UNIVERSITY OF MINNESOTA

Twin Cities Campus

Center for Integrated Natural Resources and Agricultural Management

College of Food, Agricultural and Natural Resource Sciences

107 Green Hall
1530 Cleveland Avenue North
St. Paul, MN 55108-6112

Office: 612-624-4299
612-624-7418
Fax: 612-625-5212
http://www.cinram.umn.edu/

Project Title: Lowering the Cost of Bio-energy Feedstocks while Providing Environmental Services – A Win-Win Opportunity

Contract Number: RD3-1 **Milestone Number: 7** **Report Date: Feb. 12, 2013**

Principal Investigator: Dean Current
612-624-4299
curre002@umn.edu

Contract Contact: Bridget Foss
612-624-5571
foss0134@umn.edu

Congressional District: **Minnesota fifth (U of M Sponsored Projects Administration)**
Minnesota fourth (U of M CINRAM)

MILESTONE REPORT

"Project funding provided by customers of Xcel Energy through a grant from the Renewable Development Fund."

Executive Summary (Period between 10/23/2011 and 4/22/2012)

The project continues according to schedule. The delay in the production and analysis of ash from combustion of grasses has been resolved and that work is progressing well. The work on establishment strategies and optimum planting and harvesting dates for the biomass feedstocks is has moved into the analysis phase of field data and will allow us to report results in the future. Work on the impacts of biomass harvest is continuing with the new graduate student but has benefited also from previous work done by our wildlife expert and his graduate students. The hydrology modeling work to predict the impact of biomass crops on water quality based on the measurements that were taken prior to and over the course of this project is progressing well. The tool for assessment and prioritization of needed stream channel work is currently being developed and will provide a means to complement the water quality gains provided by the planting of perennial biomass feedstocks. Our work on landowner attitudes will be complemented by work being planned with a new graduate student who will carry out that work in 2013. The market for environmental services is continuously changing so we will incorporate the latest information on those developing markets as the project comes to a close. The life cycle assessment is proceeding as planned and we continue to develop and integrate information on the economic impacts of the biomass production systems and their environmental impacts.

The project goal is to develop an efficient system for the production, pre-processing and delivery of biomass feedstocks for energy production that minimizes feedstock cost for energy facilities while maximizing landowner income and the environmental benefits of biomass production.

The project objectives are:

- Establish, research cultural practices, and estimate costs and potential cost savings for the establishment, management, pre-processing and transport of perennial biomass feedstocks from field to energy facility.
- Estimate potential energy, wildlife, water quality, carbon and soil health benefits from targeted perennial biomass feedstock plantings.
- Value environmental benefits for potential payments to landowners who provide environmental commodities.
- Complete an integrated assessment of multiple ecological services markets currently being used; identify potential buyers of ecological services provided by perennial biomass energy crops; develop an integrated ecological services payment package.
- Develop a model for the production, pre-processing and delivery of perennial biomass feedstocks to energy facilities including a life-cycle assessment of the system from field to facility.

Technical Progress:

I. Biomass crop production field to farm gate

We are developing guidelines for production of biomass from native perennial crops. The biomass is intended for energy production. These research activities will help us understand issues in producing biomass crops on farm from planting through harvesting.

<u>Experiment 1:</u> Establishment strategies for weed control

Objectives: weeds often provide excess competition with native grasses and prevent their establishment. Our goal is to develop new approaches for weed control in establishing native perennial grasses and grass-forb polycultures. Establishment treatments include spring oat, and barley companion crops, herbicides, and mowing for weed control.

Experimental design: Randomized complete block with three replications

Accomplishment: We are currently analyzing data collected in 2011 and previous years to evaluate the effects of establishment treatments on biomass dry matter yield, botanical composition, nutrient content, and weed populations across all years of the study.

Work planned: We will continuing statistical and economical analysis of the results and develop a final report and scientific manuscript.

<u>Experiment 2:</u> Optimum planting dates for native perennial crops

Objectives: There is debate regarding the best time to establish native perennial prairie plants. Some feel that winter and late spring overseeding is an effective and low cost approach. We determined the effect of planting date on the establishment of native perennial plants.

Experimental design: The experiment was replicated at three locations in Rosemount, MN, with each treatment randomly assigned to each replicate at each location (randomized complete block).

Accomplishment: In our work to date, we have found that the success of establishment was very much dependent on the winter/spring weather conditions. Therefore, we have repeated the seeding data experiment another time during the winter and broadcast seeded a mixture of switchgrass, big bluestem and Indian grass with four native forbs and four native legumes on three dates: December 2011 before snowfall; March; and a seeding is also planned for early June. To provide variable amounts of cover, we also compared seeding into a tilled seedbed with seeding into a fall seeded oat companion crop. The seeding rate for native plants was 50 seeds per sq. ft. Plots were seeded on a silt loam soil at Rosemount, MN.

We will collect stand count data using a frequency grid in spring of 2012 and biomass yield data in November 2012. The frequency grid is a metal frame containing 25 squares (15 by 15 cm) made from fence paneling. The frequency grid is randomly placed within a seeded area, and the number of cells containing 1 or more of the seeded plants are counted. Biomass yield is measured by harvesting a one meter square area to a 1 inch height from the center of each plot. The total biomass is dried at 30 C and yield expressed on a dry matter basis.

Work planned: We are continuing statistical analysis of this data over all years. Data will be analyzed as a randomized complete block using a statistical program: SAS proc mixed (Version 9.2, SAS Institute Inc., Cary NC). Replication and years will be analyzed as random effects: seeding date and seedbed preparation effects will be fixed.

<u>Experiment 3:</u> Optimum harvest dates for native perennial biomass crops:

Native plants are typically harvested for biofuel after a killing frost in November, requiring long-term storage of the harvested biomass. With outside storage, plant biomass degrades and suffers from a loss of dry matter. Instead of storage, an option is to have multiple harvests of forage from the field.

Objectives: Determine the effect of harvest date on the yield, energy content, ash content, and persistence of native perennial grasses and grass-forb polycultures

Experimental design: Randomized complete block with 4 replications. We sample plantings of switchgrass and native plant mixtures on four dates of harvest: September, December, March, May (before green-up). Samples were collected from four locations.

Accomplishment: Biomass samples have been collected for all 2011 – 2012 harvest dates. Samples from March, May, September and December 2011 have been ground and subject to mineral analysis. March and May 2012 samples are currently being ground for analysis. Moisture content and yields of biomass have been calculated for all 2011 – 2012 harvest dates (Table 1).

Data are thus far insufficient to assess the effect of harvest dates and vegetation types on mineral and nutrient profiles of harvested biomass. Mineral and nutrient data for 2011 2012 biomass harvests will provide additional data to make such inferences. Preliminary observations regarding biomass yield suggest that significant losses in yield were not observed between harvest dates from September 2010 to May 2011 (data shown in previous report), but there were differences between harvest dates in 2011 – 2012 (Table 1). Yields of the native mixture declined from September to December 2011, did not change from December 2011 to March 2012, and declined from March 2012 to May 2012. Yields of switchgrass did not change from September to December 2011 or from December 2011 to March 2012. However, March and May 2012 yields were less than September 2011 yield. Moisture content of harvested switchgrass and native mixture biomass was highest in September and December, respectively, and lowest in March and May. These observations suggest that delayed harvests of both switchgrass and native prairie mixture biomass resulted in lower moisture content in March and May than previous harvests, but in contrast to 2010 – 2011, yield losses occurred over the period from September 2011 to May 2012.

Table 1: Dry matter yield* and moisture content by vegetation type and sampling date across multiple Minnesota locations in 2011 - 2012

Crop	Sep. 2011	Dec. 2011	Mar. 2012	May 2012
	Tons DM ac^{-1}			
Native mixture	1.85 (0.13)	1.29 (0.10)	1.24 (0.14)	0.97 (0.12)
Switchgrass	2.81 (0.17)	2.38 (0.31)	2.35 (0.37)	1.95 (0.30)
	%			
Native mixture	43.2 (2.3)	40.6 (7.8)	9.8 (0.5)	10.3 (1.1)
Switchgrass	31.0 (3.8)	37.1 (11.3)	10.3 (0.7)	10.8 (1.3)

*Means are presented followed by standard errors in parenthesis

Experiment 4: Fertilizer replacement value of biofuel ash:

The combustion of herbaceous biofuels will generate a significant amount of ash that is often considered a waste product but that potentially could have value as a fertilizer. Recycling of this ash to the soil will be an environmentally sound practice that also provides a productive use of the ash generated by combustion.

Objective: The overall objective is to answer fundamental questions related to the agronomic use and potential environmental impacts of ash generated from combustion of herbaceous native perennial biomass at the Rahr Malting facilities. These following field and greenhouse studies were planned and initiated for the 2012 growing season. Because of the limited amount of ash that was generated we were forced to change the size of our field plots and to conduct a greenhouse study for monitoring corn response to the ash. Nevertheless, we will be able to provide new information on the use of native prairie ash on plant growth.

Ash field study. This study, being conducted in the field season of 2012, will examine the effect of ash application on growth of established native prairie. Two existing restored prairie sites, with a mix of native legumes, grasses, and forbs, were chosen for the study. The first site is located at Belle Plaine, MN in Scott County and the second at Becker, MN in Sherburne County. The two sites vary from one another with the Belle Plaine location one hour south of the Twin

Cities having clay loam soil and with the Becker location one hour north of the Twin Cities having sandy soil. Prior to the start of the experiment, soil samples were collected to determine soil pH, soil organic matter, P content and K content.

The treatments were varying levels of incinerated native plant biomass (the ash remains of native plant biomass used for fuel). This native plant ash was processed by sifting and screening to remove foreign materials. The eight treatments, which also include two treatments consisting of synthetic fertilizer at the 1.0X and 2.5X ash rates, are listed in Table 1. The experimental design was a randomized complete block with four replicates. Plot size is 25 ft^2 (2.3 m^2) which is smaller than originally proposed because of the shortage of ash.. Ash and synthetic fertilizer were applied to the plot by hand in April 2012. Plots will be analyzed qualitatively for visible signs of nutrient deficiencies, plant height, botanical composition and biomass in the summer and fall. At the end of the experiment in Fall 2012, soil samples will be taken and analyzed for P and K content.

Table 1. Field study treatments

	Treatment	Ash, g	Phosphate, g	KCl, g	Lime, g
1	0.5X ash	267.9	0	0	0
2	1.0X ash	535.8	0	0	0
3	1.5X ash	803.6	0	0	0
4	2.0X ash	1071.5	0	0	0
5	2.5X ash	1339.4	0	0	0
6	1.0X fertilizer	0	44.2	73.0	494.5
7	2.5X fertilizer	0	110.5	182.5	1236.3
8	Control	0	0	0	0

Ash greenhouse study. This greenhouse study will examine the effect of native plant ash on corn growth. In April 2012, 350 pounds of soil were collected from the top 15 cm of ground at near the Becker site described above. Soil samples were collected to determine soil pH, soil organic matter, P content and K content. The greenhouse experiment is being conducted at the University of Minnesota plant growth facilities in Saint Paul, Minnesota. The treatments are as above in the field study, except scaled down to pot size; additionally all ash rates will be reproduced with synthetic fertilizers. The experimental design is a randomized complete block with four replicates. In addition to the treatment amendments, nitrogen and sulfur will be supplied to the corn plants with ammonium nitrate, urea, and ammonium sulfate at the same rates at the start and during the experiment so that these nutrients are not limiting factors to corn growth. Corn plants will be measured after emergence on a weekly basis for height and shoot diameter. At the end of the experiment, corn will be harvested, dried, weighed for biomass, and analyzed for elemental composition. Soil samples will also be taken for P and K content. This information will be used to estimate P and K uptake from the ash by the corn plants.

Work planned: We will apply ash treatments monitor plant growth, harvest plants analyze plants for mineral content, and conduct appropriate statistical analysis of data.

II. Moving biomass from road/farm gate to facility

This activity is being undertaken by Koda Energy. Some of the work was initiated prior to the project start date as part of their commercial operations but they continue to evaluate other options for supplying biomass to their facility. One of the areas they have been exploring is developing a staging area for concentrating biomass and doing any preprocessing including drying required prior to shipping it to their Shakopee site. Koda Energy was awarded a Next Gen Energy Grant in 2012for the amount of $480,000. The funds will pay for construction of a biofuels staging and processing facility in Scott County. The facility will aggregate and process (drying, size reduction) various biomass fuel stocks for use in Koda's CHP biomass facility located seven miles from this new facility. Fuel stocks include urban wood waste (a contract in place with the city of Minneapolis), agri-byproducts and potentially dedicated energy crops.

The Koda Energy Next Gen project will provide crucial information as we look at the supply chain of perennial crops to biomass facilities and will allow us to better estimate the cost of options for preprocessing and storing biomass crops. Information from Koda Energy is being provided and continues to be incorporated into the Life Cycle Assessment and as part of our supply chain analysis. See section III.D. Life Cycle Assessment for more detail.

III. Measure and value environmental benefits

In this area we will measure and evaluate the specific impacts of biomass crops on the environment including: 1) changes in grassland songbird populations on areas planted and managed for biomass feedstocks; 2) changes in water quality parameters (turbidity, sediment, nitrogen and phosphorus concentrations); 3) register values reflected in emerging ecosystem markets for water quality and carbon and others as they emerge such as biodiversity; and 4) preparation of a life cycle assessment which allows us to estimate environmental impacts associated with the production, harvest and combustion of biomass crops including an evaluation of resource use and emissions as the crops are produced, transported and combusted.

A. Wildlife impacts

Graduate research assistant Robert Dunlap has created a manuscript analyzing the small mammal data from the first three years of the LCCMR biofuels study. His analyses show that voles of the genus *Microtus*, common small mammals in the study and important rodents within grassland ecosystems, declined significantly with increasing harvest percentage. Additionally, the presence of *Microtus* as well as masked shrews in the study plots was negatively affected by harvest percentage, while that of other small mammals was largely unaffected. These negative effects on presence and abundance are among the first negative impacts to be discovered in the LCCMR study, which suggests important implications for the intensity of biofuel harvests. This information will help make recommendations for intensity of harvest. Robert plans to submit this paper for publication later in the year after a thorough review process.

During the summer of 2012, Robert will complete the fourth and final year of grassland bird surveys in the originanal LCCMR biofuel plots, and perform some of the same analyses on abundances as for the small mammal data. Up to this point, no analyses on individual bird species have been performed in the study; Robert will perform these analyses as part of his Master’s thesis and incorporate them into a manuscript for submission to a publication within the next year. Robert will also help trap small mammals in the same study plots later this summer for the final year of small mammal data collection, and incorporate this data (as well as the analyses in his small mammal manuscript) into his Master's thesis.

B. Water quality assessment

Hydrology:

Data from small watersheds in Elm Creek and from runoff plots at the University of Minnesota Southern Research and Outreach Center in Waseca, MN provide the basis for modifying the SWAT model to better represent the hydrologic response of perennial crops in contrast to annual row crops in southern Minnesota. Model modifications are being made and performance evaluated – to validate a model suitable for simulating different scenarios of land cover changes associated with bioenergy crops on watersheds. At present, modifications have been completed that improve hydrologic simulation of perennial grass crops. Investigations into similar modifications necessary for agroforestry crops are currently underway. Subsequent to this phase, model outputs will then be evaluated and modified as needed to conform with data needs by colleagues to complete life cycle and economic assessments.

The model is intended to be used to study improvements of water quality associated with perennial (bioenergy) crops that be considered as field crops or as components of riparian - stream channel rehabilitation that could include agroforestry buffer systems. These agroforestry systems have the potential to produce a variety of woody and herbaceous bioenergy crops in riparian areas not suited for annual crops.

Model algorithms resulting from incorporation of bioenergy crops will be utilized as part of a larger modeling effort to assess cost effectiveness of agricultural best management practices (BMPs) including crop conversion, vegetative filter strips and wetland mitigation for improvement of water quality. The result will be a decision support system for agricultural BMPs in southern Minnesota agricultural areas. Efforts are underway to choose and/or develop the best set of modeling algorithms to provide simulations at a field scale.

Activities planned for the next 6 months - April 23, 2012 through October 22, 2012:

- Working sessions with our team of hydrologists and economists are planned for late summer 2012 as part of an iterative process of model development and testing.
- Determine best set of model tools and algorithms to simulate water quality outcomes from best management practices; incorporate into a single model framework.
- Create GIS database of landscape attributes important for hydrology and water quality modeling for selected pilot testing areas in southern Minnesota. These tasks will serve to create the prototype for the decision support system and compile the data necessary to test it.
- Research to prioritize locations for riparian restoration utilizing perennial (bioenergy) crops to achieve environmental benefits in an economically sound manner is now planned to be completed by the end of September, 2012. This work will result in a prioritization tool and is planned to be completed by the end of October, 2012.

C. Integrated assessment of ecological service markets

Landowner willingness to supply biomass crops

We will continue to work with the data from the surveys to extract additional information related to landowner willingness to supply biomass crops and present it in a format useful for extension education and potential biomass businesses. The results of this research are included in a Master's thesis and will also form part of a PhD Thesis that will likely be finished in 2013.

Assessment of Markets

The project team continues to monitor the development of ecological service markets. Since these markets are constantly developing and changing a final assessment will be made in 2013 and incorporated in the final project report to represent the current state of those markets at that time with an approximation of future trends in those markets.

Partner Rural Advantage continues to work on developing a suite of market tools and markets for ecosystem services that are being implemented on a trial basis. Results of that work will also be included in the final report and assessment of ecological service markets for a number of services including water quality, carbon, pollinator habitat among others.

D. Life cycle assessment

LCA modules of barley straw, oat straw, wild rye grass, switchgrass, and prairie grass mix were completed with further updates in farming practice, farm machinery energy use, energy use in preprocessing and direct emissions of biomass combustion at power plant. We carried out mandatory LCIA step (characterization) for five fuel crops and two optional steps: normalization and weighting.

Table 1 summarizes feedstock characteristics and electricity conversion characteristics. Conversion process efficiency in Koda Energy is assumed to be 40%. The conversion efficiency may vary by the given restriction on seasonal variation in feedstock fuel mix within 25 mile-distance.

Table 1. Characteristics of feedstocks and electricity conversion

Attribute	Barley straw	Oat as straw	Canadian wild rye	Switchgrass	Prairie Mixture
Feedstock characteristics					
Carbon sequestration (kg CO_2/kg of biomass)	1.35	1.28	1.36	1.66	1.66
Moisture (%)[1)]	10.0	10.4	12.0	12.0	12.0
btu/lb[1,2)]	7,524	8,242	7,481	7,936	8,099
Electricity conversion characteristics					
kWh/ton	4,861	5,325	4,834	5,128	5,233
electricity conversion rate (kWh/ton)	1,944	2,130	1,933	2,051	2,093
Conversion efficiency			40%		

Characterization step in LCIA is performed using an environmental impact assessment model developed by the US EPA called the Tool for the Reduction and Assessment of Chemical and other environmental Impacts or TRACI (J. Bare 2007). As shown in Table 2, we add fossil fuel depletion category to nine impact categories (three human health effects and six environmental impacts) that the TRACI method assesses.

Table 2. Impact category indicators in TRACI method

	Human health effects	Environmental impacts	Resource depletion
Impact category	• Human health cancer (kg benzene-Eq) • Human health non-cancer (kg toluene-Eq) • Human health criteria (respiratory effect)	• Global warming • Ozone depletion • Acidification • Eutrophication • Photochemical smog • Ecological toxicity	• Fossil Fuel depletion

Normalization and weighting steps are optional elements in LCA. Normalization transforms each characterized category indicator results by dividing it by a reference value. The reference values have spatial and temporal scales of the environmental mechanism by impact category and we used the reference values by each of nine impact categories shown in Table 3. Dividing each characterized value by the respective normalization reference value created dimensionless values representing the significance of each impact category in time. Normalized results show duration and magnitude of the characterized impact within a given temporal and geographical system boundary under study. However, the normalized results still do not show which impact category is relatively more dominant than others.

Table 3. Normalization reference by impact category (Kim et al. 2012)

Impact category	Normalization reference value	Normalized unit
Global warming	7.05E+12	CO_2 equiv/yr
Human respiratory effects (criteria air pollutants)	1.70E+10	PM2.5 equiv/yr
Cancerous effects	4.61E+11	benzene equiv/yr
Ecological toxicity	1.26E+12	2,4-D equiv/yr
Eutrophication	1.01E+10	N equiv/yr
Noncancerous	4.37E+14	toluene equiv/yr
Photochemical oxidation (smog formation)	2.92E+10	NO_x equiv/yr
Acidification	1.66E+12	H^+ equiv/yr
Ozone depletion	4.50E+07	CFC-11 equiv/yr
Fossil Fuel Depletion	1.27E+07	Surplus MJ

The weighting step enables synthesizing performance scores for all impact categories considered into a single score. In the weighting step, all the units in each impact category become dimensionless by applying weighting factors, which assigns value-choice of relative importance of each impact category to the normalized results. Since weighting is a converting process for different impact categories by using numerical factors based on value choices, the results can be subjective.

Our weighting procedure used weighting factors developed by National Institute of Standards and Technology (Gloria et al., 2007). They categorized three "voting groups" including producers, consumers, and LCA experts. The groups were asked to vote on the environmental impact importance by time horizons, e.g. short-term, medium-term, and long-term horizons (Gloria et al. 2007). Among the sets of weighting factors, our study chose the three groups' average weights rescaled with 10 impact categories for our weighting step as shown in Table 4.

Table 4. Weighting factor by impact category (Gloria et al., 2007)

Impact category	Weighting factor (%), all time horizon
Global warming	35
Human respiratory effects (criteria air pollutants)	11
Cancerous effects	10
Ecological toxicity	10
Eutrophication	7
Noncancerous	6
Photochemical oxidation (smog formation)	5
Acidification	4
Ozone depletion	2
Fossil Fuel Depletion	12
Total	100

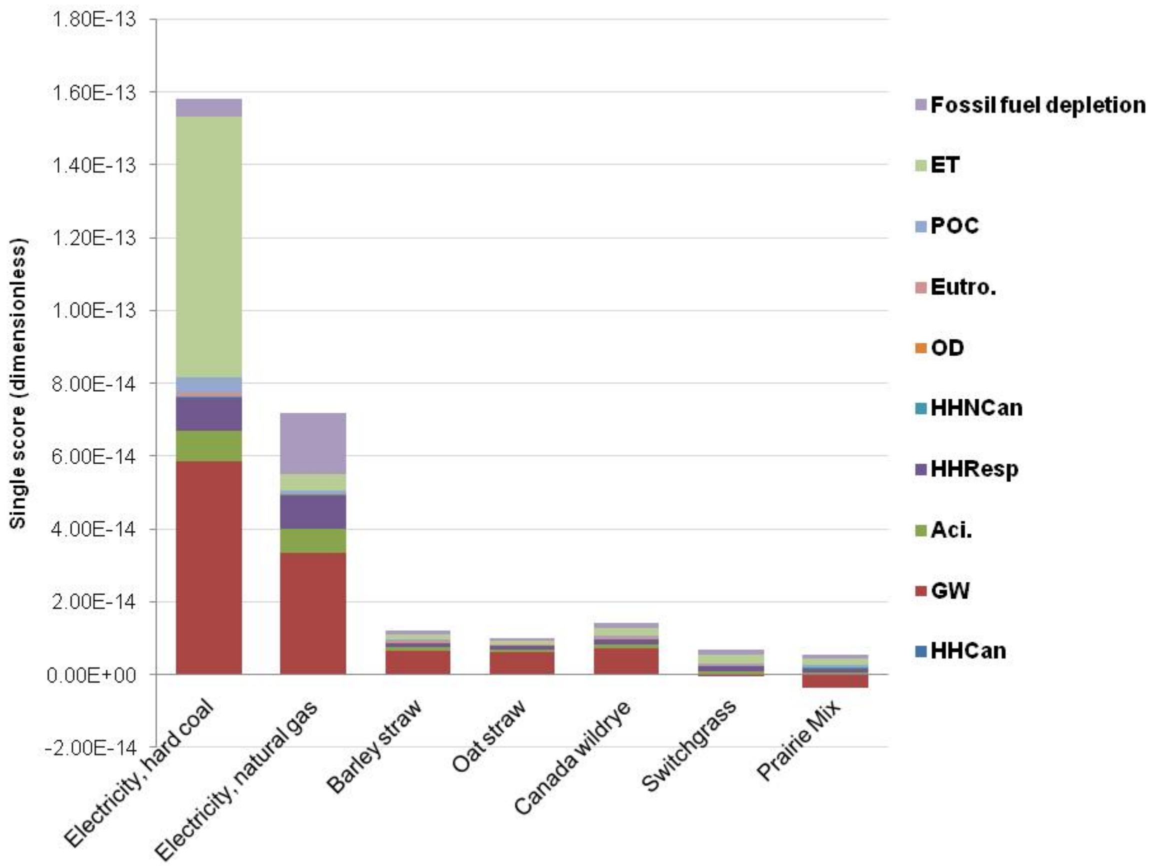

Figure 1. Comparative weighted results of baseline (hard coal and natural gas) vs. biomass electricity

*** ET: ecological toxicity; POC: photochemical oxidation; Eutro: eutrophication; OD: ozone depletion; HHNCan: Human health non-cancerous effect; HHResp: Human health respiratory effect; Aci.: Acidification; GW: global warming; and HHCan: human health cancerous effect**

For comparison, we added electricity from coal and natural gas as reference systems. The overall single score indicates that electricity generation from all biomass feedstock has more than 90% lower single score than hard coal electricity and more than 80% lower single score than natural gas electricity. For global warming, all biomass electricity generation optoins have about 6% the impact of coal electricity on average and 10% of the impact natural gas electricity.

Activities Planned for April 23, 2012 through Oct. 22, 2012

Wooschip LCA module will be added to the current five LCA modules as we complete the LCI inventory analysis. We will carry out the product-level contribution and sensitivity analysis with key parameters. As the biomass fuel mix at Koda Energy varies by local feedstock availability, it is hard to continue to receive feedstock with the lowest environmental impact such as switchgrass and prairie grass. Koda Energy biomass power plant expects a biomass fuel mix of barley grain and forage, oat grain and forage, Canada wild rye, woodchips and switchgrass. We will examine several hypothetical fuel mix scenarios by seasonal variation.

[1] Keith Butcher, Xcel Energy Report (2007), "*Identifying Effective biomass strategies,*" p25.

[2] http://www.abe.psu.edu/extension/factsheets/h/H83.pdf

[3] J. Bare (2010) "Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI),"; http://www.epa.gov/nrmrl/std/sab/traci/.

[4] Gloria T, Lippiatt B, & Coopers J (2007) Life cycle impact assessment weights to support environmentally preferable purchasing in the United States. *Environ. Sci. Technol* 41(21):7551-7557.

[5] J. Kim, Yang Y., Bae J., and Suh S. (2012), "The Importance of Normalization Reference in Interpreting LCA Results," Journal of Industrial Ecology.

IV. Economic assessment of biomass production and delivery system

This research area looks at the financial and economic aspects of biomass production from the perspective of the landowner/farmer who may be interested in producing biomass feedstocks for the market and also the value of the environmental services (water quality, recreation, carbon) to society both qualitatively and quantitatively.

A. Cost Benefit Analysis – Plan activities and begin data collection

This work is ongoing. We are continuing to gather information on both the costs and benefits of perennial cropping systems related to improvements in water quality and storage. The information we are gathering will be used to create a decision support tool that is being prepared under a $1,245,867 Section 319 project grant from the Minnesota Pollution Control Agency and the US Environmental Protection Agency. We have been able to successfully leverage the RDF funding to expand the work to begin preparation of that decision support tool.

The Section 319 Project will evaluate the cost effectiveness of different conservation measures, including the use of perennial crops for bioenergy, as a way to guide decisions on what types of measures to promote by watershed managers. The production of biomass crops will be one “working lands” conservation practice that will be evaluated and will build upon data that is generated by this RDF project.

B. Valuation of ecological services

This will continue to be done in coordination with **IIIC** above. Results from **IIIC** will be used to help determine how the public values ecological services which will allow us to use those values for our analysis. In addition to the information gathered through the survey, we will be gathering data on the emerging markets for carbon and water quality credits.

Linda Meschke and Rural Advantage have prepared a payment model (Ecopaypack) for providing payments to landowners. Rural Advantage has developed protocols and procedures for payments for pollinator habitat.

Project Status: The project continues to meet the timeline with some minor delays but with good progress in most areas.

Appendix 1 – Papers and presentations

Papers

Smith, D., D. Current, and K. W. Easter. “Farmer Willingness to Produce Perennial Bioenergy Crops” Working paper, Dept. of Applied Economics, University of Minnesota, Twin Cities, 2012.

Smith, D., C. Schulman, D. Current, and K. W. Easter. “Willingness of Agricultural Landowners to Supply Perennial Energy Crops” Paper presented at AAEA annual meeting, Pittsburgh, PA, 24-26 July, 2011.
http://purl.umn.edu/103930

Gamble, Joshua, et. al. 2013. "Harvest date effects yield and nutrient export of low-input switchgrass and native polyculture biomass" In preparation

Presentations

Dunlap, R, T Arnold, and M DonCarlos. 2012. Short-term effects of biofuel harvests on grassland birds in western Minnesota. 73rd Midwest Fish and Wildlife Conference, Wichita, KS, 9-12 December 2012.

Dunlap, R, T Arnold, and M DonCarlos. 2013. Short-term effects of native grassland biofuel harvests on small mammals in western Minnesota. 2013 Annual Meeting of the Minnesota Chapter of The Wildlife Society, Walker, MN, 5-7 February 2013.

Schulman, C., D. Smith, D. Current, L. Meschke, D. Becker “Landowner Constraints to the Adoption of Perennial Bioenergy Crops.” 13th North American Agroforestry Conference: A Profitable Land Use, Athens, GA, June 4-9, 2011.

Smith, David, C. Schulman, D. Current, K. William Easter “Willingness of Agricultural Landowners to Supply Perennial Energy Crops” Environmental and Natural Resource Economics Seminar, Department of Applied Economics, St. Paul, MN, 2011.

Smith, David, C. Schulman, D. Current, K. William Easter “Willingness of Agricultural Landowners to Supply Perennial Energy Crops” Resource and Rural Economics Division Seminar, Economic Research Service, USDA, Washington, D.C., 2011.

Smith, David, C. Schulman, D. Current, K. William Easter “Willingness of Agricultural Landowners to Supply Perennial Energy Crops” 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, PA, July 24-26, 2011.