2014 Montana State University Research Annual Report of Accomplishments and Results

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I. Report Overview

1. Executive Summary

The Montana State University (MSU) College of Agriculture (COA) and Montana Agricultural Experiment Station (MAES) is pleased to present a 2014 Annual Report of Accomplishments and Results. The report not only highlights annual accomplishments, it also represents the breadth and depth of MSU COA/MAES leadership and productivity in aspects of twenty-first century agriculture science, outreach, education and innovation. Leading Montana in cutting-edge research and delivering timely information to stakeholders continues to serve the mission of the university. This year, the university was again proud to honor the responsibly of being the state's singular 1862 land-grant designated institution, while working closely with Montana's seven other 1994 land-grant colleges. The result is a state with the most land-grant schools in the nation, and a growing, collaborative statewide-system of land-grant colleges that hopes to eventually become a regional model of interconnected 1862 and 1994 institutions.

COA/MAES 2014 accomplishments and results represent modern day achievements in 151 years of honoring the legacy and commitment within the land grant tradition. Federal Hatch Act funding continues to allow MSU's faculty scientists to meet the changing needs of Montana, explore unique solutions to pressing questions, and solve global problems in agriculture. HATCH funding continues as the critical foundation for COA/MAES scientists to be successful in competition for complimentary national-level grant funding. The college consistently ranks in the top tier of the university's annual research expenditures and has seen an increase in research activity.
Montana 2014 Agricultural Statistics

- Montana land in farms and ranches totaled 59.7 million acres, or 64.2% of the state's land base, with the majority of land being pasture and range.

- Total cash receipts (excluding government payments) for crops and livestock totaled $3,745,101; crops totaled $2,260,720 and livestock totaled $1,484,381.

- Montana hosted 13 foreign trade delegations and 60 visitors from seven nations, interested in purchasing Montana exports.

Montana remains the number one producer of dry peas and lentils. Montana producers have increased the value of what they sold by 59% from 2007 to 2012, while producers nationally increased their production value by 39%. The 2014 crop year faced warm and limited precipitation though out the year, but when precipitation was received hail often accompanied the storm. Montana recorded a record amount of acreage damaged by hail.
Montana again ranks 2nd in the U.S. in acres devoted to farms and ranches with annual crop and livestock cash receipts exceeding $3 million. The 2014 value of crop production increased to $2.3 billion, an increase of $325.1 million or 16 percent above 2011. The value of livestock increased in 2014 to 41.6 billion, up $200.6 million from 2011. According to the "2014 Montana Agricultural Statistics," published by USDA, NASS and Montana Department of Agriculture offices, agriculture demonstrated a nine percent increase, up $375.6 million from 2011. In 2011-2012, wheat production totaled 8.5 percent of

the entire U.S. production.

Montana farmers saw an increase in the production of corn and sugar beets with production up 17 percent from 2011. Dry edible pea production, and canola were up as well, but hay production fell by 26 percent this year. In 2011-2012 the state ranked 1st in the production of lentils and dry edible peas; 2nd in spring wheat, barley, Austrian winter peas, and flaxseed; 3rd in the production of winter wheat, durum wheat, hay, safflower, and canola; 4th in garbanzo beans; 5th in sugar beets and canola; 6th in the production of all hay; and in the top 10 for pinto beans.

This report highlights both long-term, traditional programs, as well as innovative programs that are early in their development, with respect and adherence to the corresponding 2014-2018 Plan of Work. COA/MAES projects and investigations in pest management and plant breeding again allowed producers and stakeholders to remain competitive in national and world markets in 2014, as well as train the next generation of plant-breeders (via the campus's breeding labs and graduate students in the Department of Plant Sciences and Plant Pathology) to ensure the nation's food and fiber supply. COA/MAES research activities produced two patent applications in plant breeding; both patent applications are a result of two new wheat lines developed in the MAES breeding programs. The patent applications are a direct result of research conducted in response to destructive diseases and pests in crop production that remain a regional threat. Additional 2014 developments of new strategies in plant and pest resistance include: educational programs and materials, achievements in biological control agents, invasive mitigation methods, and new genetic resistance successes. Improved wheat cultivars with improved pest resistance and quality characteristics, provide Montana producers the ability to continue to thrive in global markets. COA/MAES scientists also initiated new findings in animal health including significant advancements in forage intake, supplement consumption, delivery methods and vaccination research, all of which helped to enhance overall production. These achievements include 100 new registered products that range from new germplasms, to educational aids and curricula, videos and websites, nationally unique research models, and insect and plant collections numbering more than 26,000 species. COA/MAES investigators also provided quality in-depth trainings and presentations to more than 50,000 patrons, and strengthened partnerships with MSU Extension, and private stakeholders.

Tribal College Partnerships in 2014
Montana is home to eight land-grant institutions, the most of any state in the nation. Of the eight, only Montana State University, which includes MAES through the Hatch Act and Extension through the Smith- Lever Act, is part of the original Morrill Act of 1862. The other seven are tribal colleges that received land-grant designation through the Elementary and Secondary Education Reauthorization Act of 1994. These institutions and their tribal affiliations are; Anaiih Nakoda College (Gros Ventre and Assiniboine), Blackfeet Community College (Blackfeet), Chief Dull Knife College (Northern Cheyenne), Fort Peck Community College (Sioux and Assiniboine), Little Big Horn College (Crow), Salish Kootenai College (Bitterroot Salish and Pend d'Oreilles) and Stone Child College (Chippewa-Cree). Having eight land-grants is a growing source of pride for Montana as there are increasing numbers of partnerships that create comprehensive connections among them and elevate all citizens through the tripartite mission of research, education and outreach. The 1994 tribal colleges serve primarily American Indian populations located in remote, under-served communities that otherwise lack access to higher education. They are critically important to the people they serve and include culturally relevant curriculum and programs that enhance cultural and historical identity. In addition to adopting the land-grant mission in 1994, five of the reservations also partner with MSU Extension, through the Federally Recognized Tribal Extension Program (FERTEP). The Blackfeet, Flathead, Fort Belknap, Fort Peck and Northern Cheyenne reservations all have Extension agents who live and work in the community and perform duties much like county agents.

Each of the seven 1994 institutions is found on a unique Montana reservation. These are; Blackfeet, Crow, Flathead, Fort Belknap, Fort Peck, Northern Cheyenne, and Rocky Boy. The seven

reservations collectively span nine percent of Montana's land and include twelve federally-recognized sovereign tribal nations. These are; Assiniboine, Blackfeet, Chippewa, Cree, Crow, Gros Ventres, Kootenai, Little Shell, Northern Cheyenne, Pend D'Orieille, Salish, and Sioux. The reservations are sovereign and tribal governments establish services for their citizens. There are also many Indian people who live off-reservation in communities across Montana. The Montana constitution, created in 1972, includes, in Article X, section 1(2): "The state recognizes the distinct and unique cultural heritage of the American Indians and is committed in its educational goals to the preservation of their cultural identity." In 1999, the Montana Legislature passed the "Indian Education for All" law as a way of being more intentional about fulfilling this constitutional obligation (§ Mont. Code Annotated 20-1-501). Every public agency, and all educational personnel are called to work cooperatively with Montana tribes when providing instruction and implementing educational goals, and to include information specific to the cultural heritage and contemporary contributions of American Indians.

The COA, MAES and Extension cooperatively design and implement programs that best align with Montana's sovereign Indian Nations. Because this demographic is largely underserved and underrepresented, programs and goals were targeted to generate strong and beneficial interactions regarding respective Montana reservation struggles, priorities and needs. MAES and Extension again worked closely with tribal councils and colleges across the Rocky Mountain region, and agents and educators provided a variety of academic programs and opportunities within tribal communities. Cooperative efforts provided resources and training in livestock management, childhood obesity, food preservation and safety, pasture restoration, environmental stewardship, sustainable agricultural practices, resource and risk management, pesticide certification and more. American Indians and other minorities regularly participated in MAES and Extension programming not on reservations or targeted toward tribal needs, as well. Cultural sensitivity and inclusiveness again remained an institutional priority for all COA, MAES and Extension programming.

Due to increasing competition in federal funding, in conjunction with several faculty assignments having left for new institutions, the COA/MAES saw a decrease of 6.2 percent in FTE representation. However, since the calendar year began in January 2015, COA/MAES has hired three new faculty positions in Animal and Ranges Sciences, with more faculty appointments (college-wide) expected to be filled in coming months. Despite funding hardships, achievements made in 2014 continued to support and maintain agricultural crop production for the economic health of the state, region and country. COA/MAES has always maintained a close relationship with Montana State University Extension and worked extensively with them to create a new 2016 Combined Research and Extension Plan of Work. The opportunity to enhance this partnership and elevate agriculture in Montana is valued and represents a clear commitment to the heritage of the state.

As the goal statements and outcomes throughout this report attest, the agricultural challenges and opportunities in Montana are endless. Increasingly, the COA/MAES institution serves a growing, diverse constituency with limited, competitive resources.

In 2014, the Montana agricultural community worked together to reinforce the priorities for the College of Agriculture and the Montana Agricultural Experiment Station. Investigators and stakeholders facilitated focus groups and community meetings throughout the state ensuring the research priorities were current and valid for the target population. Following is a list of priorities and a planned program areas reported on in this document:

- Add value to Montana's high quality crop and livestock systems
- Develop effective livestock disease control methods
- Develop higher yielding and higher quality cultivars
- Expand research on agricultural and natural resource interactions
- Explore alternative and new crops

• Improve beef production practices and evaluate genetics to improve herds
• Increase research programs on alternative energy sources, including crops for biofuel

1. Climate Change & Environment
In the northern Rocky Mountain west, climate change and environmental studies are becoming increasingly necessitated as major environmental changes continue to accelerate. COA/MAES faculty scientists continued to recruit competitive grant dollars and personnel to bolster current and forecasted research faculty lines, undergraduate and graduate students, programs and labs, as they relate indirectly and directly to the field of climate change studies. This program saw an increase of nine new Hatch projects (not previously articulated in the corresponding 2014-2018 POW), many of them interdisciplinary in nature - as they speak to research areas that rapid climate change has affected. The agricultural community in Montana wants to add value to Montana's high quality crop and livestock systems in ongoing adaptations to climate change. Leaders in the agricultural community have prioritized research exploring new and alternative crop varieties and high yielding cultivars. Researchers are also studying how the climate is affecting native plants, insects, and wildlife as well as carbon sequestration. As the nation develops a responsive adaptation to climate change, COA/MAES scientists continued to make advancements in this critical research agenda and aims to continue excelling in the discovery and communication of how natural and managed environments and their elements function in an era of global climate change.

2. Food Safety
Food safety and security continued as important concerns for the beef industry at all production levels. Domestic and international consumers are demanding more information about the source of the meat products they purchase, including the age, health, nutrition, and handling management of the animal. COA/MAES studies again helped to ensure that Montana producers raise safe beef while improving the quality of the beef and ensure consumers are aware of the quality and health of their products through advancements in educational programs on beef quality assurance (BQA) practices, voluntary beef cattle marketing options, and ranch management issues throughout the state via meetings and interactive technologies. Food Safety also involves mycotoxins in grains and feeds and a large portion of research genres traditionally housed with Animal Health. For reporting purposes, and to correctly align with the corresponding 2014-2018 Plan of Work, the food safety category is somewhat parallel and cross-disciplinary with the Animal Health. Both programs rely heavily on pre-harvest research and investigation.

3. Integrated Pest Management
An increase in public concern about food safety, quality, cost, biodiversity, and the sustainability of natural resources such as soil, air, and water quality is pushing scientists to rely less on pesticides and look for more environmentally friendly options. In 2014, researchers again explored new and improved methods to identify and control insects, weeds, and diseases challenging Montana farmers and studied biological controls as low impact pest control options to promote sustainable practices. Producers and researchers continued to evaluate these new integrated pest management (IPM) methodologies so they can maintain a competitive position in U.S. and world markets while helping alleviate global hunger. In Montana and throughout the U.S., maintaining profitable agricultural enterprises while sustaining ecological systems has become a difficult balancing act that often results in changes in agricultural practices and environmental policies.

4. Animal Health, Production and Products
Research programs at MSU COA and MAES focused on the reproductive performance in animals, nutrition, genetic improvements for herds, and developing better animal management systems. The majority of the Animal Health program focused on pre-harvest research and investigation; namely neo-natal health of livestock, disease resistance and best breeding practices. NIFA defines sustainable agriculture as an integrated system of plant and animal production practices having a site-specific application that will over the long-term satisfy human food and fiber needs. It also discussed the

importance of enhancing environmental quality and the natural resource base essential to the agricultural community, though researchers at MSU feel little plant/animal integrated systems level research has been done that addresses all of the factors outlined in the USDA definition of sustainable agriculture. In addition, organic certified vegetable, row crop, and animal production enterprises and research have not fully taken advantage of the potential benefits of plant/animal integration and suffer from issues ranging from animal health and finishing (particularly internal parasite control, and alternatives to confinement finishing) to residue and cover crop management, and soil health issues related to extensive tillage commonly used in organic farming programs. Thus, COA/MAES scientists again made sound progress in several research projects that do and will continue to emphasize a combined animal and plant approach.

5. Plant Breeding, Genetics and Genomics
Research objectives in Plant Breeding, Genetics and Genomics again included increasing yield potential, improving winter hardiness, enhancing wheat stem sawfly resistance (and myriad complimentary pests), and improving dual-purpose end-use quality grains. MSU's intensive genomic helped Montana producers stay competitive and provide improved cultivars adapted to Montana's climatic conditions and cropping systems. Continued productivity of breeding programs improved the understanding of the genetics from key traits and allow the development of new selection tools. The broader impacts of the work are a larger and higher quality food supply for the world, an improved ability of Montana farmers to compete in a global marketplace, and a strengthening of export markets for U.S. wheat in coming years.

While the program overview and highlights in this annual report reflect just a portion of the many accomplishments during 2014, it does adequately represent the dedicated and committed talent that collectively ensures Montana's agricultural and natural resource success and longevity. Researchers at Montana State University COA/MAES also continued learning as they focused on diversity and efficiency in agricultural operations and continued to optimize grower profitability. Because of a statewide network of private producers, stakeholder groups, supported by COA/MAES faculty and staff, it is possible for MSU COA/MAES to remain committed to serving and enhancing citizen knowledge and production. On behalf of the Montana State University College of Agriculture and Montana Agricultural Experiment Station, we are pleased to present the 2014 Annual Report.

Total Actual Amount of professional FTEs/SYs for this State

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	0.0	0.0	311.5	0.0
Actual	0.0	0.0	299.7	0.0

II. Merit Review Process

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

- Internal University Panel
- External University Panel
- External Non-University Panel
- Combined External and Internal University Panel

- Combined External and Internal University External Non-University Panel
- Other (Dept. Head External to PI's Dept.)

2. Brief Explanation

Department heads with the MAES and COA review Hatch Projects at the department level. A committee of peers then reviews the project and passes it to the director for final approval. The MAES director's office ensures this process is done as efficiently as possible. The peer review committee, selected by the director after consultation with COA department heads, includes the principle investigator's (PI) department head, MAES administrator, one department peer reviewer and two additional faculty external to the PI's department. Researchers present seminars to the review committee and interested stakeholders, including faculty, staff, students, and constituents. The director requires researchers to propose new projects for a three year period, while researchers with favorably reviewed ongoing projects continue for five years. External expert reviews occur with Montana State University faculty external to the COA, as a requirement of the review process. Presenters announce all seminars ensuring broader attendance and input potential. Reviewers provide written recommendations on the following: relevance and importance of the project; relationship of the project to previous research; objectives; approach and methods; scientific and technical quality; resources; environmental, economic, and/or social impacts. The MAES administrator and department head share the responses with the PI. If the projects do not meet expectations the director will not approve them and will defer them until the researcher meets the key elements satisfactorily. Ultimately, the office staff submits the director-approved projects to USDA-NIFA for final approval.

III. Stakeholder Input

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

- Use of media to announce public meetings and listening sessions
- Targeted invitation to traditional stakeholder groups
- Targeted invitation to non-traditional stakeholder groups
- Targeted invitation to traditional stakeholder individuals
- Targeted invitation to non-traditional stakeholder individuals
- Targeted invitation to selected individuals from general public
- Survey of traditional stakeholder groups
- Survey of traditional stakeholder individuals
- Survey of the general public
- Survey specifically with non-traditional groups
- Survey specifically with non-traditional individuals
- Survey of selected individuals from the general public
- Other (Educational outreach programs)

Brief explanation.

The Montana Agricultural Experiment Station (MAES) and COA obtain stakeholder input on research priorities and programs through a small, yet well-connected group that represent the myriad interests in Montana agriculture. Stakeholder committees include the sustainable agriculture focus group, MAES State Advisory Council, Ag Coalition and other state and local groups. Agriculture interest groups consist of representation from the Agricultural Business Association, Farm Bureau Federation, Montana Stockgrowers, Montana Farmers Union, Montana Water Users,

Montana Wool Growers, Seed Growers, and the Seed Trade. It meets periodically with the dean and director to review program priorities, new initiatives, fundraising efforts, and legislative activities. The College advertises the meetings via news releases, newsletters, individual letters, and announcements at group meetings. Extension agents use county profile information to ensure those invited to the sessions reflect the diversity of the area. The MAES responds to stakeholder inputs by considering their proposals at research planning meetings with scientists, advisory groups, and administrators. Administrators solicit stakeholder input at the strategic planning process and as programs are developed, implemented, and sometimes redesigned. Local advisory committees to the research centers also provide annual and long-term guidance to the College and MAES. MAES scientists routinely participate with these groups and NRCS to provide training and expertise in many of scientific and program areas.

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

1. Method to identify individuals and groups

- Use Advisory Committees
- Use Internal Focus Groups
- Use External Focus Groups
- Open Listening Sessions
- Other (Volunteers, membership on ag. assoc. boards)

Brief explanation.

The seven agricultural research centers have local advisory groups that meet multiple times through the year. In addition, a State Advisory Council meets three times each year to discuss program focus and direction, Montana legislative priorities, and productivity/impact. These meetings are open to the public. Administrators and faculty in COA/MAES serve on agricultural association committees that annually direct and fund research activities. These committees use a variety of collection methods, but the most common are face-to-face meetings, telephone, and some video conferencing.

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

1. Methods for collecting Stakeholder Input

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

Brief explanation.

Through direct participation with agricultural stakeholder groups, broad participation in committees, and directed meetings, MAES listens to and considers defined problems or questions that research programs can address. COA/MAES considers the voice of public stakeholders at every turn and works closely alongside various producer groups to critique and share applied research and methodology. It is common for many of Montana's public and private agricultural groups to hold meetings in COA/MAES facilities on campus, or for state-wide producers to volunteer a portion of their acreage for research studies. The director targets selective meetings with non-traditional groups. Montana has an open meeting law. Therefore, all meetings are open to the public and the organizer must publish an agenda.

3. A statement of how the input will be considered

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

Brief explanation.

As a Land Grant Institution Montana State University has a solid foundation of past and future program activities that allow stakeholder input and strong interactive dialogue, and the COA and MAES clearly sets the tone for this interactive environment. The College and the research centers serve as the primary conduit for connection and delivery of education and new knowledge in agriculturally-related activities throughout rural Montana. Advancements in the Animal and Range Sciences Department provide an example of how stakeholder input resulted in specific actions. Stakeholder requests for a more comprehensive beef, cattle, and genomics program resulted in:

- A new Animal Bioscience Building built in 2010
- Three new full-time faculty positions in Animal and Range Sciences
- New equipment, including a: Torrent Personal Genome Machine for profiling genetic information taken from livestock samples
- Illimina MiSeq which collects specific information from multiple DNA molecules helping
- scientists study microbial life in a sample
- Maxwell 16 (a machine which extracts nucleic acid and runs 16 DNA samples at a time)
- Polymerase chain reaction machine
- Refrigerated micro centrifuge
- Computer bio-analyzer which measures RNA and DNA samples
- Necropsy down-draft tables for laboratories complete with ceiling cameras
- The creation of two endowed chairs for the university; one in Animal and Range Sciences and another in Plant Sciences and Plant Pathology.

The Land Resources and Environmental Sciences department had a comprehensive external review and the College is actively working on the recommendations from the review with particular emphasis on reshaping the undergraduate curriculum to include core competencies, and exploring stakeholder interactions. Last fall, the Department of Agricultural Economics and Economics also had an external review and were given high marks on programming and academic rigor.

COA researchers launched a stakeholder driven project studying Tall Buttercup, a newly listed noxious weed in Montana that is posing problems for producers in western and southwestern Montana. Found primarily in wet hay meadows, there is little information about tall buttercup

currently available, but producers are concerned because it is toxic and appears to reduce forage production. The Madison County Weed District and local producers approached the COA/MAES about helping them manage the buttercup problem.

Brief Explanation of what you learned from your Stakeholders

Stakeholders play a key role in our programs, and they are pleased with the direction the College of Agriculture and the Montana Agricultural Experiment Station is going. During recent legislative hearings key stakeholders repeatedly testified about the College and MAES research accomplishments from integrated pest management and wheat breeding programs, to the excitement generated with the application of latest molecular technologies towards agricultural and natural resource systems. It is also worth noting that, in recognition of the value MSU places on its relationship with the agricultural community and its stake in the agricultural industry, MSU named the COA/MAES current dean and director as a Vice President of the university. This is the first time Agriculture has had a vice presidency at MSU, currently occupied by Dr. Charles Boyer.

IV. Expenditure Summary

1. Total Actual Formula dollars Allocated (prepopulated from C-REEMS)			
Extension		Research	
Smith-Lever 3b & 3c	1890 Extension	Hatch	Evans-Allen
0	0	2796076	0

2. Totaled Actual dollars from Planned Programs Inputs				
	Extension		Research	
	Smith-Lever 3b & 3c	1890 Extension	Hatch	Evans-Allen
Actual Formula	0	0	2430045	0
Actual Matching	0	0	13457845	0
Actual All Other	0	0	12342841	0
Total Actual Expended	0	0	28230731	0

3. Amount of Above Actual Formula Dollars Expended which comes from Carryover funds from previous				
Carryover	0	0	1987990	0

V. Planned Program Table of Content

V(A). Planned Program (Summary)

Program # 1

1. Name of the Planned Program

Climate Change and Environment

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
101	Appraisal of Soil Resources			10%	
102	Soil, Plant, Water, Nutrient Relationships			13%	
111	Conservation and Efficient Use of Water			10%	
112	Watershed Protection and Management			5%	
121	Management of Range Resources			5%	
122	Management and Control of Forest and Range Fires			5%	
132	Weather and Climate			12%	
133	Pollution Prevention and Mitigation			12%	
136	Conservation of Biological Diversity			12%	
201	Plant Genome, Genetics, and Genetic Mechanisms			5%	
216	Integrated Pest Management Systems			5%	
903	Communication, Education, and Information Delivery			6%	
	Total			100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	0.0	0.0	76.6	0.0
Actual Paid	0.0	0.0	61.7	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

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

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
0	0	446567	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
0	0	2975805	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	2130885	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

In the northern Rocky Mountain west, climate change and environmental studies are becoming increasingly necessary as major environmental changes continue to accelerate. COA/MAES faculty scientists at MSU are actively recruiting competitive grant dollars and personnel to bolster current and forecasted research faculty lines, undergraduate and graduate students, programs and labs, as they relate indirectly and directly to climate change studies. Direct impacts from climate change not only to traditional production agriculture, but in many of the west's forests, watersheds, soils and ecosystems are currently being observed and felt at both economic and environmental levels. Because of such, many facets of this program area have outgrown annual accomplishments as previously articulated this annual report's corresponding 2014-2018 Plan of Work. In 2014, major research findings, publications and outreach initiatives in climate change have been successful thanks to continued Hatch funding. This program area saw an increase in nine new Hatch projects, many of them interdisciplinary in nature - as they speak to the myriad fields that rapid climate change has affected.
Not surprisingly, researchers learn more about climate change they are concerned about the potential impact on forests and rangelands and the ecosystems. Experts warn a warmer climate will likely result in more disturbances such as wildfires, floods, droughts, insect infestations, and an increase in invasive plants. While agriculture is vulnerable to climate change as diminished water resources constrain crop growth, which also must be considered in context of rising timberlines, land use, and invasive species.

MSU is uniquely poised and geographically blessed to be a leader in regional climate change studies, as the state's only 1862 land-grant intuition. The growth this year (in research production and program growth in climatic studies) in is representative of COA/MAES as a regional leader in climate studies housed within a STEM Land-grant university. The university's proximity to Yellowstone National Park, within a valley floor surrounded by national forests, wilderness, and agricultural rangeland (the county and state's leading economic driver) allows MSU to continue as a foundational public university that is growing a strong and dedicated climate change research portfolio. Several of the main veins of research priorities surrounding climatic influence parallel research fields such as: wildfires, wildlife, ground water sustainability and resources, watershed protection and management, cropping system sustainability, carbon sequestration, biofuel and biomaterial development, health and vibrancy of pollinator populations, diversity of trees and forestlands, and soil moisture retention and adaption studies. Through basic and applied research in these fields, COA/MAES is also able to support the drafting of national agricultural and environmental policy formulas, as a result of a growing base of collaborative work with peer institutions across the nation.

As the climate changes, the need for drought resistant cultivars of Montana crops increases. Therefore, researchers continue discovering and evaluating new crops and cultivars of spring wheat,

winter wheat and barley suitable for a warmer and drier climate. They are also studying how climate change impacts various pests throughout the State.

Educational programs are being established as an introduction to the aspects of global climate change and its implications for agriculture. Agriculture has the potential to contribute to mitigation of climate change by sequestering carbon in soils. One MSU project is gathering data to produce scientific publications and information for the general public that will improve the ability of public decision-makers to formulate policies regarding climate change and greenhouse gas mitigation. Additional projects are investigating the potential for soil carbon sequestration in rangelands and croplands. Studies also made progress in learning more about seasonal patterns and cumulative N_2O emissions from agricultural soils in the Northern Great Plains under different cropping systems, water regimens crop residue levels, and nitrogen fertility rates.

As the demand for water increases and resources decline, researchers are designing forecast and water management models for watershed and runoff controls. COA scientists focused on three activities (1) the development and assessment of new hydrologic models for mountain headwater catchments; (2) developing methods for model calibration and Bayesian inference for hydrologic models; and (3) implementing methods for predictions and quantification of uncertainties in ungauged catchments.

In the COA's Department of Land Resources is the Montana Institute on Ecosystems, a multi-institutional community dedicated to understanding complex ecosystems and the interconnectedness of people, nature, climate pressure, healthy ecosystems and economic growth. The center draws on the extraordinary landscapes of Montana and beyond to advance integrated environmental sciences and related fields. The center allots several undergraduate and graduate research opportunities on a variety of subjects as they related to climate change. These students are regularly named as bright candidates for research and advanced schooling fellowships.

As the nation develops a responsive adaptation to climate change, COA/MAES scientists continue to make great strides in this critical research agenda to continue excelling in the discovery and communication of how natural and managed environments and their elements function in an era of global climate change. Some of these aforementioned advancements in 2014 climate change studies are outlined below:

- Development of bio-based products ; polymeric materials for eco-friendly crop production
- Wheat rotation management impacts on evapotranspiration, carbon dioxide exchange and soil moisture status
- Biogeochemical consequences of canopy tree diversity in tropical watersheds
- Improved oil compositions in Camelina to meet the need for renewable and clean sources of industrial products
- Address the growing need for renewable sources of environmentally friendly biofuels and biomaterials to replace products currently manufactured from petroleum.
- Find optimum density of big sagebrush within a watershed that facilities groundwater recovery as well as sufficient shrub density/cover to support ecological function and wildlife habitat.
- Develop quantitative approaches for describing microbial controls on the biogeochemical cycling of crustal constituents.
- Study soil processes and arbuscular mycorrhizal function across a gradient of management activities related to restoration and agriculture.
- Diversity and distribution of mycorrhizal fungi that support woody plants and trees in Montana and biologically related regions
- Floodplain sediment/channel water exchange studies

• Promote a deeper understanding of our relationship with the viticultural landscape, for the benefit of sustainable practices
• Alfalfa leafcutting bee thermal biology
• Prescribed burning to suppress confier invasion into foothill rangeland
• Current and forecast future impacts on disturbance of TCEF and Yellowstone National Park ecosystems
• Pollinator colony health and sustainability
• Using airborne and satellite imagery to support monitoring and validation related to efforts to sequester carbon in Montana
• Characterize abiotic and biotic reaction mechanisms, transformation rates and fate of chemicals in agricultural and natural ecosystems
• Addressing the uncertainty in hydrologic systems (sustainable management of water in climatic uncertainty)
• Drinking water standards (metalloids)
• Basic and applied studies of natural geothermal microbial resources
• Measure and quantify gaseous loss of NH3 from fertilizer N applications and legume green manures, and to evaluate products and management practices to mitigate emissions.
• Research surrounding endemic root and crown disease problems facing small grain growers in Montana

2. Brief description of the target audience

• Crop and livestock producers in Montana
• State agricultural advisory committees
• State of Montana, Montana Department of Agriculture, BLM, USFS, and other government entities
• Participants in extension and commodity group meetings, conferences, and field days
• Regional and local water-shed and groundwater community groups
• Climate studies scientists and students
• Statewide natural resource

3. How was eXtension used?

COA and MAES researchers worked closely with county extension agents and outreach coordinators to disseminate timely and accurate information regarding the evaluation and procurement of research advancements made in climate studies and the environment. Many of these research projects were spoken of during MAES field days, throughout MSU/COA's seven research centers across the state.

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	50000	25000	2000	1000

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

Year:	2014
Actual:	0

Patents listed

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	95	95

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research citations

Year	Actual
2014	95

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of new stress tolerant crop recommendations (or changes) for Montana
2	Number of new technologies explored

Outcome #1

1. Outcome Measures

Number of new stress tolerant crop recommendations (or changes) for Montana

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Small grains are an extremely important component of Montana agriculture; eastern Montana produced nearly 48 million bushels of spring wheat in 2010, about 45% of the spring wheat produced in Montana.These figures are still accurate in 2014. More foreign markets are showing interest in purchasing durum from this area, and malt barley acres have increased in Montana and western North Dakota, as private agribusinesses have contracted up to 20 million bushels. Both wheat producers and wheat buyers are demanding higher-yield potential and resistance to climate stresses and pests.

What has been done
Two new wheat lines, Egan (winter), and Sliver (durum) were recommended to state agricultural producers and wheat growers. Both varieties are pest and stress tolerant, as factors related to climate change. Egan was released commercially and Sliver underwent standard field trials and characteristic tests.

Results
Egan was released as commercial seed, and it is the first variety for Montana with resistance to the orange wheat blossom midge. A paper published regarding genetic difference between modern and historical varieties will provide guidance to breeds for selection priorities. A novel gene for wheat stem sawfly resistance was identified. The experimental line for MT 1320 yielded most in a dryland trial. The data from the trials and subsequent yields have been disseminated to agricultural producers, industry and commodity group personnel, economic development boards and scientific peers. A continuation of of experimental durum lines that have highly-sought after characteristics will progress.

4. Associated Knowledge Areas

KA Code	Knowledge Area
102	Soil, Plant, Water, Nutrient Relationships
111	Conservation and Efficient Use of Water
121	Management of Range Resources
132	Weather and Climate
136	Conservation of Biological Diversity
201	Plant Genome, Genetics, and Genetic Mechanisms
216	Integrated Pest Management Systems
903	Communication, Education, and Information Delivery

Outcome #2

1. Outcome Measures

Number of new technologies explored

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	1

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Remote sensing technologies (analysis of imagery from airplanes and satellites) are becoming increasingly useful in issues related to land-resources and climate studies in the state. In many cases, only satellite imagery can be used to analyzes spatial and temporal patterns of historical adoption of such practices and to help understand and guide future outreach and extension efforts.

What has been done
As focus on the impacts of atmospheric CO2 increases, factors affecting sequestration also become more important.There were several significant accomplishments with respect to monitoring sites for leakage. Scientists determined that alfalfa subjected to CO2 stress, exhibited a different spectral responses than alfalfa subjected to water stress. This was a critical step in being able to uniquely identify potential responses to a leak at a geologic sequestration site. Tremendous progress was made in examining patterns of adoption of agricultural practices related to carbon sequestration using multitemporal satellite imagery.

Results

The results of such are expected to be applied to additional field studies for geologic carbon sequestration. Results to date have focused on greenhouse studies and field-based, controlled experiments.

4. Associated Knowledge Areas

KA Code	Knowledge Area
101	Appraisal of Soil Resources
102	Soil, Plant, Water, Nutrient Relationships
132	Weather and Climate
133	Pollution Prevention and Mitigation
201	Plant Genome, Genetics, and Genetic Mechanisms
903	Communication, Education, and Information Delivery

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Appropriations changes
- Public Policy changes
- Government Regulations

Brief Explanation

• Inadequate funding and technical support from partnering institutions and cooperators
• Inadequate moisture (rainfall, irrigation, snowpack) for consistent crop production
• Lack of full-time staff and part time assistant
• Major interruptions in program development
The 2014 crop year faced warm and limited precipitation thoughout the year, but when precipitation was received hail often accompanied the storm. Montana recorded a record amount of acreage damaged by hail.

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Evaluation studies were successful through the issuance and collection of surveys, published peer reviewed materials and securing peer reviewed grants. Notable evaluation results:
Researchers disseminated the results to the agricultural community at grower meetings, Certified Crop Adviser meetings, industry conferences, and MAES field days. They also shared the information with agricultural professionals at the American Society of Agronomy National meetings.
The investigator developed a web site to keep growers, agricultural consultants, and other interested parties up-to-date on the progress of various studies.
Results of a long-term study on linking upland plant community structure and riparian

processes resulted in a riparian rehabilitation guide for private and public land managers. Experts in the riparian processes distributed 700 of the guides in four Montana counties and hosted several workshops to explain how to rehabilitate degraded riparian areas. A new website was developed and is used to forecast spring and winter wheat basis in various Montana locations and can be found at http://wheatbasis.montana.edu.

Key Items of Evaluation

MSU COA researchers advanced crop options for a warmer and drier climate:
Developed a new winter wheat line, "Egan" - commercially sold and patent-pending approval (see Plant Sciences and Products program area)
• Developed two new spring wheats varieties called "WB9879CLP" and "Silver" durum
• A winter wheat, "SY Clearstone"
• Increased planting of "Vida," a drought resistant variety of spring wheat which was the top choice for growers in 2011 and 2012
• Researchers developed and shared new knowledge about carbon sequestration
• Created a riparian rehabilitation guide
• Furthered research helping forests and rangelands with emphasis on whitebark pine and sage

V(A). Planned Program (Summary)

Program # 2

1. Name of the Planned Program

Food Safety

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
121	Management of Range Resources			10%	
301	Reproductive Performance of Animals			5%	
302	Nutrient Utilization in Animals			10%	
303	Genetic Improvement of Animals			7%	
305	Animal Physiological Processes			5%	
306	Environmental Stress in Animals			5%	
307	Animal Management Systems			11%	
308	Improved Animal Products (Before Harvest)			5%	
311	Animal Diseases			15%	
315	Animal Welfare/Well-Being and Protection			7%	
503	Quality Maintenance in Storing and Marketing Food Products			5%	
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources			5%	
902	Administration of Projects and Programs			5%	
903	Communication, Education, and Information Delivery			5%	
	Total			100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	0.0	0.0	49.4	0.0
Actual Paid	0.0	0.0	49.5	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

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

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
0	0	521349	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
0	0	2744755	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	2547517	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Food Safety, in its most basic nature, aligns with national priorities to ensure the safety of the nation's food supply. This program area includes the investigation and incidence reduction of food-borne illnesses and assisting producers in providing a safer and more robust food supply, in all respects.
Protection of the health and security of food products spans the entirety of the food safety field; beginning with molecular studies, and ending with the application of sound market trends in a global food- trade market for Montana products. MAES and COA researchers are committed to ensuring, supporting and examining food safety production and processes in all levels of this program area. (*For a detailed review and reporting achievements as it relates to pre-harvest animal health research, see GFS: Animal Health, Production and Products.)
The global market is driving changes to the agricultural industry with constraints on grain and animal products. The organic market is quickly becoming one of the nation's fastest growing, as American consumers are demanding safer foods free of harmful chemicals and pesticides. Agricultural producers and agribusinesses are continually affected by supply, demand, technology, market integration, risk management and international trade dynamics. While the program area of food safety does represent traditional 'safety' measures such as food-borne illness and animal health diseases, it also incorporates and additional 'safety' measures to protect family-owned agribusinesses as well as economic policy research as it relates to the nation's food supply.
Animal health is economically essential to livestock producers who work diligently producing high quality, high profit stock. Promoting and maintaining animal health has led to advances in genetics and reproductive science and improved animal performance. Investigators with MAES and COA are studying animal health and its impact on food safety through numerous studies exploring all aspects of livestock management from genetics research projects, disease identification and prevention, to animal breeding practices, reproductive sciences, and nutrition. Studying infectious diseases is important to Montana researchers because of both the economic losses for producers and food safety concerns (the college's Department of Microbiology and Immunology focuses a great deal of research infectious diseases and animal health, and particularly infectious cattle diseases, reported in the Animal Health Planned Program in this report). This department and the college's Department of Animal and Range Science have several joint research projects developing and testing new drugs, vaccines, and diagnostic tools for fighting infectious diseases of livestock, humans, and wildlife, as well as zoonotic diseases.
Montana prides itself on being home to some of the greatest cattle and sheep operations in the United States, and also as a state that boasts an abundant wildlife population. This brings about unique research opportunities as scientists balance health concerns of livestock, wildlife, consumers and the urban-wildland interface as it relates to safety concerns in agricultural production. The goal of MAES/COA faculty

scientists is to provide objective, research-based animal health and food economics information (impacts of changes in market policy and conditions of the food and fiber sector) to the public. MAES/COA faculty and personnel in at MSU continue to be a main vein of information and research for the state's agricultural sector.

Promoting and maintaining animal health (cattle, sheep, horses, and wildlife) has led to advances in genetics and reproductive science and improved animal performance. By understanding immune systems and parasite development in livestock, and by developing novel genes and new biochemical routes of activity for drugs and vaccines, ranchers can better manage economically important diseases like coccidiosis, shipping fever, and brucellosis. Montana developed an integrated network to track calves from Montana ranches to feedlots and packing plants in other states. Tracking will provide both source and process verification for easy trace-back in case there is a disease outbreak.
Cattle research focuses on disease control, reproductive enhancement, and animal productivity. Scientists will continue investigating vaccines for rotavirus, strangles, respiratory diseases, and mastitis in cattle. Researchers are using feed studies with barley, camelina meal, and supplements to evaluate varying rations for calves and cows, and to continue producing superior feeder stock to markets outside of Montana. Scientists are devising research to understand the cause and development of immunity to bovine shipping fever and to develop novel strategies for the prevention and control of this disease complex.

Researchers in the sheep industry continued studying targeted grazing strategies to increase the competitiveness of Montana's lamb and wool in the world market. They also studied the impact of sheep grazing in weed management programs. Scientists are initiating studies about Blue Tongue and Cache Valley Virus, which are both critical diseases for lamb and sheep populations.

The new undergraduate major in Sustainable Food and Bioenergy Systems (SFBS) adds new education and research opportunities to students and faculty through the interdisciplinary degree program which promotes sustainable production, distribution, and consumption of nutritious food and bioenergy by growing a new generation of leaders through collaborative learning and hands-on experience. SFBS students explored various aspects of food and bioenergy systems as well as career opportunities in the sustainable food systems, agro-ecology, and sustainable crop and livestock production options. The SFBS program combines classroom learning, research opportunities, and meaningful field experiences to prepare students for careers that will impact the future of food and energy production.

Create databases accessible to researchers and producers to share research results readily available

- Distribute papers and research results at state nutrition conferences, field days, county meetings, and state conventions
- Prepare research articles, fact sheets, and news releases for scientists and state media
- Hold strategic planning meetings with state agricultural groups
- Develop systems that ensure food safety and agricultural security
- Integrate, where possible, best practices for beef quality assurance in programs
- Further knowledge and management of insects affecting animals and humans
- Develop effective livestock disease control methods
- Identify and mitigate the transmission of diseases between livestock and wildlife
- Increase wool and lamb competitiveness
- Implement targeted grazing strategies as weed control
- Nutritional impact of grazing on sheep and cattle
- Improve traceability of livestock

2. Brief description of the target audience

- State agencies, animal health companies, and state commodity groups
- Ranchers, seedstock industry, colleagues, and related stakeholders
- Crop and livestock producers in Montana
- National Park Service, Montana Fish, Wildlife and Parks
- Food safety workforce sector
- Montana food producers

3. How was eXtension used?

COA and MAES researchers worked closely with county extension agents and outreach coordinators to disseminate timely and accurate information regarding the evaluation and procurement of food safety.

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	10000	5000	1500	500

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

Patent Applications Submitted

Year:	2014
Actual:	0

Patents listed

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	150	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research citations

Year	Actual

2014	150

Output #2

Output Measure

- Number of publications on infectious disease and food safety research

Year	Actual
2014	200

Output #3

Output Measure

- Number of presentations on infectious disease research

Year	Actual
2014	150

Output #4

Output Measure

- Number of undergraduate and graduate students trained in animal science and biotechnology

Year	Actual
2014	3000

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Identify critical infection and resistance processes
2	Number of improvements to vaccines developed
3	Meetings that maintain or enhance Montana's presence in the production of quality meat products
4	Number of ranches using beef quality assurance practices to manage animal health and well-being issues

Outcome #1

1. Outcome Measures

Identify critical infection and resistance processes

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Identifying critical infection and resistance processes is immensely important to Montana's food producers. Providing detection, treatment and resistance for a variety of illnesses and diseases ensures that Montana's food exports are safe and meet standards for the global market, while assuring producers and patrons of a healthy and economically viable food source. Infection and resistance studies also provide a deeper understanding of human illness and their correlation and behavior with that of animal diseases.

What has been done
Identified virulence factors and protective antigens among the cell surface proteins of horse pathogen Streptoccocus, and identified new virulence factors among 13 uncharacterized cell wall proteins. Determined whether virulence factors identified in the primary objective are protective antigens, and the study expects to identify new projective antigens that can be included in a vaccine formulation for the development of an effective and safe strangles subunit vaccine

Results
2013 research objectives included cloning DNA fragments on three target genes for inactivation of the target genes, successfully obtaining Strepotcoccus equi mutants for two of the three target genes, and have generated mutants for 12 of 13 target genes. The project compared virulence of four mutants with the parent strain using a mouse model of intranasal S. equi infection, and one of the mutant was significantly attenuated in virulence. Studying animal losses allows MAES/COA scientists to continue a deeper and active understanding of food safety.

4. Associated Knowledge Areas

KA Code	Knowledge Area
301	Reproductive Performance of Animals

303	Genetic Improvement of Animals
305	Animal Physiological Processes
311	Animal Diseases
315	Animal Welfare/Well-Being and Protection

Outcome #2

1. Outcome Measures

Number of improvements to vaccines developed

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Animal losses due to environmental stresses, disease, and death create the need for an improved understanding of factors affecting Montana livestock. Infectious disease continues to cause considerable losses to livestock producers by reducing production and by reduced sales because of food safety concerns. Disease outbreaks are closely monitored in Montana to ensure quality and disease-free animals are shipped to other states.

What has been done
Research was conducted on bovine gamma/delta T cells using functional, biochemical and molecular approaches, which clarified the general understanding of the bovine immune system and how it is similar and dissimilar to the immune system in rodents and humans. This information facilitates the development of new approaches to treat infectious diseases of cattle.

Results
The direct impact of this work is a general understanding of animal immune systems and their responsive health to new improvements to vaccine development. This discovery and research affects the fields of food animal production and food safety. Several producers expressed appreciation for the alert and pro-active action taken by MSU and the state livestock department.

4. Associated Knowledge Areas

KA Code	Knowledge Area
311	Animal Diseases
315	Animal Welfare/Well-Being and Protection

Outcome #3

1. Outcome Measures

Meetings that maintain or enhance Montana's presence in the production of quality meat products

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	25

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Quality meat production is critical for producers, processors, and consumers. Educational programs geared toward specific audiences enhance food safety awareness and increases the quality of meat products produced and processed in Montana.

What has been done
An MSU professor and beef cattle specialist administered the Steer of Merit program, providing feedback on youth beef cattle projects for youth, parents, beef cattle producers, and county agents. The state Steer of Merit Committee meets annually to set industry-reflective standards for the following fair season.

Results
MSU researchers and Montana Department of Livestock researchers formed a taskforce to address this concern and develop strategies for vector mitigation. Through a series of conference calls, they developed recommendations and shared the information with Montana public.Two professors redesigned a university course in the Animal and Range Sciences Department to include social and video media. They incorporated agriculture and range science advocacy training into the course, which has allowed a broad audience to have access to advocacy materials. Several meetings were held across the state with regional, local, county and state livestock, farm and ranch boards concerning livestock health.

4. Associated Knowledge Areas

KA Code	Knowledge Area
302	Nutrient Utilization in Animals
303	Genetic Improvement of Animals
311	Animal Diseases
315	Animal Welfare/Well-Being and Protection
902	Administration of Projects and Programs

Outcome #4

1. Outcome Measures

Number of ranches using beef quality assurance practices to manage animal health and well-being issues

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Consumers are increasingly demanding more information about their food products. Producers are therefore working to track their livestock from conception to consumption. Producers are focusing on genetics, disease identification and prevention, and better feed management systems. MSU studies help ensure Montana producers raise safe beef while improving the quality.

What has been done
COA/MAES scientists and research programs allowed producers to document best management practices for raising and marketing calves. The program provides quality assurance certification, implements and documents bio-security plans on ranches, and provides informational outreach. Sheep and wool producers continued using targeted grazing to increase the competitiveness of Montana lamb and wool in the world market.

Results
During legislative testimony producers repeatedly shared the impact COA/MAES research had on their operations and how new technologies were saving money and increasing agricultural product quality.

4. Associated Knowledge Areas

KA Code	Knowledge Area
301	Reproductive Performance of Animals
302	Nutrient Utilization in Animals
303	Genetic Improvement of Animals
305	Animal Physiological Processes
306	Environmental Stress in Animals
307	Animal Management Systems
308	Improved Animal Products (Before Harvest)
311	Animal Diseases
315	Animal Welfare/Well-Being and Protection
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Competing Programmatic Challenges

Brief Explanation

- Inadequate funding and technical support from partnering institutions and cooperators
- Inadequate moisture (rainfall, irrigation, snowpack) for crops to be produced, creating excessive variability
- Lack of full-time staff and part-time assistants
- Major interruptions in program development
- Reduced support from Montana crop and animal agricultural groups, conservation and wildlife groups, private industry, private donations, and other agencies

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Montana has 2.5 times more cattle than people providing the foundation for the number one industry in the State - agriculture. It is in this context that researchers design, implement, and conduct research projects within the COA/MAES. Research in the Animal Health Program is critical to the industry in Montana and producers and consumers alike who count on the investigators to promote a healthy industry through their consistent research. Highlights for 2014 were:
• Advancements in knowledge of Staphylococcus Aureus in humans and livestock

• Hired new faculty members, two of which are core users of new molecular tools
• Evaluated 256 animals through the GrowSafe system and added new equipment to MSU research center doubling the capacity of researchers to evaluate residual feed intake
• Conducted webinars, workshops, and seminars to share up-to-date information on animal health and quality assurance reaching audiences in excess of 2,500
MSU researchers evaluated electronic identification tags and are now emphasizing DNA tracking in the sheep and cattle industry. MSU hired two faculty members in 2012 to enhance DNA and genetics management and a rumen micro-biologist. At the Northern Agricultural Research Center researchers evaluated 276 replacement heifers and developing bulls through the GrowSafe System. Reproduction, longevity and RFI are evaluated and the data will be used for long-term tracking and monitoring of the livestock.
Through the use of EID tags producers are receiving carcass information and sometimes even feedlot information, allowing them to identify production characteristics for their herd and for individual bloodlines beyond typical ranch production traits. This information allows producers to position their production for the future and identify specific markets that fit their product.

Key Items of Evaluation

The Animal Bioscience Building combined with state-of-the-art laboratory equipment assisted in the successful recruitment and hiring of three new faculty members in the Animal and Range Sciences Department for the College of Agriculture. The new faculty include a beef geneticist, a range ecologist, and a rumen microbiologist. The College also purchased an Illumina MiSeq and is using it to help members of the Crow Indian Reservation identify sources of antibacterial resistant E. coli. A collection of biting flies (mosquitos and midges) have been collected for disease collection specifically for livestock producers. A model product was produced used for estimating environmental concentrations of insecticides used for adult mosquito management. Educational aids and curricula were produced on adding value to beef cattle, these materials were presented 23 times to a total of 1,261 constituents in the North West region of the United States. Presentations for this program included state and agricultural extension agents, financial advisors, local business leaders and beef cattle and forage producers. Finally, data and research

material was
produced on a study regarding the commonality of S. aureus in the anterior nares of horses. MSU COA and MAES experienced significant faculty movement impacting this planned program, and several programs with remaining research goals have migrated with the principal investigators and their respective projects, outlined in the 2015 and 2016 Plans of Work.

V(A). Planned Program (Summary)

Program # 3

1. Name of the Planned Program

Global Food Security and Hunger -- Integrated Pest Management

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
211	Insects, Mites, and Other Arthropods Affecting Plants			27%	
212	Diseases and Nematodes Affecting Plants			25%	
213	Weeds Affecting Plants			20%	
215	Biological Control of Pests Affecting Plants			10%	
216	Integrated Pest Management Systems			18%	
	Total			100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	0.0	0.0	63.6	0.0
Actual Paid	0.0	0.0	76.8	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

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

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
0	0	617369	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
0	0	2940694	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	2682245	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

The importance of integrated pest and disease management remains a consistently critical field as invasive pest and disease species continue to threaten Montana's agricultural industry as well as the global safety of the state's food exports, and general health of the state's myriad natural resources essential to agriculture production. Pests and diseases, in all of their forms (plants, soils, animals, food storage, water), will continue to represent a colossal economic threat to Montana producers in pre and post-harvest production systems. Dwindling water resources, vulnerable natural resources and a changing climate have only exacerbated the demand for research funding and applied research as it relates to supporting and protecting Montana's agriculture industry. In 2014, producers and researchers continued to evaluate new integrated pest and disease management methodologies so they could maintain a competitive position in U.S. and world markets while helping alleviate global hunger.

The program area of integrated pest management explored new and improved methods to identify and control insects, weeds and diseases in large and small-scale cropping and agricultural productions. An increase in public concern about food safety, quality, cost, biodiversity, and the sustainability of natural resources such as soil, air, and water quality encouraged scientists to rely less on pesticides and look for more environmentally friendly options. Studying biological controls as low-impact pest control options, promote sustainable practices. In Montana and throughout the U.S., maintaining profitable agricultural enterprises while sustaining ecological systems has become a difficult balancing act that often results in changes in agricultural practices and environmental policies.

Research areas continued to privilege; insects, mites and other arthropods affecting plants, pathogens and nematodes affecting plants, weeds affecting plants, biological control of pests affecting plants and overall integrated pest management systems. Faculty scientists continued quality in-depth training programs for continuing education on integrated pest and disease management and discover, evaluate, or change new integrated pest priorities and projects. Additional outcomes included new products registered, the passing rate percentage for pesticide application licenses and a number of new broadranging stewardship practices that were implemented. Research also focused on stopping food-borne illness (preharvest for food and animal consumption). Diversification and innovative and integrated cropping systems have helped with disease and weed control while reducing dependence on fertilizer. Most land managers agree the spread of invasive plants and pests are the primary environmental threats to western wildlands and rangelands. Noxious weed invasion reduces the ecological integrity of land and water, alters ecosystems, impacts wildlife habitat and threatens survival of native plants. MSU Extension manages the Private Pesticide Applicator Training Program for the Montana Department of Agriculture. Both Extension and COA/MAES actively participated in research projects on the subject and interacted with producers, landowners and property managers to share the latest information.
Investigators with the COA and MAES focused on identifying and managing weeds, insects, and diseases, so the agricultural community in Montana can better impact global food security. They also developed and shared quality stewardship programs to identify and mitigate noxious weeds and harmful insects. Field crops are an important foundation for the Montana agricultural industry and revenue exceeded $2 billion in exported goods in 2014. The most significant crop in Montana was wheat (5.4 million acres, $1.4 billion) followed by barley (760,000 acres, $143 million). Montana farmers spent approximately $15 million on fungicide applications in 2011, but the number was much less in 2012, because of drier conditions. Although yield benefits/detriments from spraying a fungicide are difficult to estimate, most respondents estimated a 0-20 percent yield increase. Not spraying resistant varieties of grain saved $12 million. Stripe rust cost growers $48 million in 2011. Fungicide application saved growers $30 million. If the estimated worth of the wheat crop in Montana is $1.6 billion, they saved 2 percent of the crop. Susceptible varieties sprayed in a timely manner saved approximately $90 million. Savings due to herbicide and seed costs on 2,000 acres of winter wheat totaled approximately $60,000 and yields of winter wheat averaged

approximately 40 bu/acre, totaling $480,000 (est. $6/bu) in farm revenue.

Biological controls for insects, weeds, and diseases are becoming more important as traditional chemical control methods are limited. The increase in public concern about food quality and safety, natural resource biodiversity, and sustainability of the quality of soil, air, and water is mandating less reliance on traditional pesticides and more research into environmentally friendly systems.

Montana's stakeholders need new and improved methods for controlling insects, weeds, and diseases. Pesticides are a major expense to producers; however delaying or eliminating pest control measures may not always be an option. An increase in public concern about food quality, natural resource biodiversity, and sustainability and quality of soil, air, and water resources is mandating less reliance on traditional pesticides and more research into biological control systems and organic food production. An emphasis on pest monitoring (using decision-making parameters and determining economic injury levels) will optimize the use of pesticides for controlling pests. Foreign trade partners especially want decreased pesticide residues in the wheat and barley exports.

- Disseminate information in print and online to provide pest control recommendations
- Produce regional management guides
- Conduct pesticide workshops and field days to share research results
- Support FIFRA Section 18c products labeling requests
- Update pesticide applicator training materials when necessary
- Update training materials for private and commercial pesticide applicators with new information

2. Brief description of the target audience

- Crop producers, dealers, distributors, and crop protection company representatives
- Crop protection companies registration and research personnel
- Montana crop advisory boards
- Private and commercial pesticide applicators
- State of Montana, Montana Department of Agriculture, BLM, USFS, and other government entities

3. How was eXtension used?

COA and MAES researchers worked closely with county extension agents and outreach coordinators to disseminate timely and accurate information about integrated pest managment topics and issues

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	50000	25000	10000	5000

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

Year:	2014
Actual:	1

Patents listed
201400394 "Egan"

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	300	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of research citations

Year	Actual
2014	300

Output #2

Output Measure

- Multidisciplinary journal articles published

Year	Actual
2014	125

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Quality in-depth training programs for continuing education on integrated pest management
2	New IPM options discovered, evaluated, or changed/altered
3	Passing rate percentage for pesticide application licenses
4	New products registered.

Outcome #1

1. Outcome Measures

Quality in-depth training programs for continuing education on integrated pest management

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	100

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Invasive pests threaten almost every facet of agricultural production and producers need to have the latest scientific research to remain competitive in the global marketplace. An increase in public concern about food safety, quality, cost, biodiversity, and sustainability and
quality of soil, air, and water resources are also pushing scientists away from pesticides.

What has been done
The MSU research, teaching, and extension team is bringing awareness to incorporating targeted grazing into farming systems. Researchers with the targeted grazing program spoke at seven locations educating 241 participants as to the benefits of the program, and they shared information at field days. A total of 100 presentations, 25 workshops and several poster presentations disseminated new research findings, recommendations and information.

Results
Researchers held a pest management tour and visited five locations.
New online information programs are including more data to assist farmers and ranchers with weed and insect identification, including multiple trainings for the United States Forest Service and the Crow Reservation in Montana on identifying rush skelentonweed root moth, and the biological control of weeds and use of insect biocontrol agents. Many radio interviews were conducted regarding the emerging research of the wheat stem sawfly, and five private farm and ranch consultations were provided by faculty from our Western Triangle Research Center. The IPM instructors shared sustainable ag practices that will better manage diseases, insects, weeds and rodents. The training also focused on the safest and most effective ways to use pesticides.

4. Associated Knowledge Areas

KA Code	Knowledge Area

211	Insects, Mites, and Other Arthropods Affecting Plants
212	Diseases and Nematodes Affecting Plants
213	Weeds Affecting Plants
215	Biological Control of Pests Affecting Plants
216	Integrated Pest Management Systems

Outcome #2

1. Outcome Measures

New IPM options discovered, evaluated, or changed/altered

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Invasive plant species are recognized as a serious and threatening problem to Montana. Producers must continually improve pest management programs to increase productivity and profit. Consumers are demanding farmers use less chemical pesticides for food crops. Integrated pest management research also involves pest mitigation with researchers investigating both herbicides and biological control agents for insect and plant diseases. Invasive plant species are a serious economic and ecological problem for range and forested lands.

What has been done
MSU COA researchers are exploring biological control agents several species of invasive weeds that a negative impact on the state's food production. Research projects contributed to the selection of potential new control agents and an increased understanding of how to use them. They continued exploring targeted sheep grazing as an economical and ecologically sustainable tool to manage lands with large infestations of invasive plants. Numerous biocontrol agents are currently being studied for the control of noxious pests,as many target weeds currently either are without any form of biological control, or agents already established are not effective over the range of the production.

Results
Researchers released 20 gall wasps in 2009 and found an equal number of galls infesting the Russian knapweed. Since then the numbers have increased exponentially with thousands of galls

present in 2013. Additionally, a cost-benefit ratio is being researched to provide information to growers about the use of biological based pesticides for the control of the wheat stem sawfly.

4. Associated Knowledge Areas

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

Outcome #3

1. Outcome Measures

Passing rate percentage for pesticide application licenses

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	32

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Pesticide application training is important for disseminating new data and guidelines. The COA and the Extension Service work closely offering training and application licenses throughout Montana.

What has been done
MSU Pesticide Education Program administered a website which included 250 private applicator programs this year. These programs are meticulously reviewed before awarding continuing education credits awarded based on meeting the core pesticide education categories: pesticide laws, integrated pest management, calibration, pesticides in the environment, the private applicator license, and pesticide safety. Without available credits private applicators may choose to spray pesticides without adequate training, or to not manage noxious weeds and insect pests through the use of pesticides. A hands-on workshop for 18 Crop Consultants and county extension agents on plant disease diagnosis and management included virus detection. The workshop provided 16 ACA credits and six Montana Private Applicator Credits.

Results
A total of 55 pesticide education presentations were delivered to 2,000 certified applicators across Montana at 42 locations. Presentations included topics of pesticides in the environment, IPM, calibration, pesticide safety, restricted use recordkeeping, mixing and handling, alfalfa weevil IPM, and pesticide poisonings. Fumigant education training targeted 150 applicators with an intense six hours of training. Two train-the-trainer programs targeted 50 local pesticide education trainers. There are approximately 6,600 private applicators this year in Montana. Thirty-two applicators indicated they would change their behaviors as a result of the education. Changes included applicators protecting themselves and calibrating more often.

4. Associated Knowledge Areas

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

Outcome #4

1. Outcome Measures

New products registered.

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Producers and researchers are evaluating new integrated pest management (IPM) methodologies for controlling pests so they can maintain a competitive position in U.S. and world markets while helping to alleviate global hunger. It is important to develop new strategies in order for the pests to not develop resistance.

What has been done
Investigators evaluated biological control agents like Muscodor albus, a plant-swelling fungus, to treat diseases in potato and sugar beet crops. This biological control agent has the potential to replace harmful and toxic biocides currently used in agriculture. Continued evaluating targeted grazing and explored other biological control agents.

Results
MSU COA IPM experts traveled extensively to deliver educational outreach related to cropland entomology. They wrote more than 20 Ag Alerts and several articles in regional magazines,educated growers about current infestations and outbreaks, and posted educational modules on the extension webpage. They also coordinated and distributed 2000 copies of a Pulse Pest Calendar in Montana and North Dakota to growers and agricultural professionals. Additional
products produced include: study guide for MSU students was produced, a new germplasm, survey instruments, models, data and research material, weed workshops, biological control workshops, a new collection of Montana insects numbering more than 26,000 specimens, a video on pine invasions from the Northern Hemisphere in New Zealand, and models for creating

4. Associated Knowledge Areas

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

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations

Brief Explanation

The demands of producers who grow crops organically require innovative pest and fertility solutions often requiring biocontrols and alternative nitrogen sources. Organic farming and the introduction of non-traditional crops create a need for MSU researchers to delve into new approaches to crop management. The 2014 crop year faced warm and limited precipitation though out the year, but when precipitation was received hail often accompanied the storm. Montana recorded a record amount of acreage damaged by hail.

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Investigators with the COA and MAES focused on identifying and managing weeds, insects, and diseases, so the agricultural community in Montana can better impact global food security. Field crops are an important foundation for the Montana agricultural industry and revenue exceeding $2 billion in 2013. The most significant crop in Montana was wheat (5.4 million acres, $1.4 billion) followed by barley (760,000 acres, $143 million). The grain supports the livestock industry in Montana, and also the export market. A leading researcher shared that of the growers attending conferences on disease management and fungicide treatment options 65 percent could better identify diseases and had a clearer plan of how to treat them. Educating one field agronomist about stripe rust is estimated to have impacted 48,000 acres with an economic benefit to growers of $4 million. A direct economic impact of recommendations from researchers at the MSU Schutter Diagnostic lab this year was approximately $400,000 on 354,000 acres. Requests for assistance were lower, because it was a dry year with fewer disease outbreaks.

Researchers are investigating the sawfly's chemical ecology, and evaluating host plant resistance, pathogens, and cropping strategies. Researchers at MSU identified sex pheromones from hundreds of moth species and are using them to study and trap the insects and disrupt their mating by altering the odorant receptor proteins from male moth antenna. Addtionally, studies were aimed at developing microbial pesticides as practical tools for the wheat stem sawfly.

Researchers are better understanding the diversity, distribution, and activities of pollinators (including alfalfa leafcutter bees) in natural and agricultural ecosystems. The goal is to better understand the value of pollinators and predatory insects in agricultural and natural ecosystems, the effect of land management practices on these insects, and their basic biology.
Integrated management of rangeland invasive plants is also critical.

Economically, weeds impact rangeland more than all other pests combined, including billions of dollars spent on control and reduction in livestock and wildlife carrying capacity. Containing existing populations and restoring rangeland severely degraded by weeds is critical for the ecology and economics of Montana agriculture. This year two studies focused on cheatgrass and how to control it as well as revegetation methodologies. Information was shared through workshops and field days with private and public land

managers to improve rangeland health.

Key Items of Evaluation

OWBM Pest Web Creation:
Scientists, extension personnel and staff developed a real-time monitoring of pests, including the orange wheat blossom midge across Montana. Statewide producers placed live traps in their field that were monitored via a live tracking system network. A new pest website housed real-time tracking of pests that has seen dramatic use by the public. Farmers need information gathered by a community trapping network in order to make management decisions on individual farms. In response to this need, a website has been set up (http://pestweb.montana.edu/) and farmer cooperators and county agents are entering trap counts for the orange wheat blossom midge (OWBM), Sitodoplosis mosellana. OWBM was found in Montana in 2006 when it devastated spring wheat fields in western Montana, and has since spread to the 'golden triangle,' the major winter wheat production area of the state, where it threatens wheat production. Currently the website is focused on one pest, but the platform can be extended to any pest in any crop. Eventually organizers would like to have push notifications and a web-based app for farmers similar to the scab project (www.scabusa.org). This program will determine the exact distribution of the wheat midge in Montana and will track adult emergence in order to help direct scouting efforts. The scouting efforts are then used to make informed decisions on whether insecticide treatments are warranted. This program will provide training on pest identification, monitoring, and the use of IPM tactics for pest management. We will train at least 200 cooperators per year how to use the web-based system. he success of this objective will be assessed by monitoring website traffic and by the number of volunteers who monitor for the midge and provide population data to the web-site. Google analytics will be used to measure numbers of users, number of views, length of time spent on each page, tracking of where viewers come from, and to track website growth and traffic. Evaluative surveys will be distributed at education events to determine if growers increased their knowledge of OWBM and intend to use the management information provided.

Implementation of Agronomic Crops included cutworm monitoring and distribution of research based information for pest management. IPM implementation in Montana communities included:

- Real estate agent training for noxious weed identification and management:Real estate agents are required by law to inform buyers of noxious weeds on the property, but they often have no training on weed identification nor do they have an adequate background to discuss impacts associated with noxious weeds or development of integrated management plans. Buyers of small and large acreages across Montana are often people from out of state with a limited background in vegetation management, especially control of noxious weeds. The properties they purchase are often located in the wildland-urban interface (WUI) adjacent to publicly-owned recreational lands (e.g. Forest Service or Bureau of Land Management) or along rivers. Without adequate information about integrated weed management and the need to control weeds, these properties can becomes sources for further invasion, thus impacting surrounding areas and increasing the need for large scale application of herbicides. Education of landowners about invasive weeds is a major interest of our advisory group and is reflected in our letters of support. Our objective is to provide real estate agents training and materials about noxious weed identification, noxious weed laws, and integrated weed management that they can apply in their professional

interactions with clientele. We will also provide them with a list of extension resources about noxious weeds that they can provide to their clientele. We will conduct a series of training webinars (five) and in-person trainings (three) in Y1 of this grant and repeat every two to three years (beyond this grant period), depending on level of interest.

- Included IPM education in Master Gardener training
- Education for Early Detection and Rapid Response to invasive pests and first detector training for stakeholders
- Urban IPM workshops for recertification of landscape professionals
- Structural IPM education with Colorado and Wyoming
- Distributed research-based education on pests in urban environment

- Establishment of an on-farm research network:Growers in Montana are constantly being bombarded by marketing information and social pressure to use pesticides, but have very little local data to evaluate product claims. In the past couple of years, we have sought to give growers and consultants a skill set to evaluate the statistical validity of claims. We will continue these efforts and attempt to train growers to conduct their own on farm trials. In a survey associated with these educational efforts, 277 pesticide applicators responded in 12 locations in Montana that represented 250,000 acres and a gross revenue of almost $1 billion. Of the respondents, 70% said they would devote 1-5% of their farm budget to research in order to address their questions. This represents a potential in-kind grant of $30 million for participatory research, and a high level of interest in the farming community. In addition, when asked where they prefer to get their information when making management decisions, 78% of respondents indicated that 'conversations with colleagues' were the 'most liked' resource. This was confirmed by members of our advisory committee. To meet that need, we have initiated an on-farm research network in 2014 modelled on those in Iowa, Nebraska, Indiana and other areas of the world. We have received funding from the Montana Wheat and Barley Committee and the Western Sustainable Agriculture and Research Education grant program to initiate this project. We currently have an emphasis on IPM management of crop pests. In 2014 we initiated fungicide strip trials with 6 growers in Pondera, Teton, and Gallatin Counties and expect the network to grow exponentially. Other contributions to this project include Winfield Solutions donating the use of their R7 remote sensing software, BASF donating fungicide, farmers putting in additional acres of the trial at their own expense, and a film student (Ian Johnson, eleven_eleven@mac.com) using the study for drone flights and comparing the satellite data provided by Winfield to his calculated normalized difference vegetation index (NDVI) from the camera on the drone for his masters' thesis.

IPM support for pest diagnostic facilities included:

- Educated clients of the diagnostic laboratory on IPM-based pest management options
- Increased awareness of the services of the diagnostic laboratory

IPM education for pesticide applicators included:

- Pest management tour for pesticide applicators
- Create calibration kits and provide hands-on demonstrations at train the trainer updates as well as pesticide applicator trainings
- Delivery of integrated pest management information to pesticide applicators

Scientists introduced three new insects into Montana for controlling Russian knapweed and orange hawkweed: Jappiella ivannikovi (a gall midge) and two stem galling wasps. Researchers released 20 gall wasps in 2009 and found an equal number of galls infesting the Russian knapweed. Since then the numbers have increased exponentially with thousands of galls present in 2012. Researchers at MSU identified the molecular basis for evolving ligand specificity of a sex pheromone receptor. This data assisted in advancing the research toward better attacking the wheat stem sawfly with odor traps and other devices.

An important finding in 2013 was the confirmation of glyphosate-resistant kochia populations in Montana. Kochia is especially troublesome in wheat-fallow cropping systems, because it spreads quickly. Researchers are working with farmers in Montana to educate them on herbicide-resistant kochia management.

Research findings this year supported the suggestion that August is the optimal time to prescribe sheep grazing for spotted knapweed. The increased consumption of the knapweed in August versus July suggested either the knapweed was preferred in August or the ewes were becoming adapted to it.

V(A). Planned Program (Summary)

Program # 4

1. Name of the Planned Program

Global Food Security and Hunger: Plant Improvements, Genomics, and Products

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
201	Plant Genome, Genetics, and Genetic Mechanisms			10%	
202	Plant Genetic Resources			10%	
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants			10%	
204	Plant Product Quality and Utility (Preharvest)			10%	
205	Plant Management Systems			10%	
502	New and Improved Food Products			5%	
701	Nutrient Composition of Food			5%	
702	Requirements and Function of Nutrients and Other Food Components			5%	
703	Nutrition Education and Behavior			5%	
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources			10%	
723	Hazards to Human Health and Safety			10%	
903	Communication, Education, and Information Delivery			10%	
	Total			100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	0.0	0.0	72.9	0.0
Actual Paid	0.0	0.0	72.7	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

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

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
0	0	562114	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
0	0	2929705	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	2806945	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

COA/MAES are recognized as leaders in the development of new cultivars of wheat and barley that are sought by global buyers. An aggressive plant breeding program ensures development of higher yielding, disease- and insect-resistant wheat and barley cultivars. Many new cultivars are licensed with partnering companies, thus ensuring that Montana stakeholders receive maximum benefit from research discoveries. In 2014, Montana planted a total of 5.9 million acres of all wheat, making it the forth highest state for planted wheat acres in the country. As such, the majority of reporting in this area is housed within COA/MAES plant breeding advancements:

Winter Wheat: Montana planted 2.5 million acres of winter wheat in 2014, up from 2.0 million acres planted in 2013. Montana is ranked fifth for winter wheat planted acres in the United States, according to the USDA National Agricultural Statistics Service, Montana Field Office. The top four varieties listed below account for almost half of the total winter wheat planted in Montana for 2014: Yellowstone, Judee, Decade and Genou. Each of these varieties were developed by the Montana Agricultural Experiment Station (and the station's and university's subsequent wheat breeding programs) and sold as commercial seed to producers.

Spring Wheat: In 2014, Montana producers planted 2.95 million acres of spring wheat, unchanged from 2013. The state remains the second largest spring wheat producer in the country, according to the USDA National Agricultural Statistics Service, Montana Field Office. The top four varieties account for over fifty percent of all Montana's 2013 spring wheat acreage: Vida, Redder, Choteau and Mott. Vida, Choteau were both developed by MAES and sold as commercial seed to producers.

Durum Wheat: Montana producers planted 450,000 acres of durum wheat in 2014, down from 505,000 acres planted in 2013. Montana ranks second for durum acres planted in the United States according to the USDA National Agricultural Statistics Service, Montana Field Office. The top four varieties account for three quarters of the total durum wheat planted in Montana in 2014: Divide, Mountrail, Lebsock, Alzada.

Plant breeding, genetics, and genomics projects tend to be long-term with little change from year to year. Primary emphasis of the winter wheat breeding program is the development of improved cultivars adapted to Montana's climatic conditions and cropping systems. Research is ongoing to develop germplasms with excellent end-use qualities and resistance to important pest and environmental stresses. Researchers continued to evaluate more efficient screening, selection, and breeding strategies and procedures to maximize efficiency and genetic progress in winter wheat breeding. Research projects continued to develop new hard red spring wheat cultivars for Montana producers, contributing to the science of wheat breeding and genetics, and improve end-use characteristics.

The broader impacts of MSU research are a larger food supply for the world, an improved ability of Montana farmers to compete in a global marketplace, and a strengthening of export markets for U.S. wheat. The primary output of the wheat improvement program is release of improved winter wheat cultivars. Cultivar performance data is disseminated to wheat producers via the internet, traditional extension bulletins, and in popular farm press publications.

Barley cultivars with improved feed quality could provide sustainable seed and grain markets for regional grain producers, and provide marketing advantages to regional beef producers. Research is being conducted on the development of lines for the malting, feed, and ethanol industries. The development and distribution of high quality, drought tolerant barley cultivars that provide the highest production potential remained priority of barley breeding programs in 2014. We have increased our understanding of the genetic control of traits like winter hardiness, feed quality, malting quality, and drought tolerance. Our multi-state barley research focuses the disciplines of plant breeding, genetics, plant pathology, cereal science, molecular biology, and genomics for barley improvement in Idaho, Montana, and North Dakota. We recently released four feed, forage, and malt barley cultivars that fit Montana's production environments and that provided added-value to Montana barley growers and to growers throughout the Northern Plains. MSU is developing multiple pest-resistant dryland alfalfa cultivars with good agronomic traits for Montana. In addition to alfalfa projects, efforts have been made to develop new grass cultivars suitable for Montana.

As the climate changes, the need for drought resistant cultivars of Montana crops increases. Therefore, researchers continue discovering and evaluating new crops and cultivars of spring wheat, winter wheat and barley suitable for a warmer and drier climate.

Several new camelina products are being developed for use in bread, as soil amendments, and to produce omega-3 rich beef and pork. We anticipate that new high-tocopherol lines of safflower will add value to producers in eastern Montana and western North Dakota and provide a more nutritious product.

Another scientist within our Department of Microbiology and Immunology is studying food quality and metabolic parameters that influences the development and progression of fatty liver disease (FLD) which impacts tens-of-millions of Americans and can progress to liver cirrhosis. This proposal is aimed at understanding the genetic, metabolic, and systemic physiological processes that underlie FLD. The goal is to understand the pathways leading to FLD and eventually design dietary, food-source, or food supplement protocols that might eliminate or abrogate the physical manifestations of FLD. This work will test whether simple shifts in the nation's food supply or in the USDA's nutritional recommendations might be effective at reducing FLD in the U.S. From an agricultural perspective, this might mean that subtle shifts in production may increase the general health of Americans.

Researchers are exploring different crops that deliver specific value-added products to consumers. The research involves identifying consumer needs not met by current crops. Scientists intend to continue development of camelina, timtana, proatina and montina, and expand marketability and profitability to farmers. The impacts of Proatina and Timtana products have been considerable in the health food market, because they are gluten free and part of a $2.5 billion annual market. Acreage of production has risen each year. The laboratory and analytical chemistry resources devoted to this project are a key reason why these products are on the market and contributing to the general health of the gluten intolerant and gluten sensitive population, now comprising about 6 percent of the population.

Again in 2014, COA/MAES communicated information on plant breeding and genomics advances through classroom activities, field days, cultivar trials, news releases, presentations at county and state meetings, and conventions:

- Release germplasm, new cultivars, and new genomics tools and techniques
- Conduct strategic planning with state agricultural groups
- Write technical and non-technical publications
- Develop value-added, agriculturally based end-use products
- Establish biobased product and food science education and research programs
- Enhance partnerships among faculty across the Montana university system, producers, agricultural industry, and other educational institutions across the region
- Provide ways to enhance agricultural production practices to enhance product quality
- Develop research summaries and fact sheets

2. Brief description of the target audience

- Domestic and foreign buyers of quality wheat
- Farmers, colleagues, and stakeholders
- Grain associations, Montana Department of Agriculture, Montana Wheat and Barley Committee, grain elevators, and state commodity groups
- Seed companies
- Crop and livestock producers in Montana
- State agricultural advisory committees
- Economic development groups
- Participants in extension and commodity group meetings, conventions, conferences, and field days
- State of Montana, Montana Department of Agriculture, BLM, USFS, and other government entities

3. How was eXtension used?

COA and MAES researchers worked closely with county extension agents and outreach coordinators to disseminate timely and accurate information regarding the evaluation and procurement of research advancements made in plant sciences, genomics and products. Many of these research projects were spoken of during MAES field days, throughout MSU/COA's seven research centers across the state.

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	25000	15000	1500	1500

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

Patent Applications Submitted

Year: 2014

Actual: 2

Patents listed
201400394 Egan Wheat
201300353 Wheat, durum, 'Silver'

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	200	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number of foreign trade teams at MSU

Year	Actual
2014	13

Output #2

Output Measure

- Number of research citations

Year	Actual
2014	200

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of new or improved cultivar recommendations provided to Montana producers to maintain dominance in small grain markets
2	Integration of new molecular techniques into breeding projects to improve outcomes
3	Average per bushel yield increase of Montana grains while maintaining product quality
4	Number of elite lines of wheat and barley screened for agronomic and quality characteristics
5	Planted acreage percentage increase per year of new MSU-released small grains in Montana
6	Number of new food products created from Montana crops

Outcome #1

1. Outcome Measures

Number of new or improved cultivar recommendations provided to Montana producers to maintain dominance in small grain markets

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	4

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Small grains are an extremely important component of Montana agriculture. Continual development of spring and wheat varieties for Montana farmers remains a central and critical role of MSU's wheat breeding programs. Producers need to be growing varieties that are highly desired for their traits and economic return - so that Montana producers can remain dominant in small grain markets. Montana crop producers want products suitable to domestic and export markets. They want wheat varieties that can thrive under harsh growing conditions and are more insect and disease resistant.

What has been done
New spring wheat varieties have been developed and applied for commercial release to the public. One variety, Egan, is the first variety for Montana with resistance to the orange wheat blossom midge The second line, Silver, is a new durum variety, that underwent variety performance testing and yielded strong results. Two high-amylose dry pea varieties were released; Amigo and B10-10.

Results
A variety is eligible for recommendation when a minimum of 16 location-years of performance data is obtained from the MAES statewide performance trials. The Egan line is soon to be commercially available to Montana producers. Results and resistance effectiveness of Egan have been published in several popular articles in the press, and journal articles have allowed reporting the results to fellow wheat breeders. Several public presentations were given state-wide during MAES Field Days. Wheat breeding is a long-term endeavor. New crosses, the evaluation of of genetic materials, and variety performance will be posted on the department website. Dissemination of varieties has been accomplished through the established seed growers program and over one million acres were evaluated and tested.Extensive testing for agronomic traits and end-use quality in the statewide trails provides data for the Montana Agricultural Experiment

Station to consider potential release of an experimental line as a new variety.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
502	New and Improved Food Products
903	Communication, Education, and Information Delivery

Outcome #2

1. Outcome Measures

Integration of new molecular techniques into breeding projects to improve outcomes

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	60

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Wheat breeding is a long-term endeavor. Making new crosses, and evaluating genetic materials generated from previous crosses takes time and often requires the integration of new molecular techniques into breeding projects to improve outcomes. Identifying novel genes for climatic and pest and disease resistance for wheat breeding is a long-term goal that sees consistent, albeit slow, results. This genre of scientific work directly translates to sustaining Montana's agricultural economy and new food products for the global market place.

What has been done
Tested the effect of a subset of the new alleles upon wheat milling and baking quality; evaluated priority crop core subsets and other selected germplasm with morphological descriptors; identified accessions with desirable economical traits, applied molecular marker techniques to assess diversity, detected duplicated acessions; identified taxa that were difficult classify; determined relative impact of major genes that control polyphenol oxidase on Asian noodle quality; proteomic

analysis of leaf senescence, functional analysis of candidate genes by virus-induced gene slicing.

Results
Identifying successful and desirable traits ultimately transfers to recommendations seeding rates, crop rotations, nutrient management, and irrigation rates that will provide more information to growers for informed decisions about which varieties to grow and how to best manage their crop. New cultivars depend on a diverse source of genetic variability. Agronomic yield and end product quality of cereal crops such as wheat are the two most important factors affecting farmer income.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
903	Communication, Education, and Information Delivery

Outcome #3

1. Outcome Measures

Average per bushel yield increase of Montana grains while maintaining product quality

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	12

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
For the crop year of 2013, the total value of of all wheat was 1.3 million, with an 11.8 increase in average bushel yield increase of Montana grains, while maintaining product quality. Montana planted a total of 5.90 million acres of all wheat in 2014, making it the fourth highest state for planted wheat acres in the country.

What has been done

Investigators with the COA and MAES continued developing hard red spring wheat varieties for farmers and the wheat milling and baking industry. Montana planted 2.5 million acres of winter wheat in 2014, up from 2.0 million acres planted in 2013. Montana is ranked fifth for winter wheat planted acres in the United States, according to the USDA National Agricultural Statistics Service, Montana Field Office. In 2014, Montana producers planted 2.95 million acres of spring wheat, unchanged from 2013. The state remains the second largest spring wheat producer in the country, according to the USDA National Agricultural Statistics Service, Montana Field Office.

Results
Variety lines produced by the Montana Agricultural Experiment Station represented about 60% of the states' wheat growing acreage and were the top four spring and wheat lines produced by MAES in 2013. The top for spring wheat lines were Vida;Montana producers planted 599,200 acres of Vida this year, accounting for 20.3 percent of the total acres planted; Choteau -212,200 acres accounting for 7.2 percent of Montana?s seeded spring wheat. Winter wheat lines were; Yellowstone -accounting for 19.8 percent of the state's planted acreage with 494,000 acres seeded; Judee - 285,900 acres of the variety, which accounts for 11.4 percent of the total winter wheat acreage in
2014; Decade - 261,700 acres planted in 2014, or 10.5 percent of Montana?s total acres and Genou - 164,500 acres of the variety, which accounts for 6.6 percent of the total winter wheat acreage in 2014.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems
502	New and Improved Food Products
903	Communication, Education, and Information Delivery

Outcome #4

1. Outcome Measures

Number of elite lines of wheat and barley screened for agronomic and quality characteristics

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual

2014 10

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The need for high quality grains increases as the world population grows, and global buyers are looking to Montana as an international leader in the development of new small grain cultivars. Global traders want high quality wheat to enhance food production in breads and noodles, and they are looking for disease and insect resistant plants with high yield potential.

What has been done
Researchers determined the agronomic and economic impact of various crop sequences in dryland crop production in Montana and screened for key agronomic and horticultural traits such as general adaptation, phenology and growth potential. Two new varieties underwent seed increase and purification in 2013 and they are under consideration for potential release. These include Egan and two new dry-pea varieties.

Results
Researchers planted the intrastate yield trial at eight locations with yields averaging 58 bu/acre. Seven hollow-stem, one solid-stem, and one "Clearfield" experimental lines were selected for further testing and seed stock purification. Twenty lines were selected for additional testing, and a 49 entry yield trial was planted and harvested and twelve solid stem lines were retained in upper level sawfly trials. 856 lines were evaluated for agronomic potential, 99 harvested, with 60 then selected for preliminary yield testing. These included four hard white and three two-gene "Clearfield" lines. They also screened for reliable grain yield and the plants ability to retain green leaves after heading. Winter wheat investigators added 284 crosses to the germplasm base,emphasizing disease resistance and adaptation traits.Extensive testing for agronomic traits and end-use quality in the statewide trails provides data for the Montana Agricultural Experiment Station to consider potential release of an experimental line as a new variety.

4. Associated Knowledge Areas

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

Outcome #5

1. Outcome Measures

Planted acreage percentage increase per year of new MSU-released small grains in Montana

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Condition Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	5

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Montanans place a lot of trust in Montana State University as a leader in samll grain agriculture, and nowhere is it more evident than in seed selection. Producers each year request the latest information and seed options available, so they remain competitive and successful in a global grain market.

What has been done
There was a nice percent decrease from year 2012 to 2013 in the planted acreage difference of total wheat in the state of Montana. This does not reflect MSU-released small grains. Montana planted 2.5 million acres of winter wheat in 2014, up from 2.0 million acres planted in 2013. MAES and the COA released "Silver Durum," and two Clearfield hard red winter wheat varieties, "War Horse" and "Colter." Il of them were recommended in 2013 to districts throughout Montana.

Results
Field crop revenue for Montana in 2013 totaled $9.5 million with wheat being the most significant. Montana producers seeded 2.1 million acres of winter wheat last fall for the 2013 crop year, down 200,000 acres or nine percent below the 2012 winter wheat planting of 2.3 million acres. The MSU variety "Yellowstone" continues as the highest yielding winter wheat line ever developed at MSU. "Judee" and "Bearpaw" solid stem semi-dwarf cultivars were released in the fall of 2011 and are expected to soon replace "Genou." "Genou" and "Yellowstone" have increased their yield per acres by 2.8 bu/acre and 6.7 bu/acre since 2007. Spring and durum wheat production were both up as was barley.

4. Associated Knowledge Areas

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

Outcome #6

1. Outcome Measures

Number of new food products created from Montana crops

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	2

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Discovering new ways to use products increases global food security and keeps consumers engaged. Consumers continue to want more local food options, and they are more interested in how and where it was grown. Consumers continue to want more local food options, and discovering new ways to use products increases global food security and keeps consumers engaged.

What has been done
MSU researchers conducted studies on genes important to cereal grain quality and agronomic traits. New food products include: Two high-amylose dry pea vareties: Amigo and B10-10. A third line with higher amylose content and higher yields is expected to be released this spring. A forth set of lines resistant to powdery mildew will require another year of yield trails. Pea genes resistant to the wheat stem sawfly will continue to be investigated.

Results
The primary output of MSU research breeding programs is the completion of crop quality evaluations on breeders samples, and the results of which continue to be featured in journals and publications throughout Montana and beyond enhancing knowledge for producers and consumers alike. This then leads to the identification of varieties for desired end product quality and to recommend for growers to produce. These scientific discoveries help sustain Montana's world-wide reputation for producing high quality, hard wheat

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
202	Plant Genetic Resources

203	Plant Biological Efficiency and Abiotic Stresses Affecting Plants
204	Plant Product Quality and Utility (Preharvest)
205	Plant Management Systems
502	New and Improved Food Products
903	Communication, Education, and Information Delivery

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Other (Funding)

Brief Explanation

Montana experienced one of the driest growing seasons on record in much of Southern Montana, but overall had a successful year with the value of all wheat crops down 1.2% ($1,395,091 in 2013) from 1.6 million in 2012 .according to USDA NASS, Montana Field Office. The all wheat season average price decreased from 8.15 per bushel (2012) to 6.87 per bushel (2013). Much of these figures, like any year, is dependent upon global markets and climate changes from year to year.
The 2014 crop year faced warm and limited precipitation though out the year, but when precipitation was received hail often accompanied the storm. Montana recorded a record amount of acreage damaged by hail.

V(I). Planned Program (Evaluation Studies)

Evaluation Results

The development of improved winter wheat lines and cultivars continues with improvements in yield, disease resistance, and tolerance advances, combined with improved stem solidness to combat sawfly. New challenges arrive, or former pests mutate to circumvent the remedies developed to thwart their damage and renew their attack on wheat and other crop species.
Montana's spring wheat acreage during the past five years has ranged from 44 to 55 percent of the total wheat acreage planted. In 2012, spring wheat accounted for 48 percent and durum 7.8 percent of the total wheat acreages. In 2012, Montana ranked second among the wheat and durum producing states. The wheat stem sawfly, wheat rust diseases and leaf diseases including Septoria, remain threats to wheat growers in areas across Montana, and require the planting of resistant varieties.

Hard red spring wheat is grown in all areas of the state, with more than 97 percent of the acreage on dryland. The largest concentration of acreage is east of the Continental Divide along the northern tier of counties. The highest producing counties in 2012 were Roosevelt, Valley, and Toole. More than 98 percent of durum wheat is also grown on dryland, and in 2012 the highest producing counties were Sheridan, Daniels, and Roosevelt in northeastern Montana.

"Yellowstone" and "Genou" (cultivars developed by the MSU research program) are the top two planted cultivars in Montana, accounting for about one million acres in 2012.

Adoption of these cultivars by Montana wheat growers has resulted in harvest of an additional 21.5 million bushels of winter wheat over the past six crop years (2007-2012) based on production acreage and estimated yield gains over previously deployed cultivars.

Scientists developed improved winter wheat cultivars adapted to Montana cropping systems and climatic conditions. Through molecular and genetic research they discovered plants more resistant to the wheat stem sawfly and made significant strides toward introducing new rust resistant genes into Montana cultivars.

Researchers focused efforts on sugar beet and potato production and discovered biocontrol agents for different disease affecting these crops. The value of the canola crops and safflower increased significantly and producers ranked number one in the U.S. for the production of pulse crops.

The COA and MAES will continue to research and publish results for the agricultural community. New online tools provide immediate information regarding crop and seed recommendations, and researchers are working relentlessly to improve production and profitability of Montana crops.

Key Items of Evaluation

• A new germplasm, "MSUPBLB 101-10", a yellow, high-amylose dry pea suitable for conditions found on the northern Great Plains was released
• An organized collection of more than 9,000 photographs of plants, including more than 2,000 photos of grasses are maintained at www.flickr.com/phots/plant_diversity/collections. All

photographs
are georeferenced and tagged with taxonomic, ecological, and morphological information for ease of rettreival and use as primarily an educational tool and secondarily to document study sites
• Several new low glycemic lines of potato, one low glycemic line of naked oats, and one low glucosinolate Camelina sativa line for microgreens were developed
• A set of guidelines for dryland crop rotation for Montana producers is currently being developed
• "Yellowstone" and "Genou" (cultivars developed by MSU) continued to be the top two planted cultivars in Montana, accounting for about 0.934 million acres in 2012. Adoption of these cultivars by Montana wheat growers has resulted in harvest of an additional 21.5 million bushels of winter wheat over the past six crop years (2007-2012) based on production acreage and estimated yield gains over previously deployed cultivars.
• Completed complex field research experiments with nearly 1,000 experimental lines of dryland and irrigated barley.

MSU COA researchers advanced crop options for a warmer and drier climate:

Developed a new winter wheat line, "Egan" - commercially sold and patent-pending approval (see Plant Sciences and Products program area)
• Developed two new spring wheats varieties called "WB9879CLP" and "Silver" durum
• A winter wheat, "SY Clearstone"
• Increased planting of "Vida," a drought resistant variety of spring wheat which was the top choice for growers in 2012 and 2013

• MAES researchers developed and reported a new high throughput molecular marker for leaf rust resistance breeding and a new strategy for studying genes in wheat seed development.
• Researchers demonstrated two important mechanisms in plant triacylglycerol biosynthesis pathway that were published.
• Spring wheat varieties developed by the COA/MAES program were grown on more than one million acres. The two most widely grown varieties in the state, "Vida" "and Choteau," were developed at MSU. In addition, two varieties developed by marker-assisted selection were marketed for the first time in 2012.

V(A). Planned Program (Summary)

Program # 5

1. Name of the Planned Program

Global Food Security and Hunger: Animal Health, Production, and Products

☑ Reporting on this Program

V(B). Program Knowledge Area(s)

1. Program Knowledge Areas and Percentage

KA Code	Knowledge Area	%1862 Extension	%1890 Extension	%1862 Research	%1890 Research
121	Management of Range Resources			5%	
301	Reproductive Performance of Animals			12%	
302	Nutrient Utilization in Animals			10%	
303	Genetic Improvement of Animals			10%	
304	Animal Genome			10%	
305	Animal Physiological Processes			10%	
306	Environmental Stress in Animals			5%	
307	Animal Management Systems			10%	
308	Improved Animal Products (Before Harvest)			12%	
311	Animal Diseases			5%	
315	Animal Welfare/Well-Being and Protection			5%	
702	Requirements and Function of Nutrients and Other Food Components			3%	
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources			3%	
	Total			100%	

V(C). Planned Program (Inputs)

1. Actual amount of FTE/SYs expended this Program

Year: 2014	Extension		Research	
	1862	1890	1862	1890
Plan	0.0	0.0	49.0	0.0
Actual Paid	0.0	0.0	38.9	0.0
Actual Volunteer	0.0	0.0	0.0	0.0

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

Extension		Research	
Smith-Lever 3b & 3c	**1890 Extension**	**Hatch**	**Evans-Allen**
0	0	282646	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
0	0	1866886	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
0	0	2175249	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

In 2014, Animal health research continued to be of primary importance not only to Montana's beef producers, but for the larger global safety Montana's food and product exports. Animal health accomplishments include research priorities in animal health in direct correlation with humans, livestock, or food products. Primary research veins reflective of these areas are; vaccinations, nutrient utilization, reproductive performance, animal physiology, zoonotic diseases, external parasites, animal diseases, genetic improvement of animals and management of range resources. Producing the highest quality animals and obtaining the highest profit potential are essential for Montana. In this concentration, new and improved food processes are featured as well as market economics and marketing and distribution practices. Promoting and maintaining animal health has led to advances in genetics, reproductive science and improved animal performance. Scientists continued investigating vaccines for rotavirus, strangles, respiratory diseases, and mastitis. Researchers are used feed studies with barley, camelina meal, and supplements to evaluate varying rations for calves and cows, and to continue producing superior feeder stock to markets outside of Montana. Global economic changes, fertilizer prices, drought and fire, weeds and pests, expanding export markets, market volatility and cultural changes all contribute to a challenging path for producers to remain profitable and sustainable in the industry. MSU Research, Extension and COA partnered with producers to address issues and meet the needs of Montana's agricultural industry.

Animal health research programs at MSU COA and MAES focused on reproductive performance in animals, nutrition, genetic improvements for herds, and developing better animal management systems. NIFA defined sustainable agriculture as an integrated system of plant and animal production practices having a site-specific application that will over the long-term satisfy human food and fiber needs. That definition also includes the importance of enhancing environmental quality and the natural resource base essential to the agricultural community. Researchers at MSU feel little plant/animal integrated systems level research has been done that addresses all of the factors outlined in t e USDA definition of sustainable agriculture. In addition, organic certified vegetable, row crop, and animal production enterprises and research have not fully taken advantage of the potential benefits of plant/animal integration and suffer from issues ranging from animal health and finishing (particularly internal parasite control), and alternatives to confinement (finishing) to residue and cover crop management, and soil health issues related to extensive tillage commonly used in organic farming programs. Thus, COA/MAES scientists have designed several research projects that will emphasize a combined animal and plant approach.

Food safety (as it relates specifically to animal health research priorities) and security continued to be important concerns for the beef industry at all production levels. Domestic and international consumers are demanding more information about the source of the meat products they purchase, including the age, health, nutrition, and handling management of the animal. In 2014, COA/MAES studies helped to ensure that Montana producers raise safe beef while improving the quality of the beef and ensure consumers are aware of the quality and health of their products through advancements in educational programs on beef quality assurance (BQA) practices, voluntary beef cattle marketing options, and ranch management issues throughout the state via meetings and interactive technologies.

2. Brief description of the target audience

- State agencies, animal health companies, and state commodity groups
- Ranchers, seedstock industry, colleagues, and related stakeholders
- Crop and livestock producers in Montana

3. How was eXtension used?

COA and MAES researchers worked closely with county extension agents and outreach coordinators to disseminate timely and accurate information about animal health, production and products.

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	5000	25000	3000	1500

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

Patent Applications Submitted

Year:	2014
Actual:	0

Patents listed

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	200	0

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Provide translational research to producers through outreach and Extension programs.

Year	Actual
2014	100

Output #2

Output Measure

- Publish research in scientific journals.

Year	Actual
2014	150

Output #3

Output Measure

- Present research findings to the public and interested producers through seminars and workshops.

Year	Actual
2014	100

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number of off-campus educational programs offered
2	Determine management factors that affect animal products
3	Disseminate research program results to producers regarding invasive weed management and impact on livestock
4	Find genetic correlations of factors influencing residual feed intake and feed efficiency

Outcome #1

1. Outcome Measures

Number of off-campus educational programs offered

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	25

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Animal health, production and products are of significant concern to Montana producers, as animal health is a field that directly impacts the state's economy. Livestock production on Montana farms and ranches provided $ 1.6 billion of gross income to the United States Economy, and of that amount, $1.2 billion of the value-added was in beef.

What has been done
Interactions between the levels of supplement consumption, supplement delivery methods, and forage intakes by beef and cows were evaluated. The intent of this research is to determine how the basic processes controlling forage intake and utilization by ruminants can be manipulated by supplementation.

Results
Current 2014 research data was presented at the 2014 Montana Nutrition Conference and the Western Section of the 2014 American Society of Animal Health. Additionally, more than 25 off-campus meetings were held with seven different NGOs, with more than 15 presentations to more than 320 constituents.Presentation presenters included state agricultural extension agents, financial advisors, local business leaders and beef cattle producers and forage producers.

4. Associated Knowledge Areas

KA Code	Knowledge Area
301	Reproductive Performance of Animals
302	Nutrient Utilization in Animals
303	Genetic Improvement of Animals
304	Animal Genome

305	Animal Physiological Processes
306	Environmental Stress in Animals
307	Animal Management Systems
308	Improved Animal Products (Before Harvest)

Outcome #2

1. Outcome Measures

Determine management factors that affect animal products

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Beef cattle production on Montana farms and ranches annually provides more than $2 billion to the Montana agricultural sector. These operations rely heavily upon the latest agricultural management factors that affect animal products. These include; forages, supplement consumption, supplement delivery method, feeding strategies that improve forage intake and utilization by beef cows. This also includes management techniques surrounding the impacts of stress factors on performance, health and well-being of livestock.

What has been done
Interactions between level of supplement consumption, supplement delivery method, and forage intake and utilization by beef cows and calves as well as integration of feeding strategies to improve forage intake and utilization by beef cows have all been implemented. Metabolic rates of mature cows were subjected to a step-wise reduction and then increased in feeding levels with metabolic rates of mature cows fed ad-libitum. Additionally, the reproductive performance of domestic ruminants were examined, primarily in sheep.

Results
There are myriad faculty research projects that surround management factors that affect animal products; most of the research is concentrated in pre-harvest settings, as the health of neonatal animals is the most significant contributor to the economic performance of livestock operations. Pre-harvest livestock operating systems drastically reduce profit through costs associated with treatment, animal losses, reduced weaning weights and long-term effects on animal performance

and product quality. All research accomplishments are continually published in peer-reviewed journals, state groups and meetings alongside industry professionals, producers and regional scientists from peer institutions.

4. Associated Knowledge Areas

KA Code	Knowledge Area
121	Management of Range Resources
301	Reproductive Performance of Animals
302	Nutrient Utilization in Animals
303	Genetic Improvement of Animals
304	Animal Genome
305	Animal Physiological Processes
306	Environmental Stress in Animals
307	Animal Management Systems
311	Animal Diseases

Outcome #3

1. Outcome Measures

Disseminate research program results to producers regarding invasive weed management and impact on livestock

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Montana beef producers need to have contemporary research results regarding invasive weed management and the subsequent impacts on livestock. Low input grazing practices, without adversely affecting production, will minimize impact on soil and water resources, and enhance economic viability. Ultimate goals of this research include finding a economic and environmental balance between livestock production and invasive species, a very difficult task in agricultural production, but one that MSU COA/MAES continually makes scientific advancements in.

What has been done
Metabolic rates of nine cattle (each of varying weights) were measured using a portable metabolic chamber in 2013. In 2014, preliminary trails were conducted with mature cattle and will again continue into 2015. At the mid-point of four seasons, researchers will complete preliminary trials and measured against measurements of cattle grazing on invasive weeds. Additionally, another research project is centered on the integration of domestic livestock into cropping systems. Instead of using traditional tilling machinery, domestic sheep are used to terminate cover crops and various weeds.

Results
Preliminary results of the livestock integration study are showing both economic and environmental benefits to the integrated system, when the sheep are sold for processing and cover crops are terminated without the cost of producers paying for tilling machinery. Many other projects have shared applied research results in forage-based livestock production systems obtaining maximum animal performance while effectively utilizing the forage resource base, which can increase economic return. Results of myriad research projects surrounding invasive weed management (7 hatch-specific funded projects) are disseminated widely and greatly across the northern Rockies region and include; producer meetings, Extension specialist materials, popular press, IPM meetings and trainings, scientific conferences and

4. Associated Knowledge Areas

KA Code	Knowledge Area
121	Management of Range Resources
302	Nutrient Utilization in Animals
307	Animal Management Systems
308	Improved Animal Products (Before Harvest)
315	Animal Welfare/Well-Being and Protection
702	Requirements and Function of Nutrients and Other Food Components
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources

Outcome #4

1. Outcome Measures

Find genetic correlations of factors influencing residual feed intake and feed efficiency

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Montana has long had the notion to retain the highly sought after genetically superior cattle being produced, but have faced the difficulties of transportation costs associated with heavier animals without the low cost of grains. Co-products and new crop development may decrease production input costs to allow more short-term retention of the superior genetic beef cattle produced in Montana.

What has been done
Research began to investigate long term effects and interactions between crossbreeding, maternal efficiency and residual feed intake on mixed grass prairie as all heifers within the cattle herd are being developed in a GrowSafe facility recently installed at MAES' Northern Agricultural Research Station in Havre, Mont. Since the project began, approx. 276 animals have been evaluated and this data will be used for evaluating long term maternal productivity.

Results
The objective of this project is to evaluate the opportunities to increase the value of beef cattle within the state of Montana. Development of new crops within the state, with the potential to produce co-products must only be evaluated on agronomic level, but must be investigated to determine the value to Montana beef production as an alternative feed source. Increasing value of beef cattle is leading projects to graze cover crops to evaluate alternative economic streams of harvesting forage with cattle to increase gain on cattle and improve soil health.

4. Associated Knowledge Areas

KA Code	Knowledge Area
301	Reproductive Performance of Animals
302	Nutrient Utilization in Animals
303	Genetic Improvement of Animals
304	Animal Genome
308	Improved Animal Products (Before Harvest)
315	Animal Welfare/Well-Being and Protection
702	Requirements and Function of Nutrients and Other Food Components
711	Ensure Food Products Free of Harmful Chemicals, Including Residues from Agricultural and Other Sources

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Natural Disasters (drought, weather extremes, etc.)
- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations

Brief Explanation

MSU COA and MAES experienced significant faculty movement impacting this planned program. Previous projects highlighted in the 2014 Plan of Work included extensive research into brucellosis and prion diseases. The principal investigators in these projects were recruited to larger institutions with significant salary increases, and these projects were terminated. Additionally, there is some confusion between program reporting requirements between Animal health and food safety program areas, as they share a large majority of research priorities and projects. Because these two program areas are cross-disciplinary in nature, COA/MAES has elected to define food safety in solely post-harvest product terms, as outlined new a planned program in the 2016-2020 POW, to be considered within Animal Health. Any pre-harvest animal health research will be considered and reported within Animal Health; which may include previous and current Hatch project work that was originally reported under Food Safety. Additionally, COA had a joining of academic departments this year in the newly named Department of Microbiology and Immunology, where much of the COA/MAES animal health research (within the bounds of pre-harvest, neonatal animal health in a "traditional" sense) is being conducted.

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Montana has 2.5 times more cattle than people providing the foundation for the number one industry in the State - agriculture. It is in this context that researchers design, implement, and conduct research projects within the COA/MAES. Research in the Animal Health Program is critical to the industry in Montana and producers and consumers alike who count on the investigators to promote a healthy industry through their consistent research. Highlights for 2013 were:

• Advancements in knowledge of Staphylococcus Aureus in humans and livestock
• Hired new faculty members, two of which are core users of new molecular tools
• Evaluated 256 animals through the GrowSafe system and added new equipment to MSU research center doubling the capacity of researchers to evaluate residual feed intake
• Conducted webinars, workshops, and seminars to share up-to-date information on

animal health
and quality assurance reaching audiences in excess of 1,500

Key Items of Evaluation

The Animal Bioscience Building combined with state-of-the-art laboratory equipment assisted in the successful recruitment and hiring of three new faculty members in the Animal and Range Sciences Department for the College of Agriculture. The new faculty include a beef geneticist, a range ecologist, and a rumen microbiologist. The College also purchased an Illumina MiSeq and is using it to help members of the Crow Indian Reservation identify sources of antibacterial resistant E. Coli. MSU COA is now a fully functioning partner in the WIMU - Washington, Idaho, Montana, Utah Regional Program in Veterinary Medicine. This regional veterinary program continues to privilege a "one-health" thematic approach alongside parallel coursework with first-year medical students on the MSU campus as well.

Additional advancements included:

- Research reporting high variation of intake of self-fed protein and/or energy supplements by individual animals.
- Measured were identified regarding animal-stress and well being, as well as characterized factors affecting the biology of stress and immune responses of farm animals.
- Development of management strategies and/or tools to enhance farm animal well-being under conditions of climatic change and other stressful environments.
- Two years of field work were completed in incorporating sheep into farming systems. A news article and six minute video on the project's success and early findings were disseminated to a national audience.
- Circling disease advancement: prs2A-htrA-L monocytogenes strain is highly immunogenic and provides robust protective immunity against subsequent lethal L. monocytogenes challenge through the induction of strong Listeria-specific CD8 + CD4 + T cell responses.
- The understanding of the bovine immune systems and how it similar and dissimilar to the immune system in rodents and humans has made great strides in 2014. The information should facilitate development of new approaches to treat infectious diseases of cattle.
- Long-term research to determine the physiological mechanism(s) and pheromonal pathways by which the biostimulatory effect of bulls, 1.) enhances the fertility of heifers and cows and, 2.) accelerates the reproductive neuroendocrine-endocrine cascade that culminates in resumption of ovulatory cycles in postpartum, anovulatory, suckled cows.

- Developed a new model for microbial host-virus interactions which took into account the new host CRISPER anti-viral defense system, the discovery of four new viruses to science and solving the high resolution structure of an archaeal virus ATPase packaging motor.
- Generated13 S. equi mutants that each had one of the 13 target genes inactivated and cloned one virulence gene for preparation of recombinant protein.
- The genes encoding 7 antigenic cell wall-linked protenis of Steptococcus equi were separately knocked out, and each of the 7 S equi mutant was compared with parent S equi strain in virulence using a mouse model of intranasal infection.
- Established a program of investigation focused on understanding the role of innate immune parameters in bovine host defense.
- Determined if growth patterns influenced by genetics or temperament impact carcass characteristics and tenderness of beef.
- Uncovered a system of coordination between metabolic systems, wherin TrxR1 serves as a key component to coordinate activities between the redox-bioenergetics and drug/xenobitioc-metabolism systems.
- 26 horses were investigated, three separate times, for the presence of S. aureus. Studies indicated that S. aureus is not the common inhabitant of equine nasal passages and demonstrated that other staphylococcal species are common inhabitants. Potential antibiotic resistance was also investigated.
- Initial invitro studies were done on the effects of AcaiPS on bovine immune cells.
- Altered lung environments were found to respond to subsequent infection more quickly and intensely, resulting in accelerated clearance of viruses.

VI. National Outcomes and Indicators

1. NIFA Selected Outcomes and Indicators

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