind and solar sources of electricity, torrefied biomass is
readily dispatchable to meet real-time demand. A demonstration trial involving about 300 tons of torrefied biomass was performed at the T.B. Simon Power Plant at Michigan State University (MSU). This trial was largely regarded as a success, though grinding energy was higher than that required for grinding coal.

Biomass-to-liquids is an ongoing pursuit at Michigan State University, with an emphasis on deconstruction by fast pyrolysis followed by upgrading with electrocatalysis. Since the start of this project, an in-depth study of lignin-derived phenolics has led to an advanced understanding of how such molecules become saturated with hydrogen under the conditions present during electrocatalysis. Several lignin monomer studies have shown that electrocatalysis can cleave methoxy functional groups, saturate aromatic rings, and partially deoxygenate phenolics using different catalytic cathodes. The impact of this
new knowledge should extend to raw pyrolysis bio-oils to result in a new pathway to make hydrocarbon replacements for fossil fuels. If successful, this potentially carbon-negative approach will couple renewable electricity with renewable biomass to make fuels and chemicals while reducing atmospheric carbon dioxide.

4. Associated Knowledge Areas

KA Code	Knowledge Area
402	Engineering Systems and Equipment
501	New and Improved Food Processing Technologies
503	Quality Maintenance in Storing and Marketing Food Products
511	New and Improved Non-Food Products and Processes

Outcome #6

1. Outcome Measures

Number of food handlers that increased their knowledge about food safety.

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2018	4403

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Michigan State University (MSU) Extension offers a variety of trainings to individuals allowing them to gain food safety training. ServSafe? Manager Certification, a national certification program is for those working in food service, is taught in 8 and 16 hour formats. 4 ? Hour ServSafe? is available to those who are not working in a manager capacity, but require some type of food safety training. The Online Food Safety for Food Service Workers Course allows greater participation from individuals unable to attend traditional, face-to-face classes.

What has been done
ServSafe teaches about foodborne illness, how to prevent it, and how to train employees on food safety issues. The MSU Extension course provides participants education to successfully pass the Managers Certification exam. The ServSafe Manager course uses proven techniques, covering new Food and Drug Administration Food Code rules and content related to the food industry. Topics taught in the course include: providing safe food, forms of contamination, the safe food handler, the safe flow of food from purchase to serving, food safety management systems, safe facilities & pest management, cleaning & sanitizing

Results
During 2018, MSU Extension helped 1,181 complete training in both the 16 hour, 8 hour and 4 hour ServSafe? courses. The ServSafe? program reached participants in 66 Michigan counties. Overall 82% of participants passed the exam with a score of at least 75%.

4. Associated Knowledge Areas

KA Code	Knowledge Area
504	Home and Commercial Food Service
712	Protect Food from Contamination by Pathogenic Microorganisms, Parasites, and Naturally Occurring Toxins

V(H). Planned Program (External Factors)

External factors which affected outcomes
- Economy
- Appropriations changes

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

MSU Extension 2018 Cooking for Crowds program outcomes

Cooking for Crowds is for people that work or volunteer at non-profit organizations and who prepare food for the public or groups. This curriculum, developed by Penn State Cooperative Extension Service, is designed to educate non-profit groups about the risks that may occur when cooking large quantities of food. Strategies in Cooking for Crowds have been translated to fit the needs of groups such as churches and community organizations. Participants learn to prevent unsafe conditions that may cause foodborne illness during food planning, purchasing, storage, preparing and serving. By the end of the program, participants are able to identify unsafe conditions and safely plan for the food preparation and service at future food events or fundraisers.

In 2018, Cooking for Crowds was a three-hour program that reached 169 participants from 11 counties. Program length varied 120 to 180 minutes. In the past three months, an average of 187 individuals were served food by each program participant for a total of 31,665 people served, a greater than 10,000 person increase from 2017. Program results: The majority of program participants learned something new. Percentage of participants gaining new information: 42% Personal Hygiene, 78% Controlling Time & Temperature, 63% Cross Contamination, 67% Cleaning & Sanitizing, 84% Foodborne Pathogens.

Key Items of Evaluation

Lupus: Preventing onset from an environmental trigger

According to the National Institutes of Health, more than 23 million Americans have an autoimmune disorder, a condition in which the body's immune system attacks healthy cells by mistake. Dozens of diseases fall under the autoimmune category -- lupus, rheumatoid arthritis, Type 1 diabetes and multiple sclerosis are some of the most common -- and none have cures.

Symptom relief and management are currently the primary strategies for medical professionals, but the healthcare community is working hard to determine the underlying causes.

Michigan State University (MSU) researcher James Pestka, the Robert and Carol Deibel Family Endowed Professor in the Department of Food Science and Human Nutrition, is collaborating with other MSU scientists to uncover the secrets of autoimmunity.

Focusing on lupus, Pestka and his colleagues used funding from the National Institute for Environmental Sciences and the Lupus Foundation of America to conduct studies that showed how consuming the omega-3 fatty acid DHA can prevent the activation and progression of the disease when the cause is exposure to a toxic environmental substance.

DHA is inherent in many popularly consumed fish species and is also present in fish oil supplements taken daily by millions of people around the world.

Lupus, like other autoimmune disorders, is believed to be the result of a multitude of influences, including genetics and the environment. The illness is more common in those who have worked in industries such as construction and mining, where workers may come in to contact with certain substances.

"There's a toxic mineral called crystalline silica that many people in a variety of industries are more exposed to," Pestka said. "Using a mouse model with animals that were predisposed to lupus, we showed that well over 90 percent of the lesions on the lungs and

kidneys were stopped after the animals ingested DHA. We still have a long way to go, but these are tremendously positive results that can mean a great deal for all autoimmune problems."

After the findings were published, Pestka's team received $2.3 million over five years from the National Institutes of Health (NIH). The group will endeavor to determine why DHA had such a positive impact. There are theories about how DHA halted the onset of lupus in the mice, but Pestka said there isn't enough evidence to point to one conclusion.

"We think there could be a number of explanations, and like most things, it's difficult to distill the situation down into one tidy solution," Pestka said. "One thought is that the DHA could be telling the body not to overreact to the lesions, and thus the immune system isn't targeting healthy cells. There are other possible answers as well. We're learning more about the effects on the body and hope that means we can start to look at the causation side of things."

Pestka's expertise in toxicology stimulated his interest in autoimmunity, but to truly realize the potential of the team's discoveries, involvement of autoimmune disorder specialists is required.

"There is much to be learned about the human health implications of our study," Pestka said. "The next logical step after our project is to work on that. I'm very interested in ways we can collaborate with doctors, human health researchers and others who could help us take these studies to the next level."

VI. National Outcomes and Indicators

1. NIFA Selected Outcomes and Indicators

Childhood Obesity (Outcome 1, Indicator 1.c)	
0	Number of children and youth who reported eating more of healthy foods.
Climate Change (Outcome 1, Indicator 4)	
0	Number of new crop varieties, animal breeds, and genotypes whit climate adaptive traits.
Global Food Security and Hunger (Outcome 1, Indicator 4.a)	
0	Number of participants adopting best practices and technologies resulting in increased yield, reduced inputs, increased efficiency, increased economic return, and/or conservation of resources.
Global Food Security and Hunger (Outcome 2, Indicator 1)	
0	Number of new or improved innovations developed for food enterprises.
Food Safety (Outcome 1, Indicator 1)	
0	Number of viable technologies developed or modified for the detection and
Sustainable Energy (Outcome 3, Indicator 2)	
0	Number of farmers who adopted a dedicated bioenergy crop
Sustainable Energy (Outcome 3, Indicator 4)	
0	Tons of feedstocks delivered.