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	0%		15%	
201	Plant Genome, Genetics, and Genetic Mechanisms	0%		25%	
206	Basic Plant Biology	35%		25%	
402	Engineering Systems and Equipment	15%		20%	
601	Economics of Agricultural Production and Farm Management	15%		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: 2012	Extension		Research	
	1862	1890	1862	1890
Plan	3.0	0.0	6.0	0.0
Actual Paid Professional	0.0	0.0	1.9	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**
126516	0	705221	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
126516	0	705221	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
1187311	0	2512399	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Research activities included an examination of the use of glycerol as a biodiesel fuel additive or fuel extender, the establishment and nitrogen management of switchgrass for sustainable bioenergy feedstock production, experimentation which showed that additional glucose in thin stillage did not greatly accelerate fouling rates [a widely held belief in the biofuels industry], research into selection of plant genetics, planting locations, harvest moisture and drying air temperatures to improve dry grind ethanol yields, chromosome engineering by inducing ploidy [this proved to be a valuable technique in improving biomass of plants], the compression of biomass to the highest pressure level ever reported on [we discovered that at this pressure level biomass can self-combust - this was the first time such a phenomenon was reported on], exploration of rapid methods [such as high resolution thermogravimetric analysis [HR-TGA], near-infrared [NIR], and Pyrolysis-GCMS] to improve and speed up the process for identifying and selecting Miscanthus genotypes with desirable composition, and the finding that modulation of shoot maturation via variation in activities of AP2 genes can achieve some of the beneficial aspects of faster dry-down and improved cell wall composition without the negative pleiotropic effects of more upstream regulators on biomass yields [a better understanding of the regulation of the shoot maturation pathway offers a novel opportunity to both better understand the control of desirable traits and may provide new strategies for Sorghum improvement via molecular breeding approaches].

Conference presentations included the American Society of Agronomy, Soil Science Society of America, Crop Science Society of America, AACC International, the American Institute of Chemical Engineers, and the 3rd Pan American Congress on Plants and Bioenergy.

The **Dudley Smith Initiative** continued to provide financial support to bring together area landowners, Extension field staff and University of Illinois specialists to conduct research and demonstrate practical solutions for growing miscanthus, switchgrass, and more recently tropical maize. The local Extension educator has continued to conduct presentations, tours, and field demonstrations at the Dudley Smith Farm. Presentations have also been made at other state educational institution events to describe the activities associated with biomass energy production including storage of baled biomass, land application of biochar residue from burned biomass, and marketing strategies for biomass. A display and demonstration focused on the gasification test unit that operates on corn crop field residue was prepared and operated by Extension staff at the Farm Progress Show and campus annual Agronomy Day. In addition, an energy crop display was created for the Illinois State Fair.

Extension campus specialists and Extension field educators continued to support quarterly meetings of the **Illinois Biomass Working Group** that includes representatives from industry, entrepreneurs, and

agency representatives interested in building better networks to support innovative bioenergy systems and cross-listing activities with the Indiana Bioenergy Working Group based at Purdue. Extension is giving leadership to coordinating energy crop production with bioenergy processors with regional and international networks to expand cellulosic conversion technologies.

Other Extension sustainable energy activities included working with the Smart Energy Design Assistance Center [sponsored by the Illinois Department of Commerce and Economic Opportunity] to conduct energy audits to evaluate energy usage and identify opportunities for energy savings for buildings in three communities and collaboration with the Illinois Wind Energy Working group to sponsor a **Wind 101 Landowner** series and webinar on wind energy siting issues for local county officials. 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 supplies, actively promoted their website as a source of information to increase energy efficiency that includes presentations, videos, games, and links. A total of 958 youth participated in 4-H energy projects and wind science experiments during the 2011-2012 4-H year.

2. Brief description of the target audience

Members of the target audience included biofuels researchers and users of diesel or biodiesel, producers of energy crops and local conservation groups, crop consultants, farm input suppliers, regional and national agriculture industries, state and national governmental agencies, plant genetics companies, corn processors, corn ethanol and biofuel producers, commodity and producer groups, university and government researchers and industries involved in supporting the biofuels sector, dry grind ethanol plants, growers interested in producing biomass feedstocks and industries involved in producing biomass plants and seeds, manufacturing biomass planting and harvesting equipment, and developing pest control products for biomass production, scientists involved in the development of lignocellulosic feedstocks for the production of renewable biofuels, and farmers and industry interested in the use of agricultural waste for biofuel production. Extension also targeted individuals and families who wish to reduce energy consumption and expenses, as well as youth.

3. How was eXtension used?

Five Extension staff are members of the Wood Energy, Home Energy, or Sustainable Ag Energy eXtension Communities of Practice.

V(E). Planned Program (Outputs)

1. Standard output measures

2012	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	6546	2669	6093	0

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

Patent Applications Submitted

Year:	2012
Actual:	5

Patents listed
TF11147-PRO - Xylitol Production From Cellulosic Biomass; TF10181-PRO - Xylose-Fermenting Microorganism; TF11160-PRO - Enhanced Cellodextrin Metabolism; TF11111-PRO - Improved Cellobiose Fermentation Using A Mutant HXT2.4 [A219D] From Scheffersomyces Stipitis; TF12043-PRO - New Prairie Cordgrass [Spartina Pectinata] Cultivar 'Savoy' For A Bioenergy Feedstock Production

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2012	Extension	Research	Total
Actual	0	48	48

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number Of Completed Hatch Projects

Year	Actual
2012	5

V(G). State Defined Outcomes

V. State Defined Outcomes Table of Content

O. No.	OUTCOME NAME
1	Proportion Of The Use Of Biomass Relative To Total Energy [Currently At 4-5%]
2	Percent Reduction In NOx Emissions From Biodiesel
3	Increased Knowledge Of Current And Future Energy Source Options
4	Number Implementing Recommended Practices To Reduce Energy Use
5	Determination And Development Of Management Practices For Sustainable Biomass Feedstock Production
6	Determination Of The Components Which Increase Evaporator Fouling Rates
7	The Development Of A Protocol To Rapidly Estimate Variation In Miscanthus Cell Wall Composition
8	Improved Understanding Of The Regulation Of The Shoot Maturation Pathway Of Sorghum

Outcome #1

1. **Outcome Measures**

   Proportion Of The Use Of Biomass Relative To Total Energy [Currently At 4-5%]

   Not Reporting on this Outcome Measure

Outcome #2

1. **Outcome Measures**

   Percent Reduction In NOx Emissions From Biodiesel

   Not Reporting on this Outcome Measure

Outcome #3

1. **Outcome Measures**

   Increased Knowledge Of Current And Future Energy Source Options

   Not Reporting on this Outcome Measure

Outcome #4

1. **Outcome Measures**

   Number Implementing Recommended Practices To Reduce Energy Use

   Not Reporting on this Outcome Measure

Outcome #5

1. **Outcome Measures**

   Determination And Development Of Management Practices For Sustainable Biomass Feedstock Production

2. **Associated Institution Types**

   - 1862 Extension
   - 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2012	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The goal of this research is to determine and develop management practices for sustainable biomass feedstock production. During 2012, research activities were focused on determination of long-term effects of N fertilization and harvest timing on switchgrass biomass production and of corn-switchgrass companion cropping effects on switchgrass establishment. The field research was continued from previous research trials, which were established during 2009 and 2010, respectively. For the management study, switchgrass biomass was harvested either at peak standing crops, after a killing frost, or over winter for the growing season of 2010 and 2011. For the establishment study, switchgrass biomass was harvested after a killing frost in November 2010 through 2012.

What has been done
The switchgrass and corn companion cropping trial demonstrated the potential benefits of corn as a nursery crop during switchgrass establishment. This companion cropping research also provided optimum nitrogen fertilization and corn-seeding rates for both corn grain yield and switchgrass establishment. The replicated study during 2009 through 2012 indicated that the second year switchgrass biomass production under a corn-switchgrass companion system was very comparable to a switchgrass monoculture while corn grain yield was maintained. The results also indicated the importance of nitrogen fertility. The switchgrass nitrogen study showed the importance of nitrogen fertilization on switchgrass biomass production. The switchgrass biomass responses to nitrogen fertilization were highly correlated with soil fertility levels and previous cropping history. A continuous nitrogen fertilization study in multiple locations in conjunction with harvest timing will be necessary for future biomass feedstock production of switchgrass.

Results
2012 was the third growing season after establishment and we were able to evaluate biomass productivity of switchgrass depending on management practices including seeding rate, cultivars, nitrogen fertility, and harvest timing and frequency. These data will be very useful for local producers who are looking for switchgrass as an alternative energy crop for their cropping system. During 2012, research output of switchgrass feedstock production in Illinois has been presented to producers and commercial industries through field day and crop management conference events throughout the state. Currently, we are compiling three-year field data to publish on the effects of nitrogen fertility and harvest timing on switchgrass biomass yield and stand consistency.

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 #6

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
2012	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
All commercial biofuel plants use multi-effect evaporators to remove water from processing streams. Proteins, carbohydrates, fats, ash and fiber in corn thin stillage are involved in evaporator fouling. It is not understood which components increase fouling rates. Costs associated with fouling include labor and equipment needed to clean fouled heat transfer surfaces, increased capital, antifoulant chemicals and production losses.

What has been done
Effects of starch [STA] and sucrose [SUC] composition in a synthetic thin stillage fluid on fouling resistance were studied. Effects of total solids [TS] content [1 to 10% db] on fouling resistance [Rf] were also studied. Fluid flow was turbulent [Re > 4000] for synthetic thin stillage with 1% TS and was constant, irrespective of starch:glucose [STA:SUC] ratio. Rf for synthetic thin stillage with 5 and 10% TS and having various STA:SUC ratios was laminar and ranged from 500 to 1,100. An annular probe was used to measure fouling tendencies of synthetic thin stillage and Rf was found at the end of 10 hours or until the probe temperature reached 170 C. Synthetic thin stillage with 5% TS and GLU only did not foul after 10 hours while 5% TS and STA only reached the maximum probe temperature, 170 C, in 4.2 hours. Synthetic thin stillage with 10% TS and STA:SUC of 1:9 did not reach the maximum probe temperature by the end of the test period. For 1, 5 and 10% TS, Rf increased mainly because of the starch present in synthetic thin stillage, while sucrose had a smaller effect on Rf. Higher concentrations of starch in synthetic thin stillage shortened the time to reach the maximum probe temperature.

Results
Understanding from the biofuels industry is that sucrose and other sugars alone cause fouling. Inferring from these results, starch or other sugars must interact with thin stillage components to increase fouling. Additional experimentation showed that additional glucose in thin stillage did not greatly accelerate fouling rates, another widely held belief in the biofuels industry. Additional work will investigate the influence of other compounds on thin stillage and model fluid systems.

4. Associated Knowledge Areas

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

Outcome #7

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
2012	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The goal of this project is the development of a protocol to rapidly estimate variation in cell wall composition among genotypes of the dedicated bioenergy crop Miscanthus

What has been done
The goal of this study was to accelerate the process of screening biomass of approximately 40 accessions of Miscanthus germplasm for desirable end use in various biofuels processes with the following objectives: [1] sample selection and preparation; [2] generation of compositional information on Miscanthus genotypes; and [3] screening Miscanthus samples using generated data to determine composition. 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. HR-TGA provides composition information in terms of cellulose, hemicellulose and lignin. Pyrolysis-GCMS gives more detailed compositional analysis for generation of high-value chemicals and biofuels, requires only a minute amount of

samples, and has low labor requirements. NIR spectra were used for partial least squares [PLS] modeling using TGA-derived compositional data. Correlations between NIR and HR-TGA appear to be sufficiently robust such that rapid NIR analysis can be used to predict cell wall composition.

Results
Classical wet chemistry methods are time consuming; to improve and speed up the process for identifying and selecting Miscanthus genotypes with desirable composition, rapid methods like high resolution thermogravimetric analysis [HR-TGA], near-infrared [NIR], and pyrolysis-GCMS methods were explored in this study. FT-NIR [Fourier transform near-infrared] models were developed to predict biomass composition [cellulose, hemicellulose and lignin] using 40 Miscanthus samples with known composition from wet chemistry methods. Although the correlation coefficient [R-sq] obtained for cellulose [0.952], hemicellulose [0.964], and lignin [0.955] were higher, addition of more samples will make these models more robust. For this purpose, the TGA method was used to generate compositional information in terms of cellulose, hemicelluloses, lignin, ash and moisture. NIR spectra were used for partial least squares [PLS] modeling using TGA-derived compositional data. R-sq values obtained for cellulose, hemicellulose, lignin and ash in the calibration set are 0.99, 0.985, 0.999, and 0.996 respectively, while for the validation set, values were 0.715, 0.834, 0.751, and 0.977 respectively. Pyrolysis-GCMS provided more detailed compositional analysis for generation of high-value chemicals and biofuels through thermo-chemical conversion of biomass samples. Our data suggest that we have geneated a dataset that will provide a robust predicition of cell wall composition from rapid NIR analysis of samples.

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 #8

1. Outcome Measures

Improved Understanding Of The Regulation Of The Shoot Maturation Pathway Of Sorghum

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual

2012	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
This project brings together scientists with expertise in maize shoot maturation genes, sorghum genetics and sorghum biotechnology to pursue the following three research objectives: [1] to characterize the DNA sequences and expression of genes regulating shoot maturation in sorghum; [2] to investigate the contribution of natural variation in shoot maturation pathway genes to traits that distinguish sweet, forage and grain sorghum cultivars; and [3] to build upon proof-of-concept studies in maize by modifying Glossy15 activity in grain sorghum cultivars and evaluation of biomass and fermentable carbon yields with low N fertilizer inputs.

What has been done
Prior work has established that overexpression of the maize Glossy15 gene delays shoot maturation in a dosage-dependent manner. These Glossy15 overexpressing [Gl15-OX] lines exhibit delayed flowering and senescence, but also increases in total biomass and stem sugar concentrations. Importantly, field trials demonstrated that maize Gl15-OX hybrids maintain high biomass yield potential in low nitrogen soils, indicating an unexpected advantage in nitrogen use efficiency. Our third objective is to extend these findings to sorghum by increasing activity of the sorghum Glossy15 gene [SbGl15].

Results
Modulation of shoot maturation via variation in activities of AP2 genes can achieve some of the beneficial aspects of faster dry-down and improved cell wall composition without the negative pleiotropic effects of more upstream regulators on biomass yields. A better understanding of the regulation of the shoot maturation pathway offers a novel opportunity to both better understand the control of desirable traits and to develop new strategies for Sorghum improvement via molecular breeding approaches.

4. Associated Knowledge Areas

KA Code	Knowledge Area
133	Pollution Prevention and Mitigation
201	Plant Genome, Genetics, and Genetic Mechanisms
206	Basic Plant Biology

V(H). Planned Program (External Factors)

External factors which affected outcomes

- Economy
- Appropriations changes
- Public Policy changes
- Government Regulations

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

No formal evaluation of Extension programs was conducted this year but will be conducted in the future.

Key Items of Evaluation