V(A). Planned Program (Summary)

Program # 9

1. Name of the Planned Program

Sustainable Energy

☑ 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
133	Pollution Prevention and Mitigation	5%		15%	
136	Conservation of Biological Diversity	0%		10%	
201	Plant Genome, Genetics, and Genetic Mechanisms	0%		15%	
206	Basic Plant Biology	35%		15%	
402	Engineering Systems and Equipment	15%		20%	
601	Economics of Agricultural Production and Farm Management	10%		10%	
603	Market Economics	0%		10%	
801	Individual and Family Resource Management	10%		0%	
803	Sociological and Technological Change Affecting Individuals, Families, and Communities	15%		5%	
806	Youth Development	10%		0%	
	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	2.0	0.0
Actual Paid	0.0	0.0	3.5	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**
103332	0	555991	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
103332	0	555991	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
829655	0	3438968	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Activities in 2014 included the development of a better process to produce biofuels [substrate and product inhibition on yeast was removed by using granular starch hydrolyzing enzymes and vacuum fermentation], research focused on examining the riskiness of energy crop production for farmers and the impact of farmer risk and time preferences on their willingness to grow energy crops, a study focused on developing a welfare economic framework to analyze the rationale for fuel policy choices in Brazil and the trade-offs they have engendered in the fuel and sugar sectors, work investigating second-generation biofuel production capacity in the U.S. focusing on the decision facing potential investors [the decision to invest in building a cellulosic ethanol facility involves a number of risks which provide incentives to delay the investment decision until a later date despite required blending or use levels outlined by federal biofuel policy in the U.S.], an investigation into the possibility of developing sustainable biomass production systems on marginal land, the establishment of a demonstration laboratory for environment-enhancing energy to convert swine manure and algae into biocrude oil via hydrothermal liquefaction, research to assess the potential of telomere manipulation in plant improvement with regard to adaptation to global climate change and increasing yield of both food and fuel endpoints, efforts to develop information on the genome size, ploidy level, and genomic polymorphisms among accessions of the genus Miscanthus to assist in taxonomic studies, improve our understanding of the evolution of the genus, and provide valuable information to biomass crop improvement programs, the use of replicated, experimental micro-landscapes to assess how animal movements are affected by biofuel crops, and the evaluation of twenty-one species of perennial woody species for their potential as short rotation bioenergy feedstocks.

Conference presentations in 2014 included the International Symposium on Nitrogen Fixation with Non-Legumes, Ecological Society of America, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, American Society of Agricultural and Biological Engineers, American Society of Chemistry, American Society of Chemical Engineers, American Institute of Chemical Engineers, Corn Utilization and Technology Conference, Short Rotation Woody Crops Operations Working Group, University of Illinois Agronomy Day, American Association of Cereal Chemists, American Soybean Association, American Seed Trade Association, and the 68th Corn and Sorghum Seed Research Conference.

In December of 2013, the University of Illinois launched the **Institute for Sustainability, Energy, and Environment** [iSEE] on the Urbana-Champaign campus. The Institute was created to lead an interdisciplinary approach to researching solutions for the world's pressing sustainability, energy and environmental needs of today and tomorrow. The goal of iSEE is to help the campus become a model of

sustainability, energy efficiency and environmental friendliness and to prepare students to be leaders in these fields as well as good Earth citizens when they leave campus. Of note, an Extension field staff member has provided information on the availability and cost considerations that facilitated a decision to add a biomass gasification burner unit on the University of Illinois Energy Farm. A biomass heating system was also installed at a farm site this year.

In addition, Extension has facilitated the installation of a farm site biomass burner system and contributed knowledge of perennial grass feedstock production that has contributed to the establishment of a project with the Illinois Department of Transportation [IDOT] to use roadside and right-of way grasses as a more economical heating fuel substitute for propane at one of several IDOT regional maintenance sites in Illinois. The site has been identified and a press event was held to announce the project that also includes a bio-refinery to be built on campus in association with the IDOT project.

The **Dudley Smith Initiative** continued to provide financial support to create a positive loop and feedback relationship between researchers on campus and agriculturalists and leaders in the community regarding biomass energy generation. The site and related Extension programs have helped build the foundation of biomass utilization using a farm-scale model to improve biomass harvesting methods, utilization strategies, and services to provide inventories of harvestable biomass to reduce nutrient run-off. In addition, this applied research matches crop nutrient requirements with crop production goals to help protect fragile or impaired waters and watershed areas. An Extension Educator continues to provide educational field days at this research farm and to assist in managing the tropical maize research and in seeking additional resources for future biomass crop/cover crop interdependences and the environmental advantage of simultaneous research strategies.

Other Extension sustainable energy programming included presentations to college students and staff on biomass energy crops, as well as multiple presentations to consumers on landscaping, alternative energy for small acreages, and energy-efficient homes [**Reducing Energy Costs in Your Hom**e]. Using the solar/gasification demonstration trailer, posters, and samples of energy grasses and tropical maize plants, Extension Educators interacted directly with approximately one half of the 600 attendees at the **Southern Illinois Sustainable Living Expo** held at the Dixon Springs research center regarding solar, biomass, and wind technologies. Extension Educators also worked with the Illinois Wind Working Group, the Illinois Biomass Working Group, the Illinois Solar Association, and the Illinois Geothermal Association to plan and conduct the **Illinois Renewable Energy Conference** held in central Illinois that attracted over 250 participants who could attend sessions in three tracks: [1] Solar; [2] Biomass; or [3] Wind. Extension Educators also conducted a panel and presented information at the Northern Illinois Renewable Energy Summit held in Ames, Iowa. Enrollment in the **4-H Wind Energy** project provided an opportunity for 546 youth to learn about an alternative energy source.

The **Illinois Energy Education Council**, a cooperative effort of University of Illinois Extension and the investor-owned electric utilities, rural electric cooperatives, and municipal power suppliers, continued to promote their website as a source of information to increase energy efficiency through presentations, videos, games, and links. Extension also worked with the Smart Energy Design Assistance Center on campus to discuss a pilot project to partner in educating the public about the new smart grid infrastructure and alternative pricing programs in certain regions of the state.

2. Brief description of the target audience

Members of the target audience included academic researchers, policy makers, farmers, feedstock producers, potential biomass processors, biomass feedstock researchers, microbial ecologists and researchers interested in biological nitrogen fixation in non-legumes, plant breeders who wish to develop improved cultivars of Miscanthus for bioenergy, undergraduate horticulture students and students

interested in bioenergy, graduate students working in bioenergy, producers, researchers, and government employees interested in biomass feedstocks, sod growers, athletic field, golf turf, and lawn care managers, homeowners, plant breeders, ecologists, ethanol producers, starch producers, commodity associations, researchers involved with fouling phenomena, cleaning chemical suppliers and equipment suppliers, conservation biologists, wildlife ecologists, agronomists, and land managers. Extension targeted crop producers, public officials, agency employees, electricity providers, individuals and families who wish to reduce energy consumption and expenses, and youth.

3. How was eXtension used?

Two Extension staff members are members of the Sustainable Agriculture Energy or Wood Energy eXtension Communities of Practice.

V(E). Planned Program (Outputs)

1. Standard output measures

2014	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	3513	1811	651	0

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

Patent Applications Submitted

Year:	2014
Actual:	3

Patents listed

TF 11147-US [Xylitol production From Cellulosic Biomass] and TF 13135-PRO [Separation Process of Oil and Sugars From Biomass]. Issued Patents: 8,518,467 [Fiber Separation From Grain Using Elusive Process].

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2014	Extension	Research	Total
Actual	0	45	45

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number Of Completed Hatch Projects

Year	Actual
2014	2

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Number Of Program Participants Increasing Knowledge Of Bio-Energy Production/Harvesting/Storage Systems
2	Determination Of The Components Which Increase Evaporator Fouling Rates
3	The Development Of A Protocol To Rapidly Estimate Variation In Miscanthus Cell Wall Composition
4	Developing A Welfare Economic Framework To Analyze Fuel Policy Choices In Brazil
5	Quantifying The Contribution Of Nitrogen-Fixing Bacteria To Miscanthus Plant Nitrogen
6	Practice Changes To Reduce Energy Use And Energy Costs

Outcome #1

1. Outcome Measures

Number Of Program Participants Increasing Knowledge Of Bio-Energy Production/Harvesting/Storage Systems

Not Reporting on this Outcome Measure

Outcome #2

1. Outcome Measures

Determination Of The Components Which Increase Evaporator Fouling Rates

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)

As the biofuels industry grows, efficient utilization of water and recovery of nutrients will become increasingly important. In the U.S., 175 fuel ethanol plants are in operation and 25 plants are under construction; nearly all of these plants use corn, an important crop for Midwestern states. Plant capacities range from 40 to 120 million gallons of ethanol per year. Fuel ethanol plants use multi-effect evaporators to concentrate thin stillage. Evaporators must be cleaned every week or two, resulting in economic and capacity losses. Labor and chemical costs are incurred to clean the evaporators, a plant must reduce processing or shut down entirely during cleaning, and additional evaporator capacity must be installed if the plant wants to continue operating during cleaning. Cleaning procedures add water to the process, and water and cleaning chemicals must be routed appropriately. When processing difficulties arise [such as during poor fermentation or incomplete liquefaction] evaporators can be expected to foul more rapidly. Separation processes upstream from the evaporator affect its efficiency. Process designs to produce valuable coproducts also affect process efficiency and long-term sustainability. As the biofuels industry grows and matures, long-term economic operations will become increasingly important and impact the communities where they are located. Developing new uses and, more importantly, higher value for coproduct solids in process streams is needed to retain bioprocessor

competitiveness and can be accomplished through new process designs, incorporation of new technology, or a combination of both.

What has been done
The most common separation process in grain processing is the separation of water from other agricultural solids. This results in primary products and coproducts that can safely and efficiently be stored and transported. Evaporator fouling is a common, chronic problem during maize starch and ethanol production. To compensate for the consequences of fouling, capital costs are increased, operating costs are incurred, and environmental impact is increased. Despite these issues, fundamental causes of increased fouling in maize processes are not well understood. The objective of this research is to develop a better understanding of the components that accelerate fouling in maize processing evaporators.

Results
For model systems [simple mixtures with known compositions], we now have a better understanding of the components that accelerate fouling or have a small impact by themselves. Pure starch mixtures had higher mean fouling rates, higher maximum fouling resistances, and no induction periods. Addition of glucose and corn syrup solids to starch decreased mean fouling rates and maximum fouling resistances, contrary to our hypothesis. Maximum fouling resistances were dependent on overall carbohydrate polymer length. Fouling rates increased in the order: 1% starch > 1% starch + 6% corn syrup solids > 1%starch + 3% corn syrup solids + 3% glucose > 1% starch + 6%glucose. Induction periods [initial time with no fouling resistance] of pure mixtures of either glucose or corn syrup solids were longer than a pure starch mixture which had no induction period. Mixtures containing shorter chain carbohydrates, glucose, and corn syrup solids did not cause fouling either alone or in combination during the 5 hour test period.

4. Associated Knowledge Areas

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

Outcome #3

1. Outcome Measures

The Development Of A Protocol To Rapidly Estimate Variation In Miscanthus Cell Wall Composition

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)
The Energy Independence and Security Act [EISA] of 2007 calls for 36 billion gallons/year of biofuels by 2022 to reduce national dependence on foreign oil [of which about 21 billion gallons are to be from sources such as lignocellulosic biomass]. New dedicated energy crops are essential to provide lignocellulosic biomass to meet targeted demands for biofuels production in addition to corn grain and stover. A number of annual and perennial C4 grasses and herbaceous crops and trees [such as Miscanthus, switchgrass, willow, and sweet sorghum] are currently identified as potential sources of lignocellulosic biomass. Rapid determination of biomass composition is critical for the screening and selection of Miscanthus genotypes with properties suitable for conversion to bioenergy, biofuels, and renewable chemicals. Variation in Miscanthus biomass composition can be used to identify and breed for superior germplasm with enhanced lignocellulosic properties conducive to bioenergy and renewable chemical generation.

What has been done
Information on genome size, ploidy level, and genomic polymorphisms among accessions of the genus Miscanthus can assist in taxonomic studies, help to better understand the evolution of the genus, and provide valuable information to biomass crop improvement programs. Taxonomic investigation combining variation in plant morphology, genome size, chromosome numbers, and simple sequence repeat [SSR] marker polymorphisms were applied to characterize 101 Miscanthus accessions. A total of 258 amplicons generated from 17 informative SSR primer pairs were subjected to cluster and principal coordinate analysis and used to characterize genetic variation and relationships among 31 Miscanthus accessions, including four interspecific Miscanthus hybrids created from controlled pollinations, and four Saccharum, six Erianthus, and one Sorghum bicolor accessions. Miscanthus accessions were distinct from accessions in the genera Erianthus and Saccharum Miscanthus accessions fell into five taxonomic groups, including the existing taxonomic section Miscanthus, diploid and tetraploid Miscanthus sacchariflorus, and a fourth [M. x giganteus] and fifth group [Miscanthus 'purpurascens']; the last two being intermediate forms. In contrast to previous work, our findings suggest diploid and tetraploid M. sacchariflorus are taxonomically different, the latter more closely related to M. sacchariflorus var lutarioriparius. We also suggest that Miscanthus 'purpurascens' accessions are interspecific hybrids between Miscanthus sinensis and diploid M. sacchariflorus based on DNA content and SSR polymorphisms. The evolution of Miscanthus and related genera is discussed based on combined analysis and geographical origin.

Results
In light of rising energy costs, lignocellulosic ethanol has been identified as a renewable alternative to petroleum-based transportation fuels. In an attempt to reach government mandated ethanol production levels, potential plant biofeedstock candidates have been investigated, and cold-tolerant, perennial accessions within the C4 grass genus Miscanthus have been identified as leading contenders in the Midwestern U.S. To facilitate the development of improved cultivars through marker-assisted breeding, a quantitative trait locus [QTL] study was conducted on a full-

sib, F1 mapping population segregating for flowering time, height, leaf width, and yield using a genetic map consisting of 846 segregating SNP and SSR markers. This was a three year study investigating the genetic architecture underlying traits important to biomass production in a population of 221 progeny from a cross between M. sinensis 'Grosse Fountaine' and M. sinensis 'Undine' established in the spring of 2010; 72 QTLs with LOD scores above the genome-wide, permuted threshold equivalent to a P-value of 0.05 were identified across 13 traits. Of the 36 QTLs identified in 2011, 22 were detected again the following year. Both the use of spring emergence and vigor rating as a covariate to account for variation related to differences in establishment increased the power to detect QTLs in the two-year establishment period. Finally, a dry period in the middle of the 2012 growing season suggested that yield declines were due to a decrease in tiller diameter.

4. Associated Knowledge Areas

KA Code	Knowledge Area
133	Pollution Prevention and Mitigation
201	Plant Genome, Genetics, and Genetic Mechanisms
206	Basic Plant Biology
601	Economics of Agricultural Production and Farm Management

Outcome #4

1. Outcome Measures

Developing A Welfare Economic Framework To Analyze Fuel Policy Choices In Brazil

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)
Our research on Brazil has focused on developing a welfare economic framework to analyze the rationale for the fuel policy choices in Brazil and the trade-offs they have engendered in the fuel and sugar sectors.

What has been done
We also examined their distributional impacts on producers and consumers in the sugar, oil and biofuel sectors and on government revenues. Additionally, we have undertaken a normative analysis for the purpose of comparing the welfare and environmental impacts of existing policies with those justified by the goal of maximizing social welfare and addressing market failure.

Results
We find that the status quo policies are likely to have been motivated by the objectives of increasing oil exports, raising government revenue, and promoting rural development through the sugarcane sector and have had a significant adverse impact on fuel and sugar consumers, aggregate social welfare, and greenhouse gas emissions in Brazil.

4. Associated Knowledge Areas

KA Code	Knowledge Area
601	Economics of Agricultural Production and Farm Management
803	Sociological and Technological Change Affecting Individuals, Families, and Communities

Outcome #5

1. Outcome Measures

Quantifying The Contribution Of Nitrogen-Fixing Bacteria To Miscanthus Plant Nitrogen

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)
Plant productivity is often limited by the availability of nitrogen, and application of nitrogen fertilizer can account for a major portion of fossil fuel use in agricultural systems. Because nitrogen fertilizers are primarily derived from fossil-fuel intensive processes, low-N fertilizer inputs are especially important for the sustainability of bioenergy crops such as Miscanthus. Nitrogen-fixing bacteria have demonstrated the capacity to supply significant levels of biologically-fixed nitrogen in some non-leguminous crops; however, we currently lack information on the factors that govern

the abundance and activity of these beneficial microbes in perennial grasses.

What has been done
To fulfill our objective of quantifying the contribution of nitrogen-fixing bacteria to Miscanthus plant N, we conducted a field experiment to estimate the contribution of biological nitrogen fixation to plant nitrogen acquisition in first year Miscanthus × giganteus using a yield-dependent N-15 isotope dilution model. Temporal changes in plant-associated diazotroph relative abundance and community composition were analyzed with quantitative PCR and terminal restriction fragment length polymorphism of the nifH gene in rhizome and rhizosphere DNA extracts.

Results
We estimate that 16% of new plant nitrogen was derived by nitrogen fixation during the growing season, despite non-limiting soil nitrogen. Diazotroph communities from rhizome and rhizosphere changed with plant development and endophytic nitrogen fixers had significantly higher relative abundance and altered community composition at sampling dates in July and August. This study provides evidence for a small, but measurable, benefit of associative nitrogen fixation to first year Miscanthus × giganteus that underscores the potential and need for selection of breeding lines that maximize this trait.

4. Associated Knowledge Areas

KA Code	Knowledge Area
201	Plant Genome, Genetics, and Genetic Mechanisms
206	Basic Plant Biology

Outcome #6

1. Outcome Measures

Practice Changes To Reduce Energy Use And Energy Costs

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Action Outcome Measure

3b. Quantitative Outcome

Year	Actual
2014	22

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Sustainable energy is a concern of consumers as well as environmentalists and scientists who are seeking identifiable and cost-effective renewable energy sources. Consumers of energy who recognize the challenge would also like to lower their energy costs.

What has been done
Three Extension Educators with assigned responsibilities in natural resources and the environment have developed and delivered 10 Reducing Energy Costs in Your Home programs to more than 200 home owners to share information on actions and options that can be taken to save costs as well as serving as responsible stewards of non-renewable energy sources.

Results
A follow-up 'post card survey' was developed and mailed to the 41 participants in two of the ten Reducing Energy Costs in Your Home groups of participants. Twenty-three [56%] of the participants returned the completed post card. Twenty-two of the 23 respondents [96%] reported that they continue to use home heating and cooling information taught/learned at the home energy program. Eighteen of 23 [78%] believe they realized an energy cost savings from applying this knowledge. Twenty of 23 [87%] would attend additional home energy cost reduction programs in the future.

4. Associated Knowledge Areas

KA Code	Knowledge Area
801	Individual and Family Resource Management

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations
- Competing Programmatic Challenges

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

A follow-up 'post card survey' was developed and mailed to the 41 participants in two of the ten **Reducing Energy Costs in Your Home** groups of participants. Twenty-three [56%] of the participants returned the completed post card. Twenty-two of the 23 respondents [96%] reported that they continue to use home heating and cooling information taught/learned at the home energy program. Eighteen of 23 [78%] believe they realized an energy cost savings from applying this knowledge. Twenty of 23 [87%] would

attend additional home energy cost reduction programs in the future.

Key Items of Evaluation