2019 Annual Report of Accomplishments and Results

Minnesota
University of Minnesota Extension
Minnesota Agricultural Experiment Station

I. Report Overview

The NIFA reviewer will refer to the executive summary submitted in your Plan of Work. Use this space to provide updates to your state or institutions as needed.

1. Executive Summary (Optional)

This report highlights the accomplishments of the University of Minnesota's Agricultural Experiment Station (MAES) and Extension in 2019. Twelve planned programs organize the University's report on activities and impacts, as outlined in the 2017 Plan of Work. .

Extension reports on programs and initiatives as defined by structured program areas. MAES describes its research on topics related to those planned programs. In many cases, MAES research informs Extension programming. Of the 38 impacts described in 2019, 17 describe impacts achieved jointly by Hatch and Smith-Lever programs.

Revised from the 2017 Plan of Work: Extension's Strategic Plan

As part of Extension's 110th anniversary in 2019, Dean Beverly Durgan convened a committee of professionals representing all parts of Extension to refresh the organization's strategic plan and set a course for the next decade. Extension's 2020 Strategic Plan establishes a baseline of expectations and assumptions to lead Extension to "A Pathway Forward" in the coming years. Goals and strategies described in the plan respond to emerging challenges and opportunities and the need for new approaches to fulfill the land-grant mission. These trends include globalization and a competitive marketplace of ideas; an increasingly diverse society; game-changing technological advances; broad and variable funding streams; and eroding public trust of hierarchical, traditional systems.

The *2020 Extension Strategic Plan: A Pathway Forward* is built around the three essential components – scholarship, engagement and systems – that have guided Extension through more than a century of creating public value for Minnesota and beyond. This framework will focus and guide planning and decision-making across Extension. Working within this vision, Extension centers and programs will adapt goals and strategies to meet stakeholder needs while remaining consistent with the larger organization's priorities and plans.

Engagement: Extension engages in meaningful ways with individuals, families, communities and stakeholders to lead and advocate for positive change across Minnesota, the nation and the world. Relationships grounded in mutual trust and understanding allow Extension to respond nimbly and effectively when its expertise is needed. Strategies for engagement are to:

- Establish and maintain mutually beneficial relationships in the diverse communities where Extension people live and work.
- Co-create approaches and solutions that empower individuals and communities to thrive and evolve in all stages of life and circumstance.
- Innovate and bring forward new ideas by supporting opportunities for partnerships and collaboration.

Scholarship: Extension excels as the trusted, go-to source for information advancing research, education and solutions that reflect Minnesota communities and their social, economic and environmental needs. Research-based scholarship and academic excellence are the foundation for Extension's public value. Strategies for scholarship are to:

- Expect rigorous scholarship, programs, tools and methods to meet the challenges of a changing world.
- Collaborate across disciplines and geography to anticipate, identify, address and innovatively respond to key needs.
- Adapt and embrace technology as a tool for addressing grand challenges and critical societal issues.

Systems and people: Extension consistently promotes efficient, effective and integrated structures and practices that reduce administrative barriers to innovation and collaboration. Extension stakeholders understand that the organization's public value is rooted in a culture of belonging and inclusiveness. Strategies for systems and people are to:

- Attract and retain high-quality, passionate employees through consistent and effective on-boarding, professional development, mentorship, promotion and retention.
- Weave diversity, equity and inclusion into all aspects of Extension's programming and employee engagement.
- Find new and innovative ways to tell the Extension story and to share the value that Extension brings to its stakeholders and the public.

MAES. Summary of 2019 Activities

This report summarizes the effort and results related to over 350 research projects conducted by over 250 principal investigators (PIs) at five University of Minnesota colleges: College of Food, Agricultural and Natural Resource Sciences (CFANS), College of Biological Sciences (CBS), College of Veterinary Medicine (CVM), College of Education and Human Development (CEHD) and the College of Design (CDES). While the research efforts are reported under program areas, the majority of this research is broad-based and interdisciplinary and has impacts on multiple programs areas.

Due to this year's streamlined reporting process, we have **not reported** on the number of research projects focusing on the needs of underserved and underrepresented populations or the number of peer reviewed journals or patents tied to each program area.

Though Hatch funding accounts for less than 10 percent of the annual funds for MAES research, we have reported on outcomes from all projects connected to PIs who receive non-discretionary funding. NIFA non-discretionary funds support general-use infrastructure, including greenhouses and research fields, ensuring that

researchers have what they need to start projects and generate impacts and outcomes. They also provide critical funding for staffing that allows us to leverage and match other external funding sources. Notably, these funds are used to assist early career faculty as they start research programs. Without these funds, there would be less applied research, less real-world application of research, and less integration of extension and research.

Preview of 2019 Impacts - Research and Extension

NIFA-funding provides core support for critical University education and research that is making a difference in Minnesota. In 2019, MAES and Extension programs are able to report 38 significant impacts.

- Nine of these impacts give evidence that NIFA funds are resulting in economic improvements. For example, research innovations are solving problems that put the profitability of family farms in danger, and Extension is helping farmers adopt those solutions. Extension programming in communities is resulting in economic development strategies. Research is supporting entrepreneurial enterprises in wine, putting big data to work for farmers and partnering with the food industry on developing innovative new products.
- As research establishes best practices for environmental protection, Extension is providing research-based education to the public so that they make decisions that make a difference. As a result of NIFA-funded programs, Minnesotans are actively engaged in saving energy, adopting clean energy solutions, protecting Minnesota's waterways, preventing the spread of a variety of invasive species, and creating healthy green spaces in homes and communities.
- NIFA programs are also helping people achieve their human potential as citizens, parents, caretakers, and responsible healthy community members. Science and technology are helping people contribute to data collection, create community projects, protect their health, lead in their communities, and raise the next generation.

These results are possible because University of Minnesota scientists and educators are deeply engaged in their communities and in industries. They are possible because the University of Minnesota is driven to discover new ways to solve problems and create a sustainable and viable future. They are possible because educators believe that informed community members and agricultural leaders want to make decisions on behalf of the public good.

NIFA funding provides a critical financial backbone that makes these impacts possible.

Outcome #	Outcome Title/Topic	Primary Outcome Type
1	Keeping MN's poultry industry safe and successful	Economic/Efficiency
2	Measuring the risk of African Swine Fever entering the U.S.	Economic/Efficiency

3	New DNA test helps identify Palmer amaranth seeds	Economic/Efficiency
4	Providing Ethiopian scientists and farmers with the tools and knowledge needed to combat wheat stem rust	Social/Human Well-Being
5	GEMS: Enabling agricultural innovation by turning big data into actionable information	Economic/Efficiency
6	CERTS initiatives save 48.2 billion BTUs	Environmental Quality/Sustainability
7	A novel system for ammonia-based sustainable energy and agriculture	Environmental Quality/Sustainability
8	Improving animal feed produced by the corn ethanol industry	Environmental Quality/Sustainability
9	DNR promoting management and harvesting to help protect Northern forests from the effects of eastern larch beetle	Environmental Quality/Sustainability
10	Study shows genetic effect of extreme temperatures on young turkeys	Economic/Efficiency
11	Exotic earthworms continue to expand their reach and effects on forest ecosystems	Environmental Quality/Sustainability
12	Creating a community response to the opioid crisis in Minnesota	Social/Human Well-Being
13	Influencing policies, systems, and environments that shape health behaviors	Social/Human Well-Being
14	EFNEP and SNAP-ED health and nutrition education creates nutrition and lifestyle changes	Social/Human Well-Being
15	Researchers invent shape-changing textiles powered only by body heat	Social/Human Well-Being
16	U of M establishes first of its kind Plant Proteins Innovation Center	Economic/Efficiency
17	Study highlights industry shift as antibiotics use in poultry declines steeply	Social/Human Well-Being
18	New process reduces contamination in powdered foods	Social/Human Well-Being
19	Nitrogen Smart Program changes practices to decrease nitrogen loss	Environmental Quality/Sustainability
20	Mapping the zebra mussel genome	Environmental Quality/Sustainability
21	MN-Clearwater, a grain variety of intermediate wheatgrass, fuels farmer partnerships to improve MN's rural well water supply	Environmental Quality/Sustainability
22	Subfield level model for improved nitrogen fertilizer recommendations	Environmental Quality/Sustainability
23	Growing community leadership and making an economic impact	Social/Human Well-Being
24	Informing and inspiring local economic development choices	Social/Human Well-Being
25	Parent education for incarcerated fathers: Devoted Dads	Social/Human Well-Being
26	Supporting co-parenting after relationship dissolution	Social/Human Well-Being
27	University study helps lead to new policies and guidance regarding professional licenses for military spouses	Social/Human Well-Being

28	APLUS study continues to provide vital data on how young adults perceive personal finances affecting their quality of life	Social/Human Well-Being
29	4-H grows global citizenship skills	Social/Human Well-Being
30	Master Naturalists' citizen scientist projects protect the environment	Environmental Quality/Sustainability
31	Researchers developing rapid-test to help stop Chronic Wasting Disease in its tracks	Social/Human Well-Being
32	Researchers explore the interwoven roles of fire and wildlife in oak savanna conservation by introducing bison	Environmental Quality/Sustainability
33	University researchers work to break buckthorn's cycle of invasion	Environmental Quality/Sustainability
34	From grape to wine—helping Northern wineries succeed	Economic/Efficiency
35	Master Gardeners	Social/Human Well-Being
36	Benefits of bee lawns inspire legislators, land managers and homeowners	Environmental Quality/Sustainability
37	Farm transition and estate planning program prepares family farms for transfer	Economic/Efficiency
38	Extension informs fair and profitable farm rental agreements	Economic/Efficiency

II. Merit and Scientific Peer Review Processes

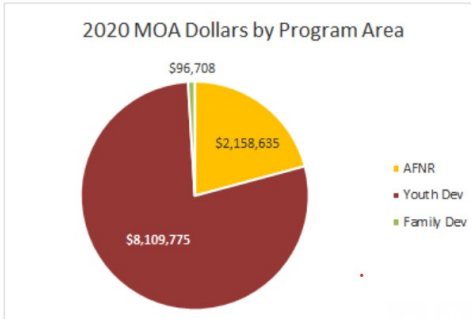
The NIFA reviewer will refer to your Plan of Work. Use this space to provide updates as needed or activities that you would like to bring to NIFA's attention.

Process	Updates
1. The <u>Merit Review Process</u>	**MAES.** The merit review of research faculty supported by MAES funding occurs within each of the five partner colleges. The process follows standards established by the University for promotion and tenure (https://policy.umn.edu/hr/tenure). This policy is essential to the protection of academic freedom and to the promotion of excellence within the University. Notably, it includes an evaluation of research quality and impact in addition to teaching and service. As the primary receiver of MAES funds, we provide updated **CFANS tenure track** data annually: As of March 2020, CFANS has 196 tenured faculty and 40 non-tenured. Of those, 144 are full professors with tenure, 52 are associate professors with tenure and 40 are assistant professors. In 2019, eight assistant professors were promoted from assistant to associate professor. Additionally, two faculty were promoted from associate professor to full professor. **Extension.** In 2019, nine regional educators were promoted after promotion review processes described in Extension's Plan of Work. Extension made changes in the classification of local 4-H program coordinators in 2019 in response to evolving responsibilities and needs of the 4-H program. ● Local 4-H program coordinators' titles are changing to Extension educator, 4-H youth development. The new title more accurately represents their responsibilities and provides consistency with other local Extension staff. This new title puts them in the same classification as "local educators without rank" in other Extension centers. The merit review process for this class of employees was described in the plan of work. ● Most 4-H program coordinators' salaries were adjusted in late July to be more competitive in a tight employment market. Extension also has increased the starting salary for these positions.

	● Current 4-H program coordinators were offered a one-time opportunity to change from a civil service to an academic professional job classification. Those who choose to reclassify will have a path to promotion without academic rank within Extension. New 4-H program coordinators will be automatically hired into the academic professional classification. These changes will help with the challenge of hiring and retaining high-quality youth development staff. Program coordinators who take the opportunity to be reclassified are being coached through the merit review and promotion process through online resources and mentorships.
2. The <u>Scientific Peer Review Process</u>	The merit review process by which research projects are selected for MAES funding is also under the direction of the deans of the five MAES partner colleges as members of the MAES deans' council. The process varies somewhat by college. In CEHD, for example, in the Department of Family Social Science, all tenured and tenure-track faculty are offered the opportunity to prepare a proposal for MAES funding. The total amount of MAES funding for research projects is shared between all approved MAES projects, which must undergo peer review. In CFANS the review process primarily takes place at the department level with the assistance and oversight of MAES administration and leadership. A minimum of three reviewers is required for each project (two internal and one external to the department). The reviewers fill out a project proposal review form and submit it to the PI and department head for revisions. Once approved at the department level, proposed projects are sent on to MAES for approval by the MAES Deputy Director before being sent to NIFA for review via the REEport system.

III. Stakeholder Input

The NIFA reviewer will refer to your Plan of Work. Use this space to provide updates as needed or activities that you would like to bring to NIFA's attention.

Stakeholder Input Aspects	Updates
1. Actions taken to seek stakeholder input that encouraged their participation with a brief explanation	**See Plan of Work.**
2. Methods to identify individuals and groups and brief explanation.	**See Plan of Work.**
3. Methods for collecting stakeholder input and brief explanation.	**See Plan of Work.**
4. A Statement of how the input will be considered and brief explanation of what you learned from your stakeholders.	**Extension.** As noted in the 2017 Plan of Work, memorandums of agreement are created with each county so that stakeholders can choose to staff local Extension educators who address issues of most concern in that county. In 2019, counties increased their investment in local Extension programs by 5.7 percent. Seventy-three of Minnesota's 87 counties maintained or increased their budgets. With regional educators in place to serve throughout a region, most MOA dollars were expended on 4-H programming. This was followed by local Master Gardener programming, and finally family development.  As noted in the Minnesota Plan of Work, regional sustainable development partnerships manage regional teams to assess needs, invite local ideas, and connect Extension and the rest of the University to local efforts. In fiscal

year 2019, RSDP brought together 278 community partners and 126 University partners to implement 135 community-driven sustainability projects across Minnesota. These projects are responding to local demands to address water quality, grow local foods options and supply change, grow clean energy, and create sustainable tourism.

Also as noted in the plan of work, program areas use advisory committees and implement stakeholder assessment at key points in program design. A 2019 example is Extension's response to the opioid crisis. As noted in Outcome #12, team members conducted 41 focus groups and held 127 meetings with 2,662 stakeholders throughout 33 communities. The forums, and the work of an American Indian Resource and Resiliency Team, uncovered opportunities for Extension to inspire community action that supports those recovering from opioid addiction in their communities.

MAES. As described in the 2017 Plan of Work, MAES-supported researchers have processes in place to effectively gather input from a variety of stakeholders. A few 2019 examples of how this feedback is used are noted below:

1. Based on a request from Minnesota state legislators and multilingual community members, project leaders in the CVM have developed chronic wasting disease (CWD) fact sheets in Korean, Khmer and Hmong languages to ensure key information on CWD reaches those Minnesota hunting communities. In addition, they created special CWD communications materials tailored to the Amish community in southeast Minnesota (Outcome #31).
2. The new Plant Protein Innovation Center (PPIC), the first center of its kind in the nation, brings together interdisciplinary researchers and industry partners to address process and knowledge gaps across the plant protein space. The original top six research priorities for the PPIC were determined using a ranking system at the center's inaugural meeting on November 28, 2018 and will be adjusted based on feedback at future meetings (Outcome #16).
3. G.E.M.S. officially launched in 2019 under the leadership of the University of Minnesota with the active involvement of a wide range of public and private, domestic and international institutions. These partners are pivotal in determining the core development priorities of the platform, as well as provide crucial input on platform design and implementation decisions including key policies related to data sharing and access (Outcome #5).

IV. Planned Program Table of Contents

V. Planned Program Activities and Accomplishments

Please provide information for activities that represent the best work of your institution(s). See Section V of the Guidance for information on what to include in the qualitative outcomes or impact statements. Add additional rows to convey additional accomplishments. You may expand each row as needed.

No.	Title or Activity Description	Outcome/Impact Statement	Planned Program Name/No.
1.	**Keeping Minnesota's poultry industry safe and successful** Integrated Extension & Research Impact	**Issue:** Minnesota is among the nation's top ten producers of eggs, chickens and pheasants, and is the number one turkey producer in the world. A high percentage of avian producers manage independent 3rd, 4th, or 5th generation family-owned farms. The 2015 avian flu outbreak caused losses in poultry production and related businesses estimated at nearly $650 million in Minnesota, pointing to the need for loss prevention through biosecurity practices. **What has been done:** University of Minnesota experts work directly with poultry producers to mold questions and challenges into research and innovation. Moreover, U of M experts have consulted directly with the U.S. Department of Agriculture, informing them about on-the-farm issues that should be addressed in legislation. During the summers of 2018 and 2019, a team of five Extension educators reached 553 individuals across the state, hauling a biosecurity education trailer more than 3,100 miles to provide easy access to biosecurity education that helps farmers write biosecurity plans and operating procedures that prevent future losses. **Results:** Consultation with the U.S. Department of Agriculture contributed risk assessment practices to the development of a 14-point security plan that's been adopted into national legislation. This plan will be implemented in September of 2020. With this legislation, poultry producers with specific annual production numbers need to have a biennial audit of their farm's written biosecurity plan, addressing 13 biosecurity principles. Extension's biosecurity outreach program, designed and tested over the past three years, is ready to support local audits, as demonstrated in its program evaluations. More than 80 percent of program participants said they were ready to write a biosecurity plan or operating procedures after the program.	Global Food Security and Hunger / #1

2.	**Measuring the risk of African Swine Fever entering the U.S.** Research Impact	**Issue:** African swine fever (ASF), a contagious disease in pigs and wild boars, has been spreading across the Caucasus region, Europe, and Asia since 2007 resulting in quarantines, controlled movement, and mandatory culling. China, since its 2018 ASF outbreak, has slaughtered an estimated 1,170,000 animals. **What has been done:** In partnership with the Swine Health Information Center (SHIC), University researchers in the College of Veterinary Medicine Center for Animal Health and Food Safety (CAHFS) have helped to track the disease via the Swine Disease Global Surveillance Project and share information relevant to US swine producers and practitioners through ASF Watch. In 2019, they partnered with a team of researchers around the world to measure the risk of ASF entering the U.S. through the smuggling of pork products in air passenger luggage. **Results:** The study shows the risk of ASF arriving in the U.S. has nearly doubled since the ASF epidemic began in 2018, and that five specific airports account for over 90 percent of the potential risk: Newark-NJ, Houston-TX, Los Angeles-CA, J.F. Kennedy-NY, and San Jose-CA. In addition, the probability is high that the ASF virus is already reaching US borders through the smuggling of pork products, but likely because of the work of US Customs and Border Protection, the virus has not entered the country. If ASF were to enter the U.S., its spread would cause immense economic damage to the pork industry and could lead to billions of dollars in losses for pork producers. The findings of this study can help support decision making for disease surveillance strategies in the U.S. swine industry and transportation hubs. CAHFS is now working with SHIC on a project intended to support control efforts in Vietnam. In addition to a "good neighbor policy," the project will also generate information that would be useful in enhancing the U.S. preparedness in the event of an ASF epidemic.	Global Food Security and Hunger / #1
3.	**New DNA test helps identify Palmer amaranth seeds**	**Issue:** Palmer amaranth is a major threat to row-crop agriculture in Minnesota. A single Palmer amaranth plant can produce half a million seeds, grow 2-4 inches in a day, and cause severe loss of crop yield. While it hasn't yet taken widespread hold in Minnesota, in other areas of the country Palmer populations have already developed resistance to five major herbicide classes. The most	Global Food Security and Hunger / #1

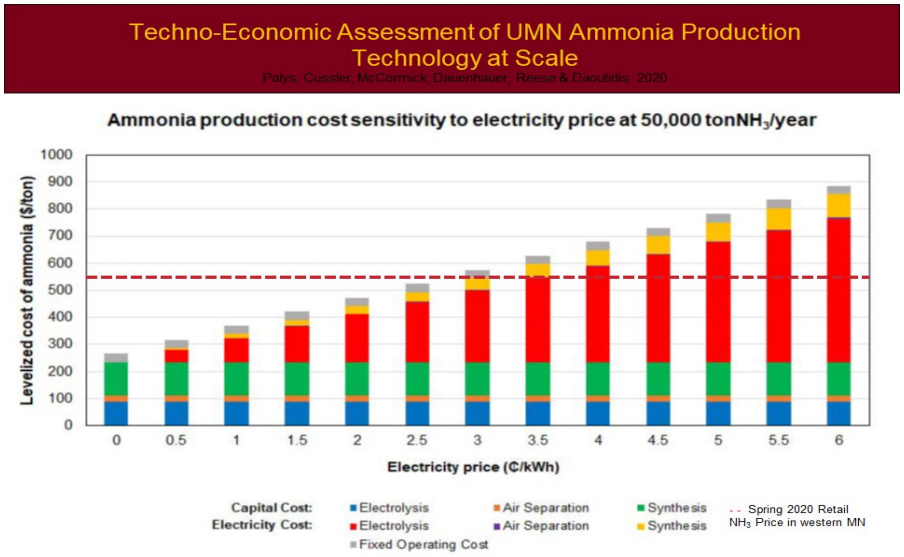
	Integrated Extension & Research Impact	common resistances in Palmer are also some of the most widely used herbicides: ALS-inhibitors, PPO-inhibitors, and glyphosate. **What has been done:** Palmer amaranth was first detected in Minnesota in 2016, but even before it hit the state, University of Minnesota researchers and Extension specialists mobilized to help state agencies and landowners develop a plan to eradicate infestations before spread to new areas. To date, growers across the state have played a key role in Palmer control by reporting Palmer amaranth to U of M Extension and the Minnesota Department of Agriculture (MDA). The MDA has added Palmer amaranth to the list of prohibited weed seeds, allowing them to prohibit selling seed contaminated with Palmer under the seed regulatory program. However, the similarities between Palmer amaranth and native pigweeds and waterhemp—particularly in its seed state—make identification of Palmer amaranth from other pigweed species difficult. The best way to resolve this identification challenge has been through the use of genetic testing. **Results:** This project brought together weed science experts from the University of Minnesota, Colorado State University, Michigan State University, Kansas State University, and the MDA to address these challenges and improve detection technologies, both for seed and for individual pigweed plants. The team assembled a collection of Palmer amaranth populations from across the globe, including plants from Africa, South America, the U.S. and Mexico. They successfully pinpointed genetic markers common to all of these populations and used these targets to develop genetic tests for Amaranth species identification. The resulting tests can identify Palmer amaranth from other pigweeds with up to three markers, each of which has over 99.7 percent accuracy. They can also identify the presence of a single Palmer amaranth seed in a sample of 200 visually identical waterhemp seeds. This technology offers a cost-effective; easy-to-use and highly accurate DNA test for Palmer amaranth seed identification. Such a tool will be instrumental in helping seed inspectors keep Palmer amaranth out of the state and out of farmer's fields. Development has been completed and this technology will be ready for deployment in 2020.	

4.	**Providing Ethiopian scientists and farmers with the tools and knowledge needed to combat wheat stem rust** Research Impact	**Issue:** Wheat is the world's most widely cultivated crop and contributes roughly one-fifth of the calories in human diets. Since the identification of wheat rust pathogen race Ug99 in the late 1990s, the discovery and breeding of resistant materials has been a priority. It became even more significant when 90-100 percent of wheat in Ethiopia was lost because of a lack of disease resistance in varieties in 2013. **What has been done:** In response to the 2013 and 2014 wheat stem rust epidemics in Ethiopia, a collaborative research and education team formed to study the biology and control of new, dangerous forms of the wheat stem rust pathogen from East Africa and other parts of the world and to provide Ethiopian scientists and farmers with the tools and knowledge needed to combat wheat stem rust. University of Minnesota researchers, in collaboration with USDA researchers based at the Cereal Disease Lab in St. Paul, MN, were responsible for several research and outreach breakthroughs related to this worldwide effort including: 1) Discovering the 2013-14 Ethiopian stem rust epidemic was caused by TKTTF; 2) Carrying out a genome-wide association study which identified seedling resistance to all three races and SNP markers associated with seedling resistance against races TTKSK, TRTTF and TKTTF; 3) Coordinating scientist training workshops in Ethiopia on wheat diseases; and, 4) Helping to facilitate the deployment of five stem rust nurseries in Ethiopia. **Results:** The latter effort quickly led to five wheat varieties being tested for rust resistance in Ethiopia. Among them was 'Kingbird', a variety previously released in Kenya for its good disease resistance, good baking quality and high yields. In May 2015, the Ethiopian Institute of Agricultural Research released 'Kingbird' for widespread agricultural use after receiving five tons of seed from plant breeders in Kenya. Researchers at the Kulumsa Agricultural Research Station then coordinated the planting and harvest of 37 hectares at multiple locations, which resulted in 80 tons of 'Kingbird' seed being harvested and distributed to Ethiopian farmers. Since that time through 2018, 35,480 tons of 'Kingbird' seed has been produced--half via partnerships with farmers and half via partnerships with public seed enterprises. Based on	Global Food Security and Hunger / #1

		genotyping of wheat lines in Ethiopian farmers' fields, 'Kingbird' was grown on approximately 36,000 hectares (89,000 acres) in 2018 which--based on average farm size--would account for it being grown on over 40,000 farms.	
5.	**GEMS: Enabling agricultural innovation by turning big data into actionable information** Research Impact	**Issue:** Open Data is potentially powerful, enabling evidence-based sustainable agricultural innovation strategies and nutritional security. However, the agricultural sector has struggled to harness the power of big data as increasing amounts of agricultural research is conducted by private companies or involves sensitive on-farm data. **What has been done:** CFANS and the Minnesota Supercomputing Institute have teamed up to drive the development of a next-generation agroinformatics data discovery, sharing and analytics platform dubbed GEMS™ (Genetic, Environmental, Management, and Socioeconomic data). **Results:** Officially launched in May 2019, the GEMS platform enables public-private, local-global research collaborations for innovation in food and agriculture. It allows data contributors to make their data functionally interoperable—via structured ontologies and data cleaning modules—and allows them to share only those data files or fields within their data that they decide to make available, thus blending the best of *both* open and private data sharing strategies. The platform supports a growing number of research collaborations and partnerships including: PepsiCo, the National and Iowa Corn Growers Associations, research ventures funded by USDA's Foundation for Food and Agriculture Research, Stellenbosch University in South Africa, and Land O'Lakes Venture37 in Malawi. By providing a safe and secure environment for sharing data at all levels, backed by a rapidly expanding set of analytical tools, GEMS is harnessing the power of big data into actionable knowledge for the whole agricultural supply chain, thus helping to reinvent how the University of Minnesota collaborates with the private sector (including farmers) on land-grant research.	Global Food Security and Hunger / #1

6.	**CERTS initiatives save 48.2 billion BTUs** Extension Impact	**Issue:** Minnesota is continuously striving for a cleaner energy supply that is also efficient, reliable, and affordable. In 2015, Minnesotans spent $19 billion and consumed a total of 1,770 trillion BTUs of energy (electricity, natural gas, petroleum products, coal and biomass) to supply energy needs. Energy use spreads across four main sectors: transportation (25 percent of total use), residential (21 percent); commercial (20 percent) and industrial (34 percent). Minnesota's energy efficiency and renewable energy goals were stated and signed into law in 2007 with Minnesota's Next Generation Energy Act. The law requires Minnesota utilities to produce 25 percent of energy using renewable resources by 2025 and established a statewide energy conservation goal of 1.5 percent of annual retail electric and natural gas sales. **What has been done:** Clean Energy Resource Teams (CERTs) work with Minnesota communities, connecting them to resources, research-based information, and networks that advance clean energy projects. CERTs provides technical assistance to cities, counties, schools, tribal nations, underserved communities, small businesses, farmers, and utilities. In 2019, CERTs hosted 26 public education events, connected with Minnesotans through 280 outreach events, and oversaw completion of 42 local clean energy seed grant projects. CERTs also tested new models for scaling-up sustainable energy impact and published 75 new stories to give others a sense of what's possible, to allow them to learn from peers, and to inspire them to take action. **Results:** In 2019, a cumulative total of 48.2 billion BTUs in annual energy savings or renewable energy offset have been achieved as a result of CERTs programming. This includes the following impacts: 1) a city subscribed to solar power for a significant portion of the city's operations (9.2 billion BTUs); 2) 10 solar systems were installed by two school districts, a county, and the state of Minnesota (8.7 billion BTUs); 3) 24 businesses completed energy efficiency and solar projects with clean energy financing (7.3 billion BTUs); and 4) 42 clean energy projects were completed with CERTs seed grants (4.8 billion BTUs). The remaining energy savings achieved in 2019 were from changes such as: the distribution of more than 6,000 energy saving items such as light bulbs and showerheads, energy efficiency in businesses and multi-family housing after assessments and using utility rebates, farms adopting solar energy, and cities that used electric vehicles for their transportation choice.	Sustainable Energy / #2

7.	**A novel system for ammonia-based sustainable energy and agriculture** Research Impact	**Issue:** Nitrogen fertilizer is an essential part of the farming process. Minnesota farmers send more than $400 million a year out of the state to buy nitrogen fertilizer, most of which comes from outside the U.S. and leaves a hefty carbon footprint. **What has been done:** A team of researchers from across the University of Minnesota has set out to develop a cleaner, more sustainable alternative to traditional nitrogen fertilizer. Their recipe relies on three abundant resources: air, water, and wind. Traditional ammonia production requires the formation of molecular hydrogen, followed by contacting the hydrogen with molecular nitrogen over a catalyst in the Haber-Bosch process for ammonia synthesis—an inefficient process. The team turned to wind energy, a resource readily available in the same regions of the state where farmers need to fertilize their crops. Specifically, wind power fuels the removal of hydrogen from water, while a separate process extracts nitrogen from air. Running hydrogen and nitrogen through a chemical reaction can take the two elements and form ammonia, which can then be used as both fertilizer and fuel. **Results:** Using wind production and energy load data from the University of Minnesota Morris Campus and the West Central Research and Outreach Center, a case study using ammonia as energy storage has shown a low carbon credit cost of $17.60/ton$CO_2$. In addition, University researchers have developed more efficient, renewable ammonia production technologies—several of which have patents. The research team is now partnering with collaborators across the nation and world with an aim to bring a large-scale demonstration project to Minnesota. With this ongoing research, Minnesota is well on its way to decarbonize the energy consumed in production agriculture.	Sustainable Energy / #2



Wind energy has been selling between 1.5 to 2 cents per kWh in Western M. By incorporating the new U of M system, ammonia fertilizer can be produced below the current retail rate

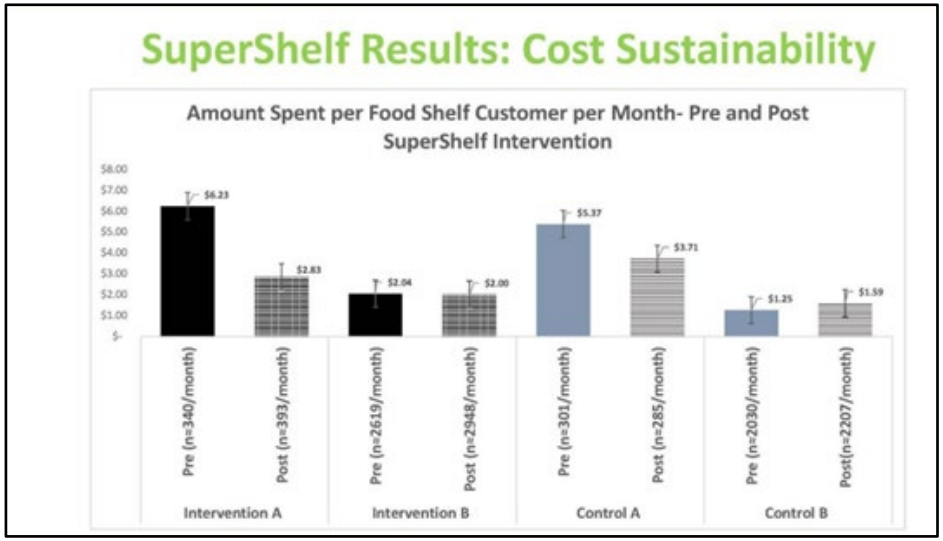
8.	**Improving animal feed produced by the corn ethanol industry** Research Impact	**Issue:** Minnesota is a leading producer of corn, some of which is used by the ethanol industry to make fuels and other products. One of those coproducts is distillers dried grains with soluble (DDGS) which have become a major ingredient in swine diets in the U.S. and global feed industry. However, greater amounts of these coproducts could be used in swine diets if researchers can overcome key barriers for their use. **What has been done:** Phytate is a component in DDGS, but monogastric animals (like swine and poultry) cannot digest it. Thus, phytate ends up in manure and contributes to environmental pollution. A team of University researchers were interested in exploring ways to improve the method used by the corn ethanol industry to create ethanol and its various coproducts. In particular, they focused on developing a way to extract the phytate during the production process.	Sustainable Energy / #2

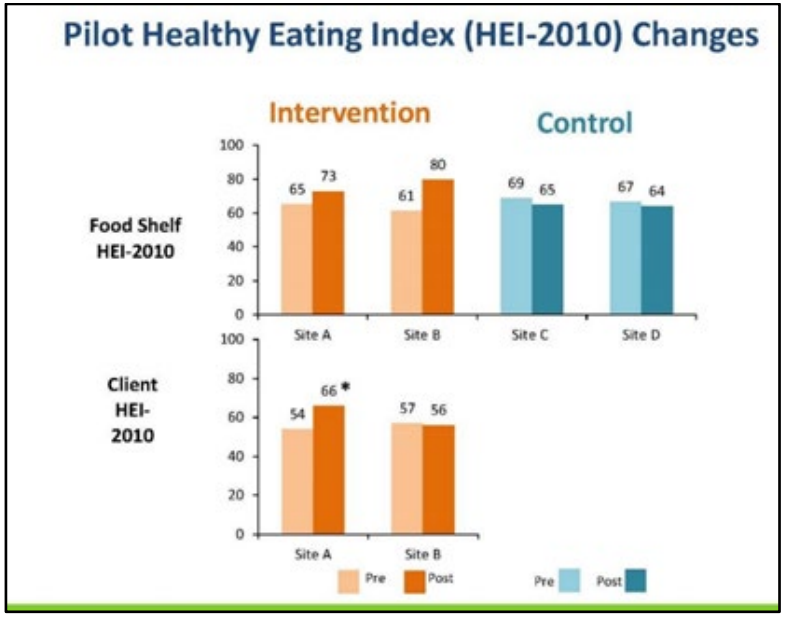
		Results: This simple method has been demonstrated on a pilot scale and can be incorporated into current corn ethanol production processes to extract high-value phytate—which is then further converted to produce inositol—and use the remaining solids as animal feed ingredients, thus both reducing pollutants and adding value from previously wasted materials. The team has been working with local companies, Absolute Energy and CHS Inc., to incorporate the technology into their systems. In addition, they have received inquiries from companies all-over the world that are interested in licensing the innovation. This revolutionary tactic will bring additional revenue to the corn ethanol industry by reducing waste, improving feed digestibility and reducing phosphorus discharge into the environment.	
9.	**DNR promoting management and harvesting to help protect Northern forests from the effects of eastern larch beetle** Integrated Extension & Research Impact	**Issue:** The outbreak of eastern larch beetles in Minnesota began in 2001 and shows no signs of slowing down. Foresters believe the nearly 500,000 acres of affected tamarack trees may never recover, thus changing the broader ecosystem in the northern parts of the state. **What has been done:** Eastern larch beetles are not new and, in fact, are native to Minnesota. They are found everywhere tamaracks grow, but throughout history, the beetles never posed a great threat and were largely ignored by forest entomologists. What has changed? University researchers have shown that populations of eastern larch beetles increase when warm, extended growing seasons permit two generations of insects to develop within a summer. Increased numbers of insects, in concert with warmer and dryer years, are likely facilitating these continued outbreaks. In Minnesota, tamaracks typically grow in bogs, swamps and other areas too wet for most trees to survive. As large tamaracks die off in high numbers, the water table rises and could lead to young trees being flooded out. **Results:** Studies from the Minnesota Department of Natural Resources (DNR) and the University of Minnesota have shown when tamaracks are just left for the beetle; young saplings left behind are less likely to survive. By one estimate, the survival rate is about 100 new trees per acre. When foresters clear and reseed before the beetle kills them off, the area can replenish with about 800 to 1,000 new saplings per acre.	Climate Change / #3

		In response, the DNR is working to speed up tamarack timber auctions in hopes they can harvest some trees while still standing and the wood is useful. Additionally, harvesting opens up the area so young sapling and other species can grow and replace them, thus hopefully protecting the fragile ecology of the forests.	
10.	**Study shows genetic effect of extreme temperatures on young turkeys** Research Impact	**Issue:** Climate change has led to a rise in mean temperature and an increase in the number of extreme temperature days. Hot and cold extremes are environmental stressors that affect livestock well-being and potentially have significant economic and food security implications. **What has been done:** A team of researchers at the University of Minnesota recently examined how temperature extremes are affecting the well-being and economic value of turkeys. **Results:** The researchers found that birds specifically bred to be larger and grow faster—more closely resembling commercial turkeys—can respond to extreme temperatures with gene changes that would lead to decreased muscle size. This was the first study on the effects of thermal challenge on gene expression in turkeys during the critical first three days following hatch. It provides direction for future studies on how climate change could affect the U.S.'s $4 billion turkey industry.	Climate Change / #3
11.	**Exotic earthworms continue to expand their reach and effects on forest ecosystems** Integrated Extension & Research Impact	**Issue:** Exotic earthworms exert major controls over how soils function. Non-native geoengineering earthworms, which rapidly consume organic matter while burrowing through soils, speed up decomposition and nutrients losses. In a warmer and wetter world, their habitats and numbers are likely to grow increasingly faster. **What has been done:** Researchers at the University of Minnesota have been exploring the invasion and ecosystem impacts of exotic earthworms in Minnesota's forests for more than a decade. Recently, they extended their research to even colder climates. In 2019, after several years of intensive earthworm surveys in the arctic Sweden, they began to examine the introduction, dispersal, and ecological impacts of European earthworms in Alaska.	Climate Change / #3

		Results: They found in Alaska, active earthworm invasion and dispersal occurs through many different types of human activities such as gardening, fishing, and road building. Although earthworms' aggressive invasion into otherwise undisturbed boreal forests is active only in Alaska's warmer southern coastal areas, the repeated introductions of earthworms do occur locally throughout the entire Alaska. Ongoing climate change will likely boost the survival and further dispersal of earthworms in the northern and interior Alaska soon. Non-native earthworms result in a cascade of ecosystem effects. These impacts include changes in carbon sequestration, forest disturbance regimes, soil and water quality, forest productivity, plant communities and wildlife habitat. Invasive earthworms further facilitate other invasive species. Considering the massive ecological cascades that exotic earthworms cause to the soil carbon and nutrient cycles, understanding the dynamics of earthworm invasion should be a key component of future climate-related conservation efforts in both boreal and temperate forest ecosystems.	
12.	**Creating a community response to the opioid crisis in Minnesota** Extension Impact	**Issue:** Like other states, Minnesota has experienced an alarming increase in drug overdose deaths. In 2017, there were 422 known opioid overdoses in Minnesota. The crisis impacts rural Minnesotans across income and educational divides, and research notes that "individuals engaged in the recovery process are asked to initiate individual-level behavior change while interacting in new ways within their nested ecologies of family, community, employment, and the broader sociocultural context" (Manuel et al., 2017). That's why it is critical to mobilize rural Minnesotans to create supportive communities for those who are trying to recover from addiction and are vulnerable to relapse. **What has been done:** U of M Extension received three opioid focused education grants in partnership with the College of Pharmacy, local county public health departments, tribal partners, and South Dakota State University Extension. Grants came from NIFA and the Substance Abuse and Mental Health Services Administration. With these grants, community forums, training, and technical assistance opportunities have reached four Northeast Minnesota Counties and two tribal communities. The project utilizes the recovery capital framework and identifies existing and needed community resources to build and sustain a recovery-friendly community. Team members conducted 41 focus groups and held 127 meetings with 2,662 stakeholders throughout 33 communities. Seven community forums educated communities and featured education and resources for those communities. A team of three American Indian tribal liaisons now connect with	Health and Nutrition / #4

		stakeholders in tribal communities, providing training and technical assistance to support the enhancement of recovery capitals. Finally, changemaker retreats were conducted to mobilize community members who are ready and willing to act to make communities more supportive of people in recovery. These retreats strengthened leadership confidence and competence and made $1,000 mini-grants available to support the implementation of projects to combat the opioid crisis. **Results:** Post event evaluations showed that forums, training, and consultations consistently enlightened communities to the struggles of opioid addiction and recovery. Moreover, changemaker retreats moved willing community members from knowledge and intention to ideation and action. After the retreats, change makers reported actively working to address opioid recovery in their communities: – Six projects are changing local systems so that they better support adults and their children through addiction and recovery. For example: changes to the child protection system that allow parents to stay connected to their children during recovery; emergency room protocols that allow for safe, informed, and non-judgmental treatment of people who present with opioid addiction; therapeutic foster homes that serve children of addicted parents, a school-based curriculum that focuses on self-discovery and wellness; and mobile client services that meet addicts wherever they are. – Six projects are creating safe and welcoming community places where those in recovery can find support. For example: arts-focused events, celebrations for recovering addicts and their children; a sober house; a yoga class just for recovering addicts; and a car repair shop that repairs cars for free for those in recovery who need cars to meet daily needs. – Three initiatives will expand community education about addiction and recovery. – Sixteen ideas received mini-grants to support implementation.	
13.	**Influencing policies, systems, and environments that shape health behaviors**	**Issue:** The 2017 Minnesota Department of Health state health assessment makes clear that health equity in Minnesota depends on changing policies, systems, and environments. For example, in Minnesota "children of color are three to five times more likely to live in poverty than white children." "The lifespan of people living in higher income areas of the Twin Cities metropolitan area can be more than 13 years longer than people living in low income areas." "Working age adults living in households earning less than $35,000 a year are 2.5 times as likely to report having	Health and Nutrition / #4

	Extension Impact	diabetes as those with higher incomes." There is a decline in grocery stores, particularly outside the metro area. **What has been done:** Extension programs are helping communities adopt policies, systems and environment changes that make a difference. In 2019, they transformed 27 food shelves using the SuperShelf model. SuperShelf transforms food shelves so that they create welcoming environments where low-income Minnesotans can access appealing, healthy food. In addition, Action Learning Seed Funds, a project co-funded with the MSDA and Minnesota's Department of Human Service, fund projects managed by change agents ready to address food systems and food equity. Organizations were supported with ongoing community building and technical assistance. **Results:** When comparing food shelves that were transformed using the SuperShelf model and those in a wait-list control group, the transformed food shelves showed a significant improvement in the amount of money spent on healthy food, and a significant improvement in self-reported healthy eating.  	

		 Twelve community change projects were implemented with Action Learning Seed Funds. They resulted in the development of new food products with local foods, development of community supported agriculture (CSA), farmers markets and community gardens, educational walking trails, multi-generational cooking classes, establishing beehives in community locations, developing a solar powered crop farm, and connecting minority owned day care centers to CSA boxes.	
14.	**EFNEP and SNAP-ED health and nutrition education creates nutrition and lifestyle changes**	**Issue.** According to the Minnesota Department of Health, 28.4 percent of adults in Minnesota were obese in 2017, an increase from 27.8 percent in 2016. Social determinants of health indicate that some groups in specific areas are more at risk of poor nutrition and increased risk of obesity because of close proximity to food deserts. Communities of color are at greater risk of experiencing health disparities. For example, 40.9 percent of American Indian Minnesotans were obese in 2017, compared to 26.7 percent of white Minnesotans. **What has been done:** Extension's 2019 grants for health and nutrition programs included the continued implementation of two major federal grants from the USDA: SNAP-Ed and EFNEP.	Health and Nutrition / #4

	Integrated Extension & Research Impact	Both programs reach limited income audiences in Minnesota, provide research-based education about healthy eating and physical activity, and promote policy, systems and environment changes to reduce disparities in food access and diet-related chronic disease. In addition to the core educational activities of both grants, Extension educators engaged in innovative and responsive programming, for example, children's gardening programs, training community members to deliver SNAP-Ed programs, nutrition programming for childcare providers, and farm-to-school initiatives. **Results:** Nutrition and lifestyle programming resulted in healthier food and lifestyle choices among participants. Using the 24-hour dietary recall tool before and after the EFNEP class series, 58 percent chose healthier foods, used safe food handling practices, increased physical activity, improved ability to prepare nutritious food, gained skills to be food secure, showed improvement in one or more food resource management practice, or read nutrition information on labels. SNAP-Ed course participants showed outcome improvements after the program. Participants increased daily fruit consumption by 15 percent; they increased vegetable consumption by 21.4 percent.	
15.	**Researchers invent shape-changing textiles powered only by body heat** Research Impact	**Issue:** Recent advances in wearable technology offer significant potential to solve problems associated with healthcare access for rural and aging communities. **What has been done:** Researchers at the University's Design of Active Materials and Structures Lab and Wearable Technology Lab recently developed a temperature-responsive textile. The new textiles resemble typical knits, except they are created with a special category of active materials—known as shape memory alloys (SMAs)—which change shape when heated. **Results:** The next steps will be to integrate the textiles into full-sized garments, which could solve a variety of problems where fit and conformance to the body are important. One area where this new technology will apply is the design of medical-grade compression socks. Individuals who use these socks need them to be tight enough to aid with blood flow, but easy to get on and off. With this new textile, patients could pull on a loose sock that would then tighten on its own.	Health and Nutrition / #4

		This work has the potential to redefine how compression garments are designed and used, which could radically improve the lives of the millions of people who rely on them to manage age-related health conditions—including in rural areas where rehabilitation treatment and face-to-face healthcare options are more limited.	
16.	**U of M establishes first of its kind Plant Proteins Innovation Center** Research Impact	**Issue:** Plant-based proteins are more in demand than ever before. As our society becomes more health conscious and more concerned with environmental footprints, demand for plant-based protein has steadily increased. However, there is limited consumer and producer knowledge of plant proteins other than soy. **What has been done:** In November 2018, CFANS established the Plant Protein Innovation Center (PPIC) to bring researchers and industry professionals together to help shape the future of plant proteins. The first of its kind in the nation, the PPIC is working to innovate how plant proteins are developed and used across the supply chain—from the land, to the lab, to the production chain. **Results:** Thus far, the PPIC has attracted 15 industry members, with more expected to join in 2020. The members are comprised of ingredient suppliers, processors, manufacturers, CPG companies, and startups. The PPIC aims to build a diverse membership cohort that represents the entirety of the value chain, from upstream to downstream, to best address the most relevant trends and challenges in the plant proteins space. Members directly influence the PPIC's research priorities, shaping the next generation of research projects, which ultimately help to build a fundamental plant protein knowledge base that benefits the industry as a whole. Ultimately, the PPIC aims to produce functional plant proteins that can succeed in the market and satisfy increasing consumer demand for more sustainable and healthy alternatives, while keeping industry needs in mind. Through precompetitive research conducted by the Center's researcher cohort of currently 21 interdisciplinary researchers, the Center will focus on fundamental science that addresses basic needs and challenges of the industry. The PPIC is establishing its mark in research outputs, delivery of knowledge, and connectivity. Among the PPIC's accomplishments within its inaugural year were a successful first round of RFPs that turned out the first two PPIC-funded research projects, two widely sought events, including the	Health and Nutrition / #4

		first "Protein Basics Short Course" and "Research Spotlight Meeting", and the acquisition of over 1.2 million dollars in funds. Some of the research successes include the optimization of protein extraction methods for yield and feasibility, as well as innovative technology involving cold plasma to enhance the functionality of pea protein.	
17.	**Study highlights industry shift as antibiotics use in poultry declines steeply** Integrated Extension & Research	**Issue:** Reducing the use of antimicrobials in every health setting is an important step in slowing the emergence of drug-resistant pathogens. More importantly, reducing the need for antimicrobials through improved disease prevention is seen as a more holistic indicator of a population's health—both human and poultry. **What has been done:** Over the past decade, University researchers and Extension specialists have been heavily involved in national efforts to develop potential alternatives to antibiotics in the poultry industry and help to share best practices to ensure antibiotics are not being overused. A recent study led by a U of M epidemiologist, in collaboration with the Food and Drug Administration and US Poultry, has found significant reductions in using most medically important antibiotics in broiler chicken and turkey production. The report covers the period of 2013–2017, and over 90 percent of broiler chickens and 80 percent of turkeys that were produced in the U.S. are represented in the dataset. **Results:** The percentage of broiler chicks that received hatchery antibiotics declined from 93 percent in 2013 to just 17 percent in 2017. Meanwhile, turkey poults that received hatchery antibiotics declined from 96 percent in 2013 to 41 percent in 2017. Tetracycline use in the feed of broiler chickens dropped by 95 percent from 2013 to 2017 and decreased by 67 percent over the same period in turkeys. The use of ceftiofur, a third-generation cephalosporin, dropped to zero in turkey poults in 2017. The results suggest that companies are making major changes in their production protocols, including using flock and herd management practices to mitigate disease introduction and spread, and, subsequently, reduce the need for antibiotic use. Improvements in antimicrobial stewardship, changing consumer demands, and changes in federal regulations are the likely key factors behind the decline.	Food Safety / #5

18.	**New process reduces contamination in powdered foods** Research Impact	**Issue:** Increasing occurrences of foodborne pathogens in dry powdered foods have become a major concern to food industries and consumers. In particular, strains of Salmonella spp. are responsible for over one million illnesses, 19,000 hospitalizations and 380 deaths in the U.S. annually. **What has been done:** U of M researchers have developed a novel method for pasteurization of food using intense pulsed light and low temperature microwave technology, along with a photocatalyst and a microwave absorbent that decontaminates granular or powdered food and food ingredients. **Results:** Researchers have shown this process reduces the microbial count in wheat kernels by over 3-5 logs in less than 15-30 seconds while maintaining under 40-60°C temperature during processing with minimal food quality changes. The process directly applies to powdered foods, grains, and nuts (i.e. wheat flour, non-fat dry milk, spices, wheat kernels, sunflower seeds, almonds, hazelnuts, etc.) and researchers have tested its effectiveness by inactivating a variety of microbial contaminants (such as C. sakazakii, E. faecium, B. cereus) commonly found in food. Implementation of this platform, which could be added easily into existing conveyor belt systems, will cost-effectively improve the safety of powdered foods, and thus enhance the competitiveness of the U.S. food industry and increase the consumption of U.S. agricultural products. In addition, the new technology will reduce the risk of foodborne outbreaks associated with the consumption of powdered foods, which will have a significant impact on the health and living standard of consumers.	Food Safety / #5
19.	**Nitrogen Smart Program changes practices to decrease nitrogen loss** Integrated Extension & Research Impact	**Issue:** Nitrates originating from agriculture have been a focus of water quality work in both surface and ground water in Minnesota for the past couple of decades. **What has been done:** Nitrogen Smart is a partnership between U of M Extension, which developed the curriculum and conducts the education, and the Minnesota Corn Growers Association. The program brings recommendations for nitrogen fertilizer and best management recommendations specific to the region and farmer's situation, yearly climate conditions, and site-specific conditions. Nitrogen Smart informs decisions by discussing the basic science of the	Water Resources / #6

		nitrogen cycle, University of Minnesota research recommendations, and the when, why and how to modify practices. To date, there have been 885 attendees for the fundamentals session, 63 for advanced and 51 have completed the course online. **Results:** Surveys six months after the program determined that practices have changed. To date, over 30 percent of attendees have lowered their application rates by just over 30 lb. N/acre. Another 20 percent say they adopted the use of nitrification inhibitors when making fall applications. This practice is known to decrease nitrogen loss. An additional 15 percent stopped making fall applications altogether. Over 10 percent say they stopped using urea fertilizer for fall applications.	
20.	**Mapping the zebra mussel genome** Research Impact	**Issue:** The zebra mussel (*Dreissena polymorpha*) is a freshwater invasive species that has spread throughout waterways in Europe and North America. Economically, they are responsible for billions of dollars of damage to the power-generation industry and to recreation and tourism. The invasive mussels also crowd out native species, destroy those species' food sources, and cause dramatic changes to the food web. Although many researchers have been studying *D. polymorpha*, there has been little genetic work done to date. **What has been done:** Researchers at the Minnesota Aquatic Invasive Species Research Center partnered with the University of Minnesota Genomics Center and the Minnesota Supercomputing Institute to analyze data and ultimately assemble and annotate the zebra mussel genome. And, in doing so, fill in a large gap in the tree of life as zebra mussels are more than 400 million years diverged from the nearest sequenced relative—roughly the same amount of evolutionary divergence as that between humans and manta rays. **Results:** The researchers used long-read sequencing and scaffolding technologies to generate a chromosome-scale assembly of the zebra mussel genome. This represents the highest quality molluscan genome assembly to date. The genome provides insights into important processes for the invasive success of zebra mussels, including shell formation, synthesis of byssal thread attachment fibers (which facilitate their attachment to surfaces and spread between water bodies), and responses to thermal stress.	Water Resources / #6

		This chromosome-level assembly is a powerful new tool for basic and applied research on zebra mussels and related invasive bivalves. The researchers identified several genes with roles in shell growth and hardening, byssal thread secretion and attachment, and tolerance of thermal and other stressors. These and others are now targets for development of control technologies.	
21.	**MN-Clearwater, a grain variety of intermediate wheatgrass, fuels farmer partnerships to improve MN's rural well water supply** Integrated Extension & Research Impact	**Issue:** Currently the crops in Minnesota's annual cropping systems only cover the soil for three months of the year, leaving the land bare and brown, and susceptible to nitrate-N leaching for the rest of the year. The leaching of nitrate-N from these systems has impaired a large number of rural municipal and private wells in several regions of Minnesota. **What has been done:** The University of Minnesota released MN-Clearwater, whose grain is approved for sale as Kernza, the first perennial grain released in the world. University of Minnesota researchers and Extension specialists, in collaboration with The Land Institute, are exploring the potential use of the crop to reduce nitrite-N leaching by 86 percent or more without asking farmers to idle any land to protect the rural well water supply. In fact, research shows that with intermediate wheatgrass (IWG), farmers get access to a more sustainable cash crop that requires fewer inputs and is proving to be an increasingly desirable grain option for the food and beverage industry. **Results:** MN-Clearwater, the University's first released IWG grain cultivar, shows an average 38 percent yield improvement over other available IWG materials and has decreased lodging which increases harvest ability. But more importantly, it is inspiring food companies, researchers and State legislators to think more creatively about how they can work with farmers to provide options that fit seamlessly into their existing cropping systems, while also helping to protect our soil and groundwater. In 2020, 'MN-Clearwater' is available to a limited number of qualified growers with a particular effort to plant the seed on farms near vulnerable wellheads—to date over 200 farmers have expressed interest in growing the crop. This initial rollout is a key step in The Forever Green Initiative's overarching goal to revolutionize Minnesota agriculture by developing new crops that provide new economic opportunities to Minnesota farmers and rural communities while simultaneously reaping significant benefits for the environment.	Water Resources / #6

22.	**Subfield level model for improved nitrogen fertilizer recommendations** Research Impact	**Issue:** Agroecosystem modeling, used for generating nitrogen (N) fertilizer recommendations, is traditionally performed at the field scale or larger. Such field level models result in an entire field getting the same fertilizing recommendation. Because of inherent variability within a field, these recommendations are not always accurate and could lead to using excess or insufficient fertilizer. **What has been done:** Researchers at the University's Precision Agriculture Center have developed a novel approach that takes the traditional modeling one step further by performing a secondary calibration using data with high spatial resolution. The software integrates remote sensing and crop systems model to spatially determine in-season N stress. **Results:** The software integrates the EPIC (Environmental Policy Integrated Climate) field (or subfield) based agroecosystem model with a geographic information system (GIS) database. It creates a simulation "template" for every unique location in a field, whether large scale (e.g. hectares) or small scale (e.g. individual plant). For each unique location, it performs a secondary calibration using any spatially precise data available (e.g., crop yield maps, aerial images indicative of crop biophysical parameters or soil characteristics) collected over any time scale. Overall, the new model integrates spatially precise data with GIS to provide better N fertilizer recommendations. These recommendations help growers made informed decisions that will ultimately improve crop N efficiency and reduce the likelihood of nitrate contamination of water resources.	Water Resources / #6
23.	**Growing community leadership and making an economic impact**	**Issue:** Extension educator Ben Winchester has examined the demand for community leadership. He considered the number of board and elected positions needed by government and nonprofits in Greater Minnesota, and estimates that one in every 34 rural Minnesotans must serve in a leadership position. In comparison, one in every 143 urban residents must serve. Leadership energy is tied to a community's ability to bring economic and civic vitality to communities.	Community Vitality and Public Finance / #7

	Extension Impact	**What has been done:** Community leadership programs at University of Minnesota Extension actively encourage rural residents to serve or to commit more to leadership in their communities, strengthen leadership competence and consider local concerns. Minnesota's community leadership model emphasizes personal development, navigating relationships, thinking critically, and acting strategically to solve problems. In 2019, Extension delivered leadership education to 23 cohorts. **Results:** Extension examined leadership role changes among participants of eight leadership education cohorts throughout the state. Of 159 participants, 64.2 percent increased their level of involvement in at least one of their leadership roles -- either to a new role, an increase from inactive to active roles, or an increase from active to leadership roles. A report published in 2019 considered the economic value of just one county-based leadership program delivered by the U of M Extension in McLeod County. The study found that the program generated $197,805 of economic benefit in 2017, including private wages and benefits attributed to the education ($33,240) and $134,615 in public value. Cumulative benefits between 2008 and 2018 can be valued at $555,400. This represents a $6.40 return on every dollar invested in the program.	
24.	**Informing and inspiring local economic development choices** Extension Impact	**Issue:** Economic development and public finance decisions, especially in rural areas with few resources and few professional staff, may be based upon assumptions, fears or erroneous information. **What has been done:** Extension's community economics educators and specialists use applied research, community development processes, and community cohorts to analyze economies, inform local decisions, and inspire local action. Facilitated conversations and consultation bring communities to support local decision-making and build consensus. Examples of applied research provided in this evaluation include: 1) economic impact analysis; 2) business retention and expansion studies; 3) visitor profiles; 4) rural business succession planning; and 5) rural resident recruitment and retention programming. In 2019, the Center for Community Vitality provided applied research and worked in-depth with more than 60 Minnesota communities. **Results:** Extension conducted follow-up surveys, interviews, and ripple effect mapping sessions in 25 communities after they completed programs. The evaluations found that 96 percent of these (24	Community Vitality and Public Finance / #7

		of the 25) agreed that Extension's Community Vitality programming influenced or inspired local decisions and resulted in positive impacts for economic development, civic life, financial, cultural, natural or built capitals. For example: - A small town committed funding to a new assisted living home; - A county decided to provide business owners with succession planning classes; - A multi-city region launched a campaign to promote recreation and business in the area; - A county launched a child care development partnership; - A regional center designed strategies to become a more welcoming community. In all, community leaders highlighted 77 positive effects on community capitals, all attributed to 25 program offerings delivered by Extension.	

25.	**Parent education for incarcerated fathers: Devoted Dads** Extension Impact	**Issue:** Father involvement is a key protective factor for children (Amato & Gilbreth, 1996) and imprisonment can negatively affect the role men play in the lives of their children. Given that families of color and families experiencing economic hardship are more likely to experience incarceration, this risk factor disproportionately impacts children who are already vulnerable. **What was done:** For a second year, five University of Minnesota Extension Family Resiliency Educators enrolled fathers incarcerated in three correctional facilities in parent education through a contract operated by the Minnesota Department of Corrections. Devoted Dads is a high dosage parenting education program, with twelve two-hour sessions. **Results:** Of 85 enrolled fathers in three correctional facilities, 61 percent identified as men of color. Fathers reported having an average of between 2-3 children. Eighteen percent had release dates before 2023. In a pre and post survey, – 39 percent more participants strongly agreed that "I have confidence in my parenting skills (23 percent at pre; 62 percent at post); – 33 percent more participants reported they strongly agreed that "I know where I can get answers to parenting questions" (24 percent at pre; 57 percent at post); – 28 percent more participants strongly agreed that "My emotional health is good, that is, I do not feel anxious, depressed or irritated" (18 percent at pre; 46 percent at post); – 27 percent more participants strongly agreed that "I feel supported by my co-caregiver(s)" (24 percent at pre; 51 percent at post); and, – 30 percent more participants strongly agreed that "I feel confident in managing my relationship with my co-caregiver(s)" (20 percent at pre; 50 percent at post).	Building Strong, Healthy Families / #8
26.	**Supporting co-parenting after relationship dissolution** Extension Impact	**Issue:** Though divorce rates are declining, 26 percent of children live with a single parent. Divorce and separation contribute, along with other adverse childhood experiences, to the risk of poor health outcomes such as depression and suicide attempts. Co-parenting is known to help children adjust, and for limited income families, supporting co-parenting after relationships end buffers against negative effects.	Building Strong, Healthy Families / #8

		What has been done: Parents Forever has been improving co-parenting relationships since 1994. The program reaches parents through referrals from court systems concerned about contentious divorce situations. The program is offered online and in person with trained trainers, trained by Extension, available in many community settings. **Results:** Six months after taking the Parents Forever course, 78 percent said that they had adjusted their parenting to better meet the needs of their children, and 20 percent said they had somewhat adjusted their parenting to better meet the needs of their children; 61 percent said they had used one of the co-parenting strategies they learned; 33 percent said they somewhat used a co-parenting strategy they learned. And 74 percent of parents said they never talked badly about the other parent in front of their children; 22 percent said they seldom talk badly. In a quasi-experimental designed study, parents who took Parents Forever reported their children had more pro social behaviors than parents who did not take Parents Forever.	
27.	**University study helps lead to new policies and guidance regarding professional licenses for military spouses** Integrated Extension & Research Impact	**Issue**: According to the Department of Defense (DoD), the military spouse unemployment rate is 24 percent and frequent military moves can make it more difficult for spouses to hold down a career. This has proven especially true for the 34 percent of military spouses who require state-issued professional licenses or certifications to work. **What has been done:** In the U.S., each of the 50 states establishes how people apply for professional licenses and the DoD has been working with states since 2011 to implement policies and laws that make it easier for military spouses to transfer licenses. In November 2017, researchers taking part in the Military REACH Project at the U's Center for Research and Outreach (REACH) released the Military Spouse Licensure Portability Examination report based on a study that examined what real changes have occurred on a state-by-state level from the DoD's effort.	Building Strong, Healthy Families / #8

		Overall, the study showed that results were mixed with some state boards interpreting the broad law differently than expected and inconsistent implementation throughout the states. The report concludes with recommendations for professionals who work with and on behalf of military families to consider as they advocate for and support efforts to improve licensure portability for military spouses. **Results:** The study was shared with the DoD's Office of Family Policy and was mentioned in the DoD's Military Spouse Licensure: State Best Practices and Strategies for Achieving Reciprocity report delivered to Congress. As part of this effort, the Pentagon has also designed a best practices continuum that shows milestones states should aim to reach to ensure they are on track. Significantly, new policies have the potential to make it easier for everyone, not just military spouses, to transfer occupational licenses between states. One positive outcome already—a nurse licensing agreement is now approved in 34 states and being considered in ten more in 2020.	
28.	**APLUS study continues to provide vital data on how young adults perceive personal finances affecting their quality of life** Integrated Extension & Research Impact	**Issue:** An increase in financial stress and health problems across the nation has spurred an interest among family and development researchers to consider the role of personal finance and financial behaviors on individuals. **What has been done:** In 2008, a team of researchers began the Arizona Pathways to Life Success for University Students (APLUS) Project. APLUS is the first ever study to examine how young people develop financial behaviors and how those behaviors relate to financial capability and well-being as adults. The success of the study relies on the 2,098 students who completed the Wave 1 survey on the financial attitudes and behaviors of college freshmen. In 2017, the research team submitted a report for Wave 4, which included survey results for 855 young adults who have continued to engage with the study. **Results:** The APLUS study has become a key reference point for insights into how college educated millennials perceive financial well-being and life quality. It has also provided significant	Building Strong, Healthy Families / #8

		information about where young adults learn about finances (fewer than 16 percent of American students are required to take a personal finance class in high school) and how that affects their life and even relationships. Notably, the study has provided data for many offshoot studies and has helped shape educational and outreach programs that improve financial literacy and help consumers make informed financial choices.	
29.	**4-H grows global citizenship skills** Extension Impact	**Issue:** Youth need to think critically in order to become contributing members in our global society. **What has been done:** Youth in 4-H become leaders by developing global citizenship skills that are critical to becoming active and involved community members. They also build decision-making and teamwork skills, which are vital for effective leadership. **Results:** A Learn and Lead study was conducted in 2018 and the report was published in 2019. The study found that 90 percent of 4-H youth helped to solve a community problem, many as part of a community group. Three out of four youth in 4-H gave back through service to better their communities--both locally and globally. Examples of community projects include clothing drives for people in need, food shelf collections, environmental improvements and monitoring for invasive species.	Youth Development / #9
30.	**Master Naturalists' citizen scientist projects protect the environment** Integrated Extension & Research Impact	**Issue:** Care for land and water cannot be done solely by professionals. Citizens who are aware of their habitat, and are available to monitor and address issues are a sustainable answer for protecting the environment, which is continually at risk. **What has been done:** In 2019, 1,718 Extension-trained volunteers provided 109,671 hours of service to 161 partner organizations. Extension offered 66 advanced training courses to enhance the skills of 1,076 Master Naturalists, and an additional 353 participated in 15 biome training courses.	Natural Resource Management / #10

		Results: Hours are valued at $2.79 million and were the equivalent of 52 full-time employees managing natural resources and environmental ecosystems. Of these service hours, 30,150 provided research-based education and interpretation programs that reached 333,485 people. Citizen science and stewardship projects impacted 608,564 acres by restoring pollinator habitat, planting trees, removing invasive species and conducting bird counts.	
31.	**Researchers developing rapid-test to help stop CWD in its tracks** Integrated Extension & Research Impact	**Issue:** More than 70 deer have tested positive for Chronic Wasting Disease (CWD) in Minnesota since it was first detected in 2002. While still rare in MN, its potential spread is a constant worry for the Department of Natural Resources (DNR) who control the state's $1 billion annual deer-hunting industry. CWD is a death sentence for the animals that contract it as there's no cure and no vaccine for this brain disease. **What has been done:** University of Minnesota researchers in the College of Veterinary Medicine have been collaborating to help stop CWD in its tracks for over a decade and have been exploring potential public safety concerns poised by the disease as it has spread throughout the state. But their efforts have been hampered because CWD prions can persist in the environment for years by binding to soil and being absorbed by plants before infecting other deer. Monitoring and predicting their spread is nearly impossible as the only way to confirm CWD is by killing the animal and sending samples out for expensive tests that take days or weeks to complete. To help combat this issue, a team of University researchers are working to develop a rapid, accessible test that would work not only on live animals but also, soil, meat processing equipment, feces, blood and samples from other animals—thus helping to shed light on where CWD is going, not just where it has been. **Results:** To date, the research team and their collaborators have developed RT-QuIC technology that will facilitate several exciting research avenues. With this technology, the team analyzed tissue samples from CWD-positive white-tailed deer and got a confirmation of protein-misfolding within nine hours. The next step will be to confirm that RT-QuIC testing can correctly identify positive samples from about 500 deer provided by the DNR.	Natural Resource Management / #10

		A rapid, field-based test would revolutionize efforts to control this contagious and deadly neurodegenerative disease. In the meantime, University researchers are working closely with Extension and the DNR on a public information campaign to help inform Minnesota's diverse hunter community of current policies and risks associated with CWD.	
32.	**Researchers explore the interwoven roles of fire and wildlife in oak savanna conservation by introducing bison** Research Impact	**Issue:** In the Midwest, oak savannas were once abundant—in Minnesota alone they once accounted for 10 percent of the native vegetation. However, as a fire dependent ecosystem, oak savannas have been significantly reduced by farming and development. Today, intact oak savannas are one of the rarest ecosystems on earth. **What has been done:** Each spring, the fire team at the Cedar Creek Ecosystem Science Reserve conducts prescribed burns at locations around the station totaling over 900 acres. This annual effort is part of a long-term research experiment to better understand the role of fire in maintaining prairie and oak savannas. One downside of the burns has been the killing of young oak trees, which cannot survive the hot and intense fires. Researchers at Cedar Creek were interested in exploring the role traditional wildlife may have played in helping protect the oaks that play an integral role within the ecosystem by providing shelter to wildlife. Starting in 2018, they introduced bison, hoping that bison grazing the native prairie grass would reduce the intensity of the fires—thus sparing the young oaks and giving them time to mature. **Results:** Beyond their popularity with the public, areas grazed by the bison have been 180°C cooler during the burns. In addition, areas grazed by bison have shown very high survivorship among young oak seedlings. Cedar Creek has been practicing prescribed burning since the 1960s, making it one of the longest ongoing scientific fire experiments in the world. Throughout this time, they have learned invaluable information about the role fire plays in nutrient cycling, ecosystem health, and the restoration and maintenance of rare landscapes. And now, they are adding to this, the exploration of the role native wildlife plays in balancing these fragile systems.	Natural Resource Management / #10

33.	**University researchers work to break buckthorn's cycle of invasion** Integrated Extension & Research Impact	**Issue:** Buckthorn is an invasive, non-native plant species that affects countless acres and wallets in Minnesota. In North America, it often forms thickets that can impede hunters, hikers, and wildlife moving through the forest and is especially successful at outcompeting native plants in shady conditions. **What has been done:** Due to its status as a noxious weed, buckthorn management recommendations are plentiful, but many are struggling with the time and cost needed for multi-year post-management strategies that keep buckthorn at bay. With the "Cover It Up" project, University researchers at the Minnesota Invasive Terrestrial Plants and Pests Center aim to improve Minnesota's forest health by breaking the cycle of invasion by revegetating with dense native plant cover to shade out buckthorn after removal—a technique that has been successfully used in prairie restoration. **Results:** The researchers have discovered that buckthorn seedlings need a certain threshold of light to survive. If light availability drops to 3-4 percent throughout the spring, summer and fall, it's enough to prevent buckthorn growth. Additionally, some native species have shown promise in helping to suppress regrowth including: wild grasses, flowering herbs and young trees, but researchers stress geography and planting conditions play a key role in determining the right mix of native species. Results so far suggest that revegetation can suppress buckthorn, but researchers now need to explore how to scale it and apply it across various conditions. For phase two of the project, the team is expanding their reach via a citizen science program that, with the public's help, will allow them to carry out experiments in woodland areas across the state. Ultimately, this work could change the way we think about buckthorn management—by helping Minnesota land managers save significant time and money in their long-term restoration efforts—along with improving the overall health of Minnesota's forests.	Natural Resource Management / #10

34.	**From grape to wine—helping Northern wineries succeed** Integrated Extension & Research Impact	**Issue:** Everybody knows Napa and Sonoma, but what about the Upper Mississippi River Valley or Alexandria Lakes? Since the 1970s, cold climate grape growers and winemakers have been slowly but surely making a name for themselves and along the way have built a cold-climate wine industry worth an estimated $400 million ($80.3 million in MN). But, because of the young age of cold-hardy grapes cultivars, northern winemakers require guidance on how to get the best results from their grapes. **What has been done:** The U of M Grape Breeding and Enology project blends variety development and winemaking expertise. On the enology side of the project 50-150 experimental wines from test cultivars are developed each year. The project aims to benefit the regional wine industry by determining the optimum processing methods for both new and existing cold-hardy grape cultivars, and providing local support for the analytical, technical, and educational needs of the Minnesota wine industry. The University hosts regular winemaker roundtables where practitioners meet and evaluate each other's wines, learn about production practices, and build a community of practice. In addition, researchers in the project are interested in characterizing the unique components of new cultivars introduced to the industry. Due to their interspecific ancestry, U of M cultivars have different color, tannin structure, and flavor compounds than traditional wine grapes that affect the finished wine. The better these unique matrices are understood, the easier it is for growers and winemakers to produce high-quality wine. **Results:** Today, there are over 80 wineries in Minnesota and the industry supports about 10,500 jobs. In 2019, 22 workshops or field days supported 533 grape growers and others to learn about best practices in managing grape growing, including disease and pest management, supporting cold hardy grapes, and troubleshooting grapevine issues. In addition, U of M experts conducted a sensory analysis at the Cold Climate Grape Conference in 2017 and 2018 with experimental 'Itasca' wines (made with the new Itasca grape, which is about 30 percent lower in total acidity than Frontenac gris) to provide some initial insight to winemakers making 'Itasca' wines for the first time. Sensory panelists preferred wines without Malolactic fermentation (MLF), with Yeast V116 and no MLF, no skin contact for a "less sour" wine, and cold treatment at 45°F to increase tannins and/or raise pH.	Horticulture / #11

		By providing the industry with the latest advances in propagation, hybridization, cultivation and winemaking, U of M researchers and extension specialists are ensuring the introduction of vines with superior performance in both vineyard and winery and helping guarantee the continued growth of the wine industry throughout MN and the world.	
35.	**Master Gardeners** Integrated Extension & Research Impact	**Issue:** Community volunteers, acting as citizen scientists, are uniquely situated to collaborate with local organizations and groups, know and address local opportunities, and engage and educate people in their communities. With proper education, they can address critical issues that have been identified by the University of Minnesota Extension: – Teaching research-informed horticulture practices – Promoting invasive species management and native species conservation and restoration in landscapes; – Teaching others ways to help native bees and other pollinators thrive in home and community landscapes; – Promoting water-wise gardening and landscaping practices to conserve water and minimize polluted runoff; – Promoting the use of sustainable techniques for growing local food; – Teaching ways to create resilient landscapes that adapt to climate change; and, – Creating access to plants and green space for communities' health and wellbeing. **What has been done:** In 2019, Master Gardener volunteers, trained and supported by Extension, volunteered 143,821 hours and reached 195,124 Minnesotan. These Master Gardeners worked on 370 garden projects and delivered 1,625 educational events that addressed the program priorities. **Results:** Volunteers for garden projects donated 33,615 pounds of produce, created 46,030 square feet of rain gardens, created and maintained 73 schoolyard gardens, and supported the creation of 372,984 square feet of pollinator-friendly gardens.	Horticulture / #11

36.	**Benefits of bee lawns inspire legislators, land managers and homeowners** Integrated Extension & Research Impact	**Issue:** Turfgrass lawns are ubiquitous in urban and suburban areas, covering over two percent of the land area of the continental U.S. but they don't provide nectar or pollen for bees. **What has been done:** A group of interdisciplinary researchers at the University of Minnesota teamed up to explore flowering bee lawns as a concrete way that public land managers and homeowners can support bees. They conducted experiments to: 1) Determine which low-growing flowering plants could sustain growth within turf, continue to flower after mowing and provide food for a diverse number of bees; and, 2) Test flowering lawns in public parks and gather public perceptions on pollinators and flowering lawns. **Results:** Researchers collected 3,507 bees over the three-year study. They collected fifty-seven unique bee species off of lawns with only Dutch white clover, while they collected 60 unique bee species off of florally enhanced lawns with Dutch white clover, self-heal and creeping thyme. Of the 502 park visitors surveyed, 95-97 percent supported creating flowering lawns in public parks. Aesthetics and supporting bees were the two most commonly mentioned potential benefits of flowering lawns. In August 2019, the research team released a Flowering Bee Lawn Toolkit for Land Managers based on their research. Minneapolis Parks and Recreation Board has already added bee lawns to their sustainable landscape plans and the Minnesota Legislature has gotten involved by funding a $900k grant program to assist homeowners with the cost of creating bee friendly habitats including bee lawns—over 4,000 residents applied for 2020 funds. Ultimately, this work will assist land managers and homeowners to adopt more sustainable land management practices and, in time, change perceptions on what the ubiquitous urban green space should look like.	Horticulture / #11
37.	**Farm transition and estate planning program prepares family farms for transfer**	**Issue:** In 2017, the average age of principal farm operators was 56.6 years. The business and personal assets of those who produce the world's food supply need to be protected as owners move into retirement and pass their business assets on to the next generation. **What has been done:** Between January and March 2019, Extension educators held 11 Create Your Farm Legacy workshops in locations throughout the state, and reached 302 participants. Most	Agricultural Business Management / #12

	Integrated Extension & Research Impact	attendees were from crop farms (54 percent) followed by diversified crop and livestock farms (25 percent). Content incorporated research findings and focused on transfer goals, business structures, succession planning, mechanisms for inheritance, fair vs. equal distribution and communicating with family. **Results:** A six-month follow-up evaluation determined whether participants moved forward with transition and estate plans. Of those who responded, 59 percent had begun updating their transition plans and 56 percent were updating their estate plans. The self-reported value of the personal and farm assets protected by their estate plans ranged from $600,000 to $12,000,000.	
38.	**Extension informs fair and profitable farm rental agreements** Extension Impact	**Issue:** Farmland rental rates have increased dramatically as commodity prices reached record levels and remain high compared to historic averages since 2008. Extension's agricultural business management faculty receive an average of three questions daily about fair and profitable rental agreements. Farmers and landlords need information in order to better negotiate fair and profitable rental agreements. **What has been done:** To meet demand, the Extension team developed, designed and delivered 40 workshops across the state, reaching a total of 889 farm and ranch family members, landlords and agricultural professionals. **Results:** Workshop participants were asked to determine what monetary value they would place on the information they received and how it helped them determine rental agreements. The total financial impact of this program effort is estimated at $81,651,600 dollars. The financial impact is based upon participants from 68 of Minnesota's 87 counties attending one of the workshops. Using 2018 estimated average cropland rental rates for each county, multiplied by the number of participants from each county or $200 per acre of rent based on total acres of participants who attended workshops.	Agricultural Business Management / #12