V(A). Planned Program (Summary)

Program # 1

1. Name of the Planned Program

Agricultural And Biological Engineering

☑ 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
112	Watershed Protection and Management	20%		10%	
133	Pollution Prevention and Mitigation	5%		10%	
141	Air Resource Protection and Management	35%		10%	
401	Structures, Facilities, and General Purpose Farm Supplies	10%		20%	
402	Engineering Systems and Equipment	15%		15%	
403	Waste Disposal, Recycling, and Reuse	5%		10%	
404	Instrumentation and Control Systems	0%		15%	
405	Drainage and Irrigation Systems and Facilities	10%		10%	
	Total	100%		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	3.0	0.0
Actual Paid	0.0	0.0	3.2	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**
9841	0	442256	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
9841	0	442256	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
79015	0	1152255	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research activities in 2014 included an ongoing project with a focus on improving the efficiency of liquid agricultural chemical application systems [through the development of a real-time droplet size monitoring system for low-pressure field sprayers], the development of a novel handheld impedance analyzer system for use in animal health applications, continuing work to develop a framework and methodology for collecting information and evaluating field-based supply chain logistics, an effort to characterize the emissions from livestock buildings [with a focus on particulate matter emissions] and to develop integrated technologies to reduce emissions from livestock buildings [with a focus on biofilter technology], research findings indicating that drift reduction technologies can be successfully used to apply sprays containing both dicamba and glyphosate [the differences seen indicate pattern width/uniformity might be more of an issue than droplet size], work relating bioreactor performance to both air and soil temperature [the temperature of the water in the bioreactor is a function of both the air and soil temperatures which are not necessarily correlated], and a recent study showing that hydrothermal liquefaction [HTL] treatment of livestock manure can simultaneously produce an energy-dense bio-oil and effectively destruct a range of bio-active compounds in manure including various antibiotics and estrogenic compounds.

Conference presentations included the South African Sugar Research Institute, John Deere Technology Innovation Center, South African Institute of Agricultural Engineers, American Society of Agricultural and Biological Engineers, Certified Livestock Manager Training Workshops, North Central Weed Science Society Annual Meeting, Water Environment Federation, and the International Congress of Pesticide Chemistry/American Chemical Society National Meeting.

Extension activities related to this planned program are interdisciplinary in nature and relate to other planned programs featured in this report [Sustainable Energy, Natural Resources and the Environment, and Animal Health and Production]. A great deal of effort was devoted to education focused on livestock manure management through eight statewide **Certified Livestock Manager Training** workshops that covered not only the basics of nutrient management, but also new technologies, current research and emerging trends. The training and completion of an online five-part quiz series also meets state livestock waste management training requirements for producers. Livestock producers with 300 or more animal units must be recertified through training and/or exam passage every three years.

With limited Extension specialist FTE's, Extension has chosen to expand outreach through websites. The **Manure Central** website [**http://web.extension.illinois.edu/lfmm/manure.html**] registered more

than 400,000 page views this past year and consists of several sections that included: [1] **Certified Livestock Management Training** and **Illinois Manure Management Plan** materials designed to help livestock producers in developing manure management plans to more efficiently and safely use manure as a fertilizer [the website allows customizing the plan to meet a given producer's needs and facilitates any required annual updates]; [2] **Manure Share**, an exchange program that brings gardeners and landscapers searching for organic materials for use in composting or field applications in contact with livestock owners with excess manure; [3] **Small Farms Manure Management** for individuals with less than 300 animal units; [4] **EZregs** for users who have established accounts to store their questions and Extension educator responses related to identifying environmental regulations that pertain to specific agricultural and horticultural operations and practices in Illinois; and [5] **Compost Central** which features resources for composting of livestock manure, food scraps, and yard waste. Additional training was provided for custom manure haulers in Illinois, with certification and testing provided on a voluntary basis.

With respect to farm equipment education, a total of 15 **Operation S.A.F.E. Fly-In** seminars were conducted in Illinois and nine other states by an Extension pesticide safety education staff member to ensure that aerial applications of fungicides to corn are accurately applied and encompassed information related to spraying equipment. The three regional **Crop Management Conferences** included a presentation by an agricultural engineering Extension Specialist on calibrating sprayer quality requirements for pesticide applicators.

One of the Commercial Agriculture Extension Educators presented information and demonstrations of unmanned aerial vehicles [drones] and their potential use in crop scouting and management to 1,180 participants at 17 educational events this past year.

Extension faculty and staff with agricultural engineering expertise have also provided leadership in programming that addresses sustainable energy [see Sustainable Energy planned program]. In addition, there were 37,000 page views of the **Agriculture Safety and Health** website.

2. Brief description of the target audience

Members of the target audience included researchers, the agricultural chemical [herbicide and fertilizer] industry, chemical application equipment manufacturers, students and researchers in the areas of biosensors and nanotechnology applied to agriculture, agricultural engineers, environmental consultants, researchers in the livestock industry, animal scientists, livestock producers, agriculture consultants, livestock commodity group representatives, undergraduate students in agricultural and biological engineering, aerial applicators, commercial and private ground rig applicators, pesticide adjuvant manufacturers, farmers, crop scouts, turf grass applicators, pesticide registrants, drainage contractors, wastewater treatment facility staff, wastewater treatment equipment providers, regulators, environmental scientists, and environmental engineers. Extension target audiences included crop producers, certified crop advisers, livestock producers, custom manure haulers, pesticide applicators, gardeners, landscapers, and youth.

3. How was eXtension used?

eXtension was not used in this program

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	716	1400	3276	0

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

Patent Applications Submitted

Year:	2014
Actual:	2

Patents listed

Issued Patents: 8,602,329 [Variable Orifice Nozzle] and 8,712,144 [System and Method for Detecting and Analyzing Features in an Agricultural Field].

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	21	21

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number Of Completed Hatch Projects

Year	Actual
2014	1

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number Of Subsurface Bioreactor Acres In Illinois
2	Implementation Of Global Engineering Solutions Using Agricultural Machinery
3	Improved Understanding Of The Environmental Impact Of Anthropogenic Nanoparticles On Photosynthetic Cyanobacteria
4	Utilizing Biofiltration To Mitigate Amonia Emissions From Livestock Buildings
5	Developing Novel Processes That Are Cost-Effective In Reducing The Risks Associated With Bioactive Compounds In Wastewaters
6	Optimization Of Sprayer Performance With A Focus On Drift Reduction
7	Developing, Updating, And Using A Manure Management Plan

Outcome #1

1. Outcome Measures

Number Of Subsurface Bioreactor Acres In Illinois

Not Reporting on this Outcome Measure

Outcome #2

1. Outcome Measures

Implementation Of Global Engineering Solutions Using Agricultural Machinery

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)
Considerable research has gone into developing agricultural machines that can perform the necessary operations on farms in a timely and efficient manner. However, this development has taken place with relatively little consideration of the overall system in which the machine is expected to operate, especially in a global context. Sufficient understanding of the environment and constraints in which the machinery must operate in different countries leads to a more effective supply of appropriate equipment for farmers. A systems approach is an effective way to analyze the overall farming operation, accounting for tractor-implement matching, machinery work rates and productivity, and in-field environmental impacts such as soil compaction resulting from equipment selection and usage. The purpose of this project is to develop a framework and methodology for collecting information and evaluating field-based supply chain logistics with a global perspective in order to be able to implement global engineering solutions concerning agricultural machinery.

What has been done
During visits to China, South Africa and Italy, the PI was able to strengthen contacts with university institutions and with industry. A visit to South Africa and particularly the South African

Sugar Research Institute [SASRI] was valuable in obtaining a fresh perspective about global engineering relative to agricultural practices at both the large and small scale. Potential research collaborations related to data analytics are currently being explored with linkages to both SASRI and the University of KwaZulu-Natal.

Results
Two graduate students completed their theses addressing topics concerning the mapping and analysis of agricultural machinery operations. These projects were undertaken in collaboration with the John Deere Technology Innovation Center. In addition, the PI has discussed with colleagues the establishment of a laboratory focusing on data analytics for precision agriculture. The PI has also connected with companies that provide tools for agricultural information management and these are currently being installed and commissioned. These tools will be used for research associated with this project and for teaching.

4. Associated Knowledge Areas

KA Code	Knowledge Area
401	Structures, Facilities, and General Purpose Farm Supplies
402	Engineering Systems and Equipment
404	Instrumentation and Control Systems

Outcome #3

1. Outcome Measures

Improved Understanding Of The Environmental Impact Of Anthropogenic Nanoparticles On Photosynthetic Cyanobacteria

2. Associated Institution Types

- 1862 Extension
- 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)
One of the salient features of biological, agricultural and environmental applications of nanotechnology is that the nanoscale devices and systems are of the same size-scale as

biomolecules. While the size similarity offers unique and powerful routes to directly manipulating biomolecules, the increased application of nanotechnology raises concerns about potential unintended interactions and consequences between nanoparticles and living systems. In our research program we focus on the environmental impact of anthropogenic nanoparticles on an important group of bacteria, viz. photosynthetic cyanobacteria. These organisms convert solar energy to simple sugars and are primary producers in most aquatic ecosystems. We will develop novel analytical capabilities as well as experimental methodologies to quantify the risk associated with various nanoparticles on the growth and photosynthetic capabilities of cyanobacteria. The results of our work will be published not only through scientific publications and professional meetings, but also through the web, where we will develop tools to engage broader citizen participation for addressing concerns and questions pertaining to nanotechnology in the environment.

What has been done
Activities included the development of devices and systems incorporating microfabrication and nanotechnology, the development of a novel handheld impedance analyzer system for use in animal health applications, the development of a framework for economic, environmental and health risk assessment for nanotechnologies applied to food, agriculture and biological systems, and the development of mathematical models to understand ecological and evolutionary interactions in ecosystems subjected to nano[bio]technological intervention.

Results
Our group produced education and outreach materials on nanofabrication, sensing, systems integration and application risk assessment as well as mathematical models to illustrate dynamic systems properties in ecosystems perturbed with nano[bio]technological agents.

4. Associated Knowledge Areas

KA Code	Knowledge Area
133	Pollution Prevention and Mitigation
402	Engineering Systems and Equipment
404	Instrumentation and Control Systems

Outcome #4

1. Outcome Measures

Utilizing Biofiltration To Mitigate Amonia Emissions From Livestock Buildings

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)
Biofiltration is recognized as an effective technology to mitigate ammonia emissions from livestock buildings. Biofilters are bioreactors that can absorb ammonia and then oxidize it into nitrite and nitrate-using microorganisms. Woodchips and composts are often used as packing materials, thus making it an affordable method. This study focuses on improving the basic biofilter engineering designs [media selection and airflow resistance measurement], ammonia removal efficiency, and the effect of moisture on nitrous oxide generation. We conducted studies of various biofilter media, especially airflow characteristics linking particle size distribution, moisture content, condensation, and other factors. Physical and chemical properties and airflow resistances of eleven commonly-used biofilter media, including ten organic and one inorganic, were characterized. The density, porosity, particle size distribution, pH, total C, total N, and organic matter content of each material were analyzed using standard methods. The airflow resistance properties were tested on a large chamber. Based on the observations of moisture, bed thickness, and compaction effects on air flow resistance, an empirical equation was developed and can be used as an initial database for future biofilter designs.

What has been done
Ammonia removal of biofilters was studied in relation to moisture content and pH condition of target organic media. A baseline test was carried out to examine ammonia removal efficiency and nitrification kinetics at extreme conditions. The results suggested that nitrogen compound management is critical in achieving stable and high ammonia removal efficiency. Moisture is believed to be the most important factor in determining biofilter performance. It affects both ammonia mitigation and nitrous oxide generation. It was found that ammonia removal efficiency was improved when media moisture content was increased from 35% to 55%, but further increasing moisture content did not enhance ammonia mitigation but did increase nitrous oxide generation. Nitrous oxide generation from biofilters was also researched, and was related to organic media moisture content, pH condition, and microbial communities. In-depth understanding of the ammonia removal process, as related to moisture content and pH condition of organic media, was obtained. Due to the research, we can better predict ammonia removal based on media moisture content, pH condition, and ammonia loading history.

Results
Based on the results of moisture effects on biofilter performance, it is critical to manage the moisture content in the biofilter media. A moisture sensor was developed to control the moisture content in biofilter media in order to achieve high ammonia removal efficiency and low nitrous oxide generation in this project. We have an improved algorithm for the biofilter design process based on media airflow characteristics, particle sizing, and moisture content control.

4. Associated Knowledge Areas

KA Code	Knowledge Area

133	Pollution Prevention and Mitigation
141	Air Resource Protection and Management
401	Structures, Facilities, and General Purpose Farm Supplies
402	Engineering Systems and Equipment
403	Waste Disposal, Recycling, and Reuse
404	Instrumentation and Control Systems

Outcome #5

1. Outcome Measures

Developing Novel Processes That Are Cost-Effective In Reducing The Risks Associated With Bioactive Compounds In Wastewaters

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)
This project focuses on the removal of emerging contaminants [such as pharmaceuticals, steroids, surfactants, and plasticizers] that have been detected in wastewater discharges from various human and livestock sources. According to the Union of Concerned Scientists 70% of total annual antibiotics used in the U.S. [11,200 tons] are used for non-therapeutic purposes with cattle and swine, and a significant fraction [up to 75%] is excreted in an unaltered state. When released into the environment, these bioactive chemicals can exert selective pressures on microbial communities and cause them to develop antibiotic resistance as a defense mechanism. Antimicrobial drug resistance has become a major concern with an estimated economic impact of $4 to $5 billion. A significant number of studies have been done on the removal of pharmaceuticals and antibiotic resistance in drinking water and wastewater, and while some removal of pharmaceuticals has been observed in conventional wastewater treatment processes, most are not effectively designed to remove micropollutants. Thus, there is a critical need to better understand the fate, transport, and transformation of these emerging contaminants in water purification processes and to develop novel processes that cost-effectively reduce the risks associated with bioactive compounds in wastewaters. This study will provide new knowledge on the effects of novel water treatment processes, which are expected to have certain advantages.

In particular, we are focused on treatment systems using activated carbon adsorption, ion exchange, membrane bioreactors, algal treatment systems, hydrothermal liquefaction, and various hybrids of these components.

What has been done
Our recent work has shown that hydrothermal liquefaction [HTL] treatment of livestock manure can simultaneously produce an energy-dense bio-oil and effectively destruct a range of bio-active compounds in manure including various antibiotics and estrogenic compounds. These results showed that HTL reaction times of 60 minutes and/or reaction temperatures of 300 degrees C provided nearly complete removal of the measured contaminants to below detection limits. By simultaneously producing valuable bio-crude oil and destructing bio-active compounds in animal manure, this process can improve the economic return of livestock production and reduce negative environmental impacts.

Results
Our research also showed that HTL treatment of manure can produce some additional chemical compounds that have deleterious biological effects. Specifically, we showed that the aqueous organic mixture produced by HTL exhibited mammalian cell cytotoxicity with a LC-50 at a dilution of 7.5% and also showed inhibitory effects on anerobic bacteria and algae. Subsequently, we showed that biological treatment with algal bioreactors can effectively capture/remove a variety of organic contaminants and reduced mamallian cytotoxicity by 30%. Integrating adsorbents into bioreactors treating HTL wastewaters can improve the performance. These biological post treatments of HTL wastewater were able to effectively remove target contaminants and produce additional biomass feedstocks for HTL or biogas, which improves the net energy production for integrated systems providing both bioenergy production and wastewater treatment.

4. Associated Knowledge Areas

KA Code	Knowledge Area
112	Watershed Protection and Management
133	Pollution Prevention and Mitigation
402	Engineering Systems and Equipment
403	Waste Disposal, Recycling, and Reuse
405	Drainage and Irrigation Systems and Facilities

Outcome #6

1. Outcome Measures

Optimization Of Sprayer Performance With A Focus On Drift Reduction

2. Associated Institution Types

- 1862 Extension
- 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)
In order to optimize sprayer performance both efficacy and drift need to be considered. Many applicators, particularly aerial, are looking to reduce their application volumes to increase their productivity. In addition, many of the pesticides currently used in crop protection are contact or locally systemic products. These products require increased coverage in order to be effective. Lower spray application volumes and less systemic pesticides both require the use of smaller droplet sizes in order to maintain efficacy. Even systemic products have experienced efficacy issues in recent years, likely because of poor coverage and deposition associated with the use of large drift-resistant droplets. Due to glyphosate resistant weeds, dicamba and 2,4-D resistant crops are expected to be commercially available within the next several years. These two herbicides will likely require a smaller droplet size than glyphosate in order to be effective. The need for a smaller droplet spectrum to provide effective coverage will increase the risk of these products drifting off target. Benefits of low volume aerial applications include increased productivity and timelier applications.

What has been done
The final year of drift reduction nozzle and adjuvant testing for dicamba-glyphosate applications was completed. As with last year, the research was conducted on a population of glyphosate resistant waterhemp. In addition to the nozzles and adjuvants, this year's study included the use of a pulse width modulation system. Results indicate that drift reduction technologies can be successfully used to apply sprays containing both dicamba and glyphosate. The differences seen indicate pattern width/uniformity might be more of an issue than droplet size. Another study of aerial fungicide applications to corn was conducted, and soybeans were added as an additional crop.

Results
Data confirms previous studies that show that the use of an oil-based adjuvant can help improve the efficacy of the applications. Also completed was a study to determine the effects of cutting off nozzles at the ends of the booms on agricultural aircraft. Two variables were measured: downwind drift deposit and total swath width. A system using a laser and radar was developed to record the speed and height of aircraft for research projects. It uses bluetooth technology to transmit data to a tablet computer. This technology will also be used for spray pattern testing clinics.

4. Associated Knowledge Areas

KA Code	Knowledge Area
133	Pollution Prevention and Mitigation
141	Air Resource Protection and Management
401	Structures, Facilities, and General Purpose Farm Supplies
402	Engineering Systems and Equipment
404	Instrumentation and Control Systems

Outcome #7

1. Outcome Measures

Developing, Updating, And Using A Manure Management Plan

2. Associated Institution Types

- 1862 Extension
- 1862 Research

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	151

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Improper manure management has environmental consequences. Livestock and poultry producers face challenges in understanding and minimizing these negative impacts.

What has been done
[1] Educational efforts included continued maintenance and updating of the Illinois Manure Management Planner website which is used by stakeholders to learn about manure management and to access resources to create Manure Management Plans for facilities. [2] Training, certification and testing programs were conducted for custom manure haulers. Operators who haul and apply manure to cropland for hire are not regulated in Illinois, but through collaboration with other Great Lakes states a voluntary training and certification program is provided that helps these individuals better understand Illinois regulations and evolving best management practices for environmental protection. [3] In addition, annual training for the Certified Livestock Manager Training program was conducted at 8 sites across the state. This state program requires livestock

and poultry producers to attend training and become certified once every 3 years. The curriculum includes key information on best management practices, nutrient management information, and updates on regulations and associated information. [4] Assistance was provided in developing curriculum on waste management for livestock and poultry operations to certify Technical Service Providers [TSPs] who act as consultants and who specialize in developing Comprehensive Nutrient Management Plans [CNMP's] for producers that are actively using conservation practices and implementing the latest best management practices.

Results

[1] The Illinois Manure Management Planner website received 14,147 accesses, with 77 new accounts created and 74 plans updated and/or modified. [2] Twenty-six manure haulers, environmental managers and their employees attended the Custom Applicator Training program. Collectively, their production units and clients represented over 500 million gallons of annual manure application. All 26 individuals completed and passed the Level 2 examination for custom applicator certification. [3] One hundred eighty-one [181] individuals attended the Certified Livestock Manager Training programs. According to the survey data, 82% of attendees responded that they currently had manure management plans. Of these respondents, 46% updated and used their plan annually.

4. Associated Knowledge Areas

KA Code	Knowledge Area
112	Watershed Protection and Management
133	Pollution Prevention and Mitigation
141	Air Resource Protection and Management
403	Waste Disposal, Recycling, and Reuse

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Economy
- Appropriations changes
- Competing Programmatic Challenges
- Populations changes (immigration, new cultural groupings, etc.)

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

Commercial Pesticide Applicator Training

Using the results of a survey of practice changes that was mailed to a random sample of participants in the 2011-12 Commercial Pesticide Applicator training and in response to the question asking them how much they had improved implementing 12 practices as a

result of the training, it can be assumed that of the 9,164 participants in this year's training, 6,020 [65.7%] improved calibration procedures [frequency, accuracy, and measurement], 4,930 [53.8%] improved equipment maintenance [inspecting, cleaning, and replacing worn nozzles], and 4,838 [52.8%] improved changing of the type, size, or materials of the nozzles used as a result of attending the training.

Key Items of Evaluation