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%		20%	
206	Basic Plant Biology	35%		20%	
402	Engineering Systems and Equipment	15%		20%	
601	Economics of Agricultural Production and Farm Management	10%		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: 2013	Extension		Research	
	1862	1890	1862	1890
Plan	3.0	0.0	6.0	0.0
Actual Paid Professional	0.0	0.0	3.6	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**
128158	0	753705	0
1862 Matching	**1890 Matching**	**1862 Matching**	**1890 Matching**
128158	0	753705	0
1862 All Other	**1890 All Other**	**1862 All Other**	**1890 All Other**
672284	0	3411431	0

V(D). Planned Program (Activity)

1. Brief description of the Activity

Activities included work to improve our understanding of enzyme and yeast behavior with the goal of improving ethanol plant productivity and reducing energy inputs during ethanol production, an experiment focusing on determining sustainable practices for the establishment and nitrogen management of switchgrass for biomass feedstock production, an examination of seed germplasm of black locust as a potential bioenergy feedstock crop from Afganistan, Iran and Uzbeckistan [seedlings were produced from these seeds and are being grown in the field for evaluation of resistance to common problems found in U.S. seed populations], the use of replicated, experimental micro-landscapes to assess how animal movements are affected by biofuel crops [our focal species is the meadow vole, a grassland species that is absent from current row-crop agriculture in the Midwest region], a project with the objective of quantifying the contribution of nitrogen-fixing bacteria to Miscanthus plant nitrogen and identifying plant and microbial traits and environmental factors that influence diazotroph colonization and activity [understanding factors that influence plant-microbe mutualisms will allow for the optimization of associative N fixation in perennial grasses and thereby enhance sustainability of these bioenergy crops], an examination of biofuel production strategies from cereal grains and various processing byproducts, the development of baseline data on the implications of using different feedstocks for biofuel production, research to improve our understanding of components that accelerate fouling in maize processing evaporators, work to quantify the roles of genetic and transgenetic maize improvement on plant mineral nutrient use, the breeding of Miscanthus cultivars with improved winterhardiness and high yield-potential in the central and northern Midwest, and the development of near-infrared [NIR] spectroscopy as an inexpensive and high-throughput method for evaluating quality characteristics of Miscanthus genotypes.

Conference presentations included the Energy Bioscience Institute Retreat and Energy Farm Tour, EBI Feedstocks Symposium, American Chemical Society, World Congress on Industrial Technology, Cluster of Excellence in Plant Sciences, 2nd Workshop on Genetics of Maize-Microbe Interactions, Ecological Society of America, American Seed Trade Association's Corn and Sorghum Seed Research Conference, XV National Congress of Plant Biochemistry and Molecular Biology, International Heat Exchanger Fouling and Cleaning, American Institute of Chemical Engineers, American Society of Agronomy, Crop Science Society of America, and the Soil Science Society of America.

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 [such a tropical maize] utilization using a farm-scale model to improve biomass harvesting methods and develop utilization strategies and services to provide inventories of harvestable

biomass for national efforts to reduce nutrient run-off and match crop nutrient requirements with crop production goals with fragile or impaired waters and watershed areas. Field days and tours have reached over 400 adults in the past two years. In addition, an energy crop display was created for the Illinois State Fair. A multi-state project is underway involving biomass bale transfer to a biomass research and development site in North Carolina to provide heat and power to large commercial poultry production facilities. That effort will have a direct relationship on improving practices that reduce phosphorus nutrient loads due to land application of manure and fertilizer run-off.

Extension campus specialists and Extension field educators continued in coordination with other campus institutions to support applied research and outreach education with respect to biomass heat and power. This past year Extension staff have become involved with Illinois Department of Transportation [IDOT] staff in a program to determine the feasibility of using roadside harvestable biomass as a fuel feedstock for regional and district IDOT maintenance facilities across the state. Extension has provided support to develop site identification and assessment, industry networks and contacts and appropriate renewable energy furnace systems availability, and capacity matching. Most recently this collaboration has brought support from the Governor's office and is a potential model for harvestable biomass combustion systems being considered for regional Illinois Department of Corrections facilities.

Other sustainable energy programming involved displays and demonstrations at the Illinois State Fair, Farm Progress Show and Southern Illinois Sustainability Expo reaching an estimated 1,000 attendees, as well as at the first regional Green Energy Business Summit that attracted 300 participants. Workshops were also conducted that addressed small wind, biomass, and solar power for homeowners. Interest in solar power re-emerged due to a drop in the cost of solar panels. 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. In addition, 507 youth were enrolled in the 4-H Wind Energy project.

2. Brief description of the target audience

Members of the target audience included the dry grind and cellulosic ethanol industries and allied companies such as seed, enzymes/biotech and equipment companies, basic scientists and production agriculturists interested in plant utilization for animal growth or production of value added products such as biofuels, energy grass producers, government officials, biomass conversion specialists, undergraduate and graduate students, producers of energy crops and local conservation groups, crop consultants, farm input suppliers, regional and national agriculture industries, state and national governmental agencies, green industries of the Midwest [including members of the nursery and landscape industries, botanical gardens and arboreta], conservation biologists, agronomists, sorghum breeders and producers, commodity groups, industry segments that support cereal grain processors, and farmers who wish to grow crops to meet U.S. renewable energy needs. Extension also targeted individuals and families who wish to reduce energy consumption and expenses, as well as youth.

3. How was eXtension used?

Two Extension staff are members of the Wood Energy and Home Energy Communities of Practice.

V(E). Planned Program (Outputs)

1. Standard output measures

2013	Direct Contacts Adults	Indirect Contacts Adults	Direct Contacts Youth	Indirect Contacts Youth
Actual	6637	4193	2428	0

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

Patent Applications Submitted

Year: 2013

Actual: 4

Patents listed

TF 07188-CON [Method of Producing Solvent in the Presence of Furfural and Hydroxymethyl Furfural]; TF 09115-DIV [Methods and Compositions for Improving Sugar Transport, Mixed Sugar Fermentation, and Production of Biofuels]; TF 10181-US [Xylose-Fermenting Microorganism]; and TF 12043-US [Prairie Cordgrass Cultivar 'Savoy' for Biofeedstock Production].

3. Publications (Standard General Output Measure)

Number of Peer Reviewed Publications

2013	Extension	Research	Total
Actual	0	35	35

V(F). State Defined Outputs

Output Target

Output #1

Output Measure

- Number Of Completed Hatch Projects

Year	Actual
2013	4

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 Sustainable Practices For The Establishment And Nitrogen Management Of Switchgrass For Biomass Feedstock Production
3	Quantification Of The Contribution Of Nitrogen-Fixing Bacteria To Miscanthus Plant Nitrogen
4	The Development Of Baseline Data On The Environmental Impacts Of Using Different Feedstocks For Biofuel Production
5	Understanding The Causes Of Evaporator Fouling In Maize And Ethanol Production Systems
6	Improving Yield Per Unit Of Nitrogen And Per Acre
7	An Examination Of The Land Use, Economic, And Environmental Implications Of Cellulosic Biofuel Production

Outcome #1

1. Outcome Measures

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

2. Associated Institution Types

- 1862 Extension

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2013	26

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Society is facing many choices related to renewable energy and University of Illinois Extension seeks to provide information that will assist in making informed decisions.

What has been done
Extension programming related to biomass energy production has focused on how renewables are produced on the land and how renewable energy crops are developed, introduced, utilized and often reinvented to provide immediate value to consumers and early adopters. This has been translated into working with farmer networks and other stakeholders to support their adoption of renewable energy research findings and to apply that new knowledge to their respective environments. Over 100 individuals have been involved as collaborators and stakeholders engaged in University of Illinois Extension biomass energy activities. In addition, 11 Illinois biomass industry collaborators have been engaged in biomass energy projects. Eleven programs were delivered with a biomass energy theme and they addressed biomass and nutrient management strategies, biomass energy feedstock safety net, biomass heat and power with small farm application, food, fuel, and fiber, woody biomass systems, and biomass and cover crop strategies reaching approximately 400 participants.

Results
An incomplete inventory of results of Extension demonstrations, exhibits, field days, workshops, tours, presentations and networking follows: [1] Biomass Energy Crops Production: Collaborator sites number 13 and include three sites for evaluating sugar extraction, three sites for collaborator field day demonstrations, five sites regionally distributed for end-use as combustion materials, and two sites for end-use of biomass crops as animal feed options. These activities are field-based and augment biomass energy crops produced on campus research sites; [2] Biomass Markets Partially Established: Illinois local and regional markets include six combustion trial sites, two sites for industrial trialed materials for adsorbent and bedding material, and a ChipEnergy

market site for densified biomass for heat and power and designer biochar feedstock. Contacts have also been made with three states that have markets for displacement of propane and furnace oil, production of feedstock-based combustion pellets, and power for a poultry facility using litter adsorbent and convertible through gasification; [3] Energy crops integrated with cover crops [maize and tropical maize with warm-season and cool-season perennials grasses] were demonstrated on two field sites; and [4] Renewable feedstock heat systems installed and associated with ongoing Extension supported programs [two have been installed and two more are in the planning stage].

4. Associated Knowledge Areas

KA Code	Knowledge Area
402	Engineering Systems and Equipment
601	Economics of Agricultural Production and Farm Management

Outcome #2

1. Outcome Measures

Determination Of Sustainable Practices For The Establishment And Nitrogen Management Of Switchgrass For Biomass Feedstock Production

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2013	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The goal of this experiment is to determine sustainable practices for the establishment and nitrogen management of switchgrass for biomass feedstock production. The specific objectives to achieve the goal will be: Study 1. Companion Cropping Corn in Switchgrass During Switchgrass Establishment Year: [1] To evaluate the productivity of corn and switchgrass during the year of establishment; and [2] To determine the effects of corn plant populations and N fertilization on switchgrass establishment and corn yield. Study 2. Nitrogen Fertility Management of Switchgrass for Sustainable Bioenergy Feedstock Production: [1] To determine nitrogen fertilizer application rate and source to maximize biomass production in different regions of Illinois; [2] To determine the effects of N application rates on feedstock quality; and [3] To determine the effects of harvest timing on switchgrass N response and stand longevity.

What has been done
Corn yields responded to nitrogen fertilization with the highest yields being achieved at the 224 kg N ha-1 for all seeding rates [48,000, 59,000, 69,000 [control] seeds ha-1]. There was no significant difference of corn yields among seeding rates except for the 48,000 seeding rate at 224 kg N ha-1 which was significantly lower than other treatments. Switchgrass was successfully established under companion cropping with corn and biomass yields increased from the second to third year. There was no significant difference of switchgrass biomass yields observed among different corn seeding rates. However, switchgrass biomass yields were lower in switchgrass and corn companion plots than in switchgrass control plots in which no corn was planted. The results of these two studies show that companion cropping switchgrass with corn can result in a successful switchgrass establishment. When doing a cost analysis on the amount of income generated from companion cropping and no companion crop, companion cropping yields a higher gross income than the control. Depending on the end use of the field, companion cropping switchgrass with corn may be a desirable method for switchgrass establishment.

Results
Switchgrass biomass yield responses to N-application rates were highly variable for all soil types and climatic conditions based on this study. In general, however, lower N fertilizer application rates achieved maximum biomass yields as harvest timings were successively delayed. There were no significant differences in biomass yield between urea and slow-release Environmentally-Smart Nitrogen [ESN], except under conditions where N loss from the soil is likely. Applying ESN also increased the nitrogen content in the harvested biomass, which is an undesirable characteristic of a bioenergy feedstock. The results of this experiment showed that although yield reductions occurred with delayed harvest timing, the quality of the biomass improved the most when harvest was delayed until late winter or early spring. If fermentation to biofuels is the goal, a late-fall harvest is recommended to take advantage of higher biomass yield, relatively higher cellulose and hemicellulose concentrations, and relatively lower protein and ash concentrations. Conversely, early spring harvest may be the best option if thermochemical processing is the goal, or if storage and transportation issues with moisture content are most important.

4. Associated Knowledge Areas

KA Code	Knowledge Area
133	Pollution Prevention and Mitigation
206	Basic Plant Biology
601	Economics of Agricultural Production and Farm Management

Outcome #3

1. Outcome Measures

Quantification Of 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
2013	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
Our objective in this research is to quantify the contribution of nitrogen-fixing bacteria to Miscanthus plant N, and to identify plant and microbial traits and environmental factors that influence diazotroph colonization and activity. Understanding the factors that influence plant-microbe mutualisms will allow for the optimization of associative N fixation in perennial grasses, and thereby enhance sustainability of these bioenergy crops. We hypothesize that the efficiency of plant-microbe mutualisms will vary as a function of microbial community structure and environmental conditions. We further hypothesize that the efficiency of such mutualisms varies among plant species or genotypes. Nitrogen efficiency is important for the sustainability of crops, and especially critical for biofuel feedstocks. Improving our understanding of the biological mechanisms governing beneficial associations between gramineous bioenergy crops and nitrogen-fixing bacteria has the potential to enhance the sustainability of biofuel feedstocks. We are currently in the early stages of breeding perennial grasses for use as bioenergy feedstocks, making this a key time to evaluate the sustainability and N efficiency of these crops. There is relatively little information on how plant genetic variation affects diazotroph associations and natural N fixation. However, our preliminary data indicates that plant genetics play an important role. Thus, the results of this study are expected to facilitate efforts to breed Miscanthus for improved efficiency of plant-microbe interactions.

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 on mature Miscanthus plant during its growing season using an N-15 isotope dilution approach. A total of ten sample collecting time points were made for five replicated fields during the experimental period. Total plant available nitrogen, N-15 labeled plant available nitrogen in bulk soil, and the accumulation of N-15 labeled nitrogen in plant tissue were monitored during the experiment. Nitrogen-fixing bacteria community from rhizosphere and endosphere of Miscanthus plant were also collected at each sampling time. So far, we finished measuring the total and N-15 labeled plant available nitrogen in bulk soil. The rest of the samples are still under processing. For work focusing on identifying important ecological drivers and environmental factors, identical M. × giganteus rhizomes cultivated in four field sites in NE, KY, IL, and NJ were collected for microbial analysis after three years of cultivation. Our data indicated that local soil edaphic factors had great influence on the diazotroph assemblage in rhizosphere, and less influence on the endosphere community. Despite differences in regional microbial species pools, the same Miscanthus genotype selects for specific assemblages of endophytic diazotrophs. Surprisingly, although the total soil nitrogen affected the richness and diversity of the diazotrophs in endosphere to some extent, the microbial assemblage seemed to receive little

influence from the artificial nitrogen fertilization.

Results
Our 20-week greenhouse experiment using four different Miscanthus genotypes indicated that different Miscanthus genotypes tend to recruit different diazotroph species from the bulk soil. Using 454-generated nifH sequences, we are able to identify the main diazotroph species that reside inside the plant tissue and rhizosphere soil, and also we identified OTUs that respond to different Miscanthus genotypes. We will continue to analyze the results from a large sequencing project and evaluate the Miscanthus associated microbiome as a function of plant genotype. As samples from our large N-15 isotope dilution experiment are processed, we will be able to quantify N fixation in mature Miscanthus.

4. Associated Knowledge Areas

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

Outcome #4

1. Outcome Measures

The Development Of Baseline Data On The Environmental Impacts Of Using Different Feedstocks For Biofuel Production

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2013	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
The primary accomplishment of this project was to provide baseline data on the implications of using different feedstocks for biofuel production. Miscanthus in particular is a new candidate feedstock in the Midwest.

What has been done
For birds, the primary factors to consider are what is attracted to a given cover type and, during the breeding season, how successful the species are that attempt to nest. Simply counting

'species seen' is rarely sufficient since viability of constituent populations depends on breeding success. For miscanthus, the results are clear that it offers poor habitat for wildlife and birds in particular. On the other had, switchgrass appears to offer suitable habitat for breeding of selected grassland birds.

Results
Given that grassland-dependent species in the Midwest have declined more than any other habitat group, these data are important if acreage devoted to feedstocks increases. Of particular interest is land that is marginal for rowcrop production but beneficial to wildlife when grass is present [for example, under a CRP contract]. If marginal land is converted to feedstock production the type of feedstock and tillage practice will have important implications. Largescale conversion to Miscanthus will likely have advere effects, but other options such as switchgrass will help to maintain widlife populations in the region. Data for these types of decisions are a primary accomplishment of this project.

4. Associated Knowledge Areas

KA Code	Knowledge Area
136	Conservation of Biological Diversity
206	Basic Plant Biology

Outcome #5

1. Outcome Measures

Understanding The Causes Of Evaporator Fouling In Maize And Ethanol Production Systems

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2013	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
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, productivity is reduced and environmental impact is increased. Despite these issues, fundamental causes of increased fouling in maize processes are not understood. Process streams are biological in origin and have variable compositions. The objective was to develop an

improved understanding of components that accelerate fouling in maize processing evaporators.

What has been done
Two experiments were performed with commercial and model processing streams. In the first experiment, we used model materials [starch and sucrose] to study fouling characteristics of streams having well defined compositions. In a second experiment, commercial thin stillage samples were treated by adding carbohydrate materials [starch and sucrose] and tested in a fouling rig to simulate variation in composition.

Results
In the first experiment, sucrose had smaller effects than granular starch on heat transfer fouling. In the second experiment, inclusion of granular starch in thin stillage increased the rates of fouling. These introductory results have broad implications on process strategies. In model thin stillage, the fouling resistance increased with increased starch concentration. Higher levels of starch in model thin stillage shortened time needed to reach 170°C. Model thin stillage containing only sucrose did not foul during ten hours of testing. In model thin stillage, there was a larger effect on fouling tendencies from starch content than sucrose content. With increased starch levels in thin stillage, the rates of fouling were increased.

4. Associated Knowledge Areas

KA Code	Knowledge Area
133	Pollution Prevention and Mitigation
206	Basic Plant Biology
601	Economics of Agricultural Production and Farm Management

Outcome #6

1. Outcome Measures

Improving Yield Per Unit Of Nitrogen And Per Acre

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2013	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)

Improving the amount of yield produced per unit of N and per acre [NUE] is a complex problem requiring an understanding of the genes and metabolic pathways involved. The impact of sustainable modern maize crop production practices, including fertilizers, fungicides, populations, tillage, and stover management, will be evaluated for maize plants grown for grain yield or high-biomass varieties for renewable bioenergy and biofuels. The major goals of this project are to determine the mechanisms regulating photosynthate partitioning and carbon partitioning engineering and to analyze the limitations to photosynthetic productivity caused by environmental factors.

What has been done

Understanding the interaction of environmental, genetic, and management factors in altering light interception, photosynthesis, and corn productivity is needed to feed a growing world population. Work in 2013 helped to quantify the roles of genetic and transgenetic maize improvement on plant mineral nutrient use, the need for higher plant populations to optimize biomass production and corn yield, and the ability to use tropical maize hybrids as a biomass and sugar source for bioethanol production. Specific results included determining that when corn is grown continuously in the same field, year-after-year, the productivity is especially hindered by hot, dry weather, limiting nitrogen availability, and further hindered by accumulated corn residue. Additionally, we learned that some modern, transgenic corn-rootworm protected [Bt] maize hybrids have increased biomass and grain accumulation that is accompanied by increases in N,P, K, S, and Zn in the grain. The yield-responsive Bt hybrids had double the phosphorous and biomass accumulation during mid-grain fill than their traditional counterparts. The results of these experiments may lead to a re-evaluation of fertilizer levels and production environments necessary for maximum grain yields.

Results

We have obtained much needed data on the nutrient uptake and partitioning of current hybrids, which will provide an opportunity to further refine fertilizer method and timing recommendations for maize biomass and grain production. We also learned that in favorable environments, transgenic corn-rootworm protected hybrids not only produce more total biomass and yield, but also maintain greater nutrient and photosynthate aquisition during grain filling. We have also learned that the response of grain yield to fertilizer nitrogen in current hybrids is more dependent on uptake of fertilizer nitrogen than the efficiency of fertilizer nitrogen utilization, and approximately two-thirds of genetic gain [over the decades] for grain yield at high nitrogen fertilizer can be explained by improvements in grain yield at low nitrogen. We also learned that the primary causative agents of the continuous corn yield penalty are nitrogen availability, corn residue accumulation, and weather.

4. Associated Knowledge Areas

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

Outcome #7

1. Outcome Measures

An Examination Of The Land Use, Economic, And Environmental Implications Of Cellulosic Biofuel Production

2. Associated Institution Types

- 1862 Research

3a. Outcome Type:

Change in Knowledge Outcome Measure

3b. Quantitative Outcome

Year	Actual
2013	0

3c. Qualitative Outcome or Impact Statement

Issue (Who cares and Why)
This project will examine the land use, economic, and environmental implications of cellulosic biofuel production in the U.S., including the effects of biofuel production on food and fuel production and prices and on greenhouse gas emission mitigation under various policy scenarios.

What has been done
We developed a numerical simulation model to analyze the economic and environmental potential of using various types of cellulosic feedstocks for bioenergy production. We developed a framework to investigate the economic incentives for landowners to switch from growing an annual crop to growing energy crops.

Results
We found: [1] Carbon taxes would cause a significant increase in nitrogen use in association with a shift from petroleum to biofuels, and that a second-best carbon pricing policy would stop short of a first-best price in order to moderate the impacts on carbon; [2] The Renewable Fuel Standard [RFS] could raise the present value of cumulative payments needed to maintain the CRP at its current level by 19% over 2007-2020; [3] The increase in crop prices under the RFS is likely to be about 20%; [4] The tax credit for corn ethanol and import tariff that accompany the RFS can delay the transition to advanced biofuels and exacerbate the negative impact of the RFS on food crop prices; [5] Both the RFS and LCFS have the potential to lead to economic benefits for the U.S. by improving the international terms of trade; [6] The RFS could reduce greenhouse gas emissions by the U.S. by 5%, but this would be offset by indirect land use changes in the rest of the world and by a rebound effect in the fuel market [the net reduction may be as low as 0.5%]; and [7] The tax credit for corn ethanol and import tariff that accompany the RFS can delay the transition to advanced biofuels and worsen the negative impact of the RFS on food prices.

4. Associated Knowledge Areas

KA Code	Knowledge Area
133	Pollution Prevention and Mitigation
601	Economics of Agricultural Production and Farm Management

V(H). Planned Program (External Factors)

External factors which affected outcomes

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

Brief Explanation

V(I). Planned Program (Evaluation Studies)

Evaluation Results

No formal evaluation study was carried out by Extension.

Key Items of Evaluation