cenusa bioenergy

Annual Progress Report

Agro-ecosystem Approach to Sustainable Biofuels Production via the Pyrolysis-Biochar Platform

September 2014

Agriculture and Food Research Initiative Competitive Grant
No. 2011-68005-30411

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Agro-ecosystem Approach to Sustainable Biofuels Production via the Pyrolysis-Biochar Platform (AFRI-CAP 2010-05073)

Project and Objective Executive Summaries - August 1, 2013 – July 31, 2014

Executive Summary – CenUSA Bioenergy

We are pleased to highlight significant outcomes from Year 3 – a watershed year for CenUSA Bioenergy – and outline a vision and stakeholder-driven agenda going forward for Year 4.

USDA/ARS Announces Release of *Liberty*, a High-yielding switchgrass Cultivar. Producing excellent yields of biomass for bioenergy, the new switchgrass (*Panicum virgatum* L.) cultivar *Liberty* has pushed northward the agricultural zone where high-yielding switchgrass can be grown, and like the prairie grasses from which it was bred, Liberty prospers in marginal soils.

In multi-year trials made possible by CenUSA at Mead, NE and DeKalb, IL, both in USDA Plant Hardiness Zone 5, Liberty produced 8.2 and 7.3 tons/acre biomass, respectively, which was 1.6 to 2.5 tons/acre greater than the previously released upland cultivars adapted to the region. See Exhibit 1 for detailed information about release and availability of Liberty seed. CenUSA and ARS, Nebraska collaborated on the press release that states that Liberty 'promises to revolutionize biomass production' (Exhibit 2). An article on Liberty was the lead story in the inaugural edition of BLADES, CenUSA's new newsletter.

High Biomass Production on Marginal Soils. Design of management systems capable of achieving high biomass production on marginal soils, while minimizing system environmental footprint, is central to CenUSA's mission. In 2013 switchgrass biomass yields exceeded 11 metric tons/ha on marginal sites previously known to have low alfalfa and corn yields because of low potassium (K) and phosphorus (P) fertility. These biomass yields were achieved with no additional nitrogen (N) fertilization, but were comparable to stover yields from a high-yielding corn crop grown on excellent soils. Greenhouse gas emissions from the switchgrass stands were extremely low (similar to native vegetation) and very little N, P, or K left the field to contaminate ground or surface waters.

ISU Team Develops Process to Stabilize Phenolic Oligomers from Pyrolysis of Biomass. Researchers at Iowa State University have developed a proprietary process, low temperature, low pressure (LTLP) hydrogenation, to stabilize phenolic oligomers produced from pyrolysis of biomass. These compounds, derived from lignin in biomass, are extremely reactive even at room temperature, making them difficult to process into products. Once stabilized, these oligomers have potential as **heating oil**, and also as a **refinery blendstock**, as well as **starting material for synthetic polymers and carbon fibers**.

In Year 4 the LTLP hydrogenation process will be used with ADM's biorefinery processes to determine if high value products, including phenolic monomers, can be generated from ADM's lignin streams. Parallel experiments will be performed with the lignin stream from Renmatix.

Engaging Industry and the EPA. Beginning in 2012 and continuing into 2013 we have experienced considerable 'industrial pull.' This is attributable in part to two significant workshops we organized and held. The first, *Roadmap to Commercialize Thermochemical Biofuels Processing in the Midwes*t, held in 2012, is still having impact. Our industrial partners ADM and Renmatix introduced the technologies they represent (acetic acid pulping and supercritical hydrolysis) at the 2012 workshop.

Our second significant workshop was *Enhancing Mississippi Watershed Ecosystems with Perennial Bioenergy Crops*, held in conjunction with University of Minnesota and the Mississippi River Gulf of Mexico Watershed Nutrient Task Force. It showcased our integrated modeling assessment of the Mississippi River Basin and the connection to the hypoxic zone in the Gulf of Mexico. This modeling system identifies the most cost-effective locations to target conservation investments, including the development of perennial feedstocks, to address the Gulf of Mexico hypoxic zone. An important outcome from this workshop was the appointment of Dr. Christopher Clark from EPA to our Advisory Board.

We used insight gained from these workshops for part of our strategic planning for the new initiative on Commercialization, which has been formalized as Objective 10.

Creating a Stakeholder-driven Agenda. We engaged an independent evaluator to perform unbiased and unvarnished in-depth telephone interviews with all members of our Advisory Board. The purpose was to gain stakeholder insight into the commercialization of biofuels and bioproducts and to chart a viable path forward. Because CenUSA's Advisory Board a) has representation for each of our key stakeholder groups, and b) knows us well, this analysis represents a strong validation of our path forward. Their points of highest priority (see Exhibit 3 for the full report) were:

- They were anxious to see real-world applications;
- They wanted an emphasis on looking broader than just switchgrass as a feedstock, and wanted to make sure that there were multiple markets for switchgrass.
- They suggested looking broader than just transportation fuels.

We used this input for part of our strategic planning for the new initiative on commercialization, ultimately leading to the formation of our new Commercialization Objective (Objective 10).

Developing Human Capital to Lead Tomorrow's Bioenergy Production. Wouldn't it be a major coup if a high school science fair project on switchgrass as a potential source of bioenergy was entered in the International Science Fair? One of CenUSA's summer students, Brian Prchal, now a high school junior, did just that when his project, *The Effects of Applying Wastewater Biosolids on Bioenergy Tests Plots and Various Varieties of Switchgrass*, performed under the mentorship of Carl Rosen of UMN, was rated so highly at the Regional Science Fair that it was advanced to the National Competition *AND* given automatic entry into the International Science Fair.

Transitioning from high school to university students: We routinely perform formative and summative evaluations on our CenUSA Summer Internship Program, and they are almost always positive. But until now we did not have in-depth analyses of the impact the summer experience had on students' personal and scientific growth, leadership development, and the ability to find a job. Nor did we have any information on the impact of the program to the mentor. We performed in-depth interviews on three representative students and parallel interviews with their mentors (see Exhibit 4). Results of these longitudinal surveys revealed the highly positive impact that CenUSA is having on developing tomorrow's leaders in bioenergy production.

The following are representative quotes from the students:

- *Thanks to CenUSA, I got a job in the plant biotech industry.*
- *The experience was the single most defining factor in my career plans for the future.*
- *I got to call the shots in my research project, which was an exciting experience most 20 year-olds don't get.*

Communicating Success. Among the dozens of this year's publications, presentations, videos, webinars and factsheets, the one of which we are most pleased is 'Midwest Vision for Sustainable Fuel Production,' which is at this writing under consideration as a cover article in *Biofuels* and co-authored by CenUSA's entire leadership team. The article charts the progress of CenUSA Bioenergy, and in the final section, *Future Perspectives*, sets forth a roadmap of additional research, technology development and education required to realize commercialization.

In addition, we have completely re-vamped our communications strategy, including our web site, added a newsletter (*BLADES*), and social media platforms. Since publishing our first issue of *BLADES*, traffic to our web site has increased 261% over baseline and traffic to our video/webinar sites has increased by 111% as well.

Assessing Overall Progress. We have employed the Fuel Readiness Level/Feedstock Readiness Level (FRL/FSRL) tool, with slight modifications, to track parallel progress in developing a fuel and conversion platform (purple bars) and a supporting feedstock system (green bars). The following tables (Fuel Readiness Level Tool) represent team consensus, and **illustrate** that the two systems are well synchronized.

Fuel Readiness Level Tool. Herbaceous perennials include switchgrass, big bluestem, and low diversity mixtures of big bluestem, Indiangrass and sideoats grama. However, switchgrass is the most advanced herbaceous perennial due to extensive and focused **bioenergy**-specific research conducted for more than 25 years at multiple locations.

Fig. 1 Fuel Readiness Level Tool

Fuel Readiness Level (FRL)

1	2	3	4.1	4.2	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7	8	9

Biochar Product Readiness Level

1	2	3	4.1	4.2	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7	8	9

ADM Acetosolv Pulping Readiness Level

1	2	3	4.1	4.2	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7	8	9

Renmatix C5 and C6 Sugar Production Readiness Level

1	2	3	4.1	4.2	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7	8	9

Corn Stover Feedstock Production[1]

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Herbaceous Perennial Feedstock Production

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Corn Stover Feedstock Market

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Herbaceous Perennial Feedstock Market

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Biochar Market

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

ADM Pulp Market

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Renmatix C5 and C6 Sugar Market

[1] Herbaceous perennials include switchgrass, big bluestem, and low diversity mixtures of big bluestem, indiangrass and sideoats grama. However, switchgrass is the most advanced herbaceous perennial due to extensive and focused bioenergy-specific research conducted for more than 25 years at multiple locations.

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Corn Stover Policy – Program Support and Regulatory Compliance

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Herbaceous Perennial Policy – Program Support and Regulatory Compliance

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Biochar Policy – Program Support and Regulatory Compliance

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

ADM Pulp Policy – Program Support and Regulatory Compliance

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Renmatix C5 and C6 Sugars Policy – Program Support and Regulatory Compliance

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Corn Stover Linkage to Fuel Conversion Process

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Herbaceous Perennials– Linkage to Fuel Conversion Process

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Biochar– Linkage to Fuel Conversion Process

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

ADM Pulp – Linkage of Switchgrass to Conversion Process

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Renmatix C5 and C6 Sugars – Linkage of Switchgrass to Conversion Process

1	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	7	8	9

Highlights of Year 4 Team Plan-of-Work

Going Forward into Year 4. With encouragement from NIFA's Bill Goldner and unanimous support of our Advisory Board, we have added Objective 10, Commercialization, to CenUSA's project portfolio. Archer Daniels Midland Company (ADM) and Renmatix will be formal collaborators and lead parts of Objective 10; all other Objectives will have elements of commercialization interwoven in them (See conceptual diagram, right, that shows Commercialization as a crosscutting Objective). For example, Vermeer, a farm equipment manufacturer, will collaborate with Objective 9 (Extension and Outreach), and Biochar Now, a purveyor of soil amendments, will collaborate on Objective 4 (Markets and Distribution) and Objective 2 (Biochar).

The addition of Objective 10, and particularly the development of additional bioproducts, addresses the stakeholder-identified need to develop additional markets for perennial grasses to reduce risk to farmers for planting them. Concomitantly, the ability to produce bioproducts such as lignin, hemicellulose, cellulose, stabilized phenolic oligomers and biochar, reduces risk to the biorefinery.

CenUSA Bioenergy is on the right course. Now at its project midpoint, CenUSA has already established that perennial grasses will be part of the U.S.'s biomass and renewable bioenergy portfolio. CenUSA is well positioned to continue its positive trajectory in Year 4. The project team has coalesced around Objective 10 (Commercialization) and looks forward to a year of discovery and implementation.

It is highly likely that a major outcome of Year 4 activities will be the development of additional markets for perennial grasses. This outcome is significant, as additional markets will reduce risk to both farmers and to biorefiners

CenUSA has played an important role in bringing together a large number of scientists, collaborators, and students to work together to evaluate options for developing a regional system for producing fuels and other valuable bio-based products from perennial grasses grown on marginal land. This large-scale interdisciplinary approach has not only led to new scientific discoveries and outcomes and educational materials and experiences, but it has fostered the emergence of a transdiscipline. All project participants have been actively engaged in spanning the multiple disciplines necessary to succeed in this endeavor. As a result, they have become conversant with each other's scientific language and have produced coordinated research and education outcomes that are exceptionally relevant to our collective goal.

Executive Summary – Feedstock Development Objective

The Feedstock Development Objective continues to focus on developing perennial grass cultivars and hybrids that can be used on marginal cropland in the Central United States for the production of biomass for energy. Year 4 focus is on selection and breeding of switchgrass.

Co-Project Directors

- Mike Casler, USDA-ARS, Madison, Wisconsin, michael.casler@ars.usda.gov, 608.890.0065.
- Rob Mitchell, USDA-ARS, Lincoln, Nebraska, Rob.Mitchell@ars.usda.gov, 402.472.1546.

Accomplishments – Year 3

- Completed the first year of harvest and data collection on 36 regional biomass trials of switchgrass, big bluestem, and indiangrass.
- Planted an additional 26 regional biomass trials, including the newest and most elite breeding populations of switchgrass and big bluestem.
- Documented improved winter hardiness and survivorship of lowland-type switchgrass in USDA Hardiness Zone (HZ) 4, owing to two cycles of selection for survivorship within the cultivar Kanlow. These results provide documentation of range expansion for the lowland type that now includes USDA HZ 4 and possibly HZ 3.
- Completed the most extensive and definitive study of heterosis in switchgrass to date. Documented the existence of heterosis within lowland x lowland hybrids and demonstrated the strong relationship between later flowering and higher biomass yields.
- Created biomass samples of switchgrass and other warm-season grasses that will be used to expand the NIRS calibrations for biomass quality traits to include a broad range of warm-season energy grasses.
- Created biomass samples of switchgrass and big bluestem that can be used to address specific hypotheses regarding the role of plant traits such as lignin and ferulates in regulating conversion efficiency using either a fermentation or pyrolysis platform.
- Created selection indices that can be used to simultaneously increase dry matter yield, ethanol yield, and high heating value content of switchgrass biomass. Documented the superiority of these selection indices compared to other breeding systems and selection criteria.
- Released 'Liberty' switchgrass, the first switchgrass cultivar to combine late flowering and high biomass yield of the lowland type with winter hardiness of the upland type. Expanded the range of late-flowering switchgrass to include USDA HZ 3 and 4.

Planned Activities, Outcomes, and Impacts - Year 4

- Conduct second year of harvest on 2012 field trials.
- Select warm-season grass samples for hypothesis testing and NIRS calibration of biomass quality traits.
- Evaluate rust resistance of switchgrass and big bluestem cultivars in regional trials.
- Monitor arthropod abundance and diversity in warm-season grass trials in Nebraska and Wisconsin.

- Establish new switchgrass and big bluestem selection nurseries that will put the new selection index theory into practice.
- Begin the first cycle of genomic selection and the first cycle of phenotypic selection (as a control) within WS4U-C2 and Liberty switchgrass populations.

Executive Summary – Sustainable Feedstock Production Systems

This CenUSA Bioenergy objective focuses on conducting comparative analyses of the productivity potential and the environmental impacts of the most promising perennial grass bioenergy crops and management systems using a network of 14 fields strategically located across the Central United States. The goal is to produce a quantitative assessment of the net energy balance of candidate systems and optimize perennial feedstock production and ecosystem services on marginally productive cropland while maintaining food production on prime land.

Co-Project Directors

- Robert Mitchell, USDA-ARS, Rob.Mitchell@ars.usda.gov, 402.472.1546.
- David Laird, Iowa State University, dalaird@iastate.edu, 515.294.1581.
- Jeffrey Volenec, Purdue University, jvolenec@purdue.edu, 765.494.8071.

Accomplishments – Year 3

- Factor Analysis Plots and Systems Analysis Plots were harvested for biomass yield in Iowa, Illinois, Indiana, Minnesota, and Nebraska. Soil samples have been secured and analyzed.
- Biomass from key plots has been characterized for carbohydrate composition including total carbon, sugar, starch, neutral detergent fiber, acid detergent fiber, cellulose, and hemicellulose and the non-carbohydrate constituents, lignin and ash.
- Where soil fertility is a management factor being used to enhance productivity on marginal soils/sites, soils and biomass samples have been analyzed for the major plant nutrients nitrogen (plants only), phosphorus, and potassium.
- The impact of soil biochar amendments on yield, soil water cycling, soil carbon, greenhouse gas emissions and various soil quality parameters has been evaluated.
- Greenhouse gas emissions have been compared among various biomass production systems, with maize production for grain and native prairie sites serving as controls.

- Water movement and with it nutrient loss to surface waters via tile lines and erosion were determined at specific sites for several biomass production systems.
- In response to the CenUSA Advisory Board's recommendation in December 2013, the portfolio of biomass systems under evaluation was expanded (at no additional cost) from native perennial grasses (switchgrass, big bluestem, Indiangrass) to include additional perennial (Miscanthus x giganteus, hybrid poplar, prairie cordgrass) and annual (sweet sorghum, dual-purpose sorghum, photoperiod-sensitive sorghum, teff, oats, and winter wheat) systems.
- Extensive data analyses were conducted to compare system efficiencies including calculation of yield of carbohydrate fractions per hectare and system nutrient use.
- About 20 tons of switchgrass, big bluestem, and low diversity mixture bales were pelleted and numerous projects are underway such as comparing the composition of baled and pelleted material for biochemical and thermochemical conversion.
- Data were used to calibrate/validate the Soil Water Assessment Tool model and a new version with more robust algorithms for biomass systems was released.
- Statistical analyses were conducted to determine significant differences among system performance attributes (e.g., yield, N use, cellulose production and greenhouse gas production).

Planned Activities, Outcomes and Impacts – Year 4

- Measure yield and other agronomic production attributes of these biomass systems
- Monitor/document weed/insect/disease pressure and use control measures as necessary.
- Continue analysis of soils and plants for nutrients and carbon pools.
- Continue greenhouse gas and water quantity/quality measurements.
- Conduct statistical analysis of data.
- Prepare annual reports of data for GHG emissions, biomass production, surface soil characteristics, and management.
- Continue to improve biophysical models by calibrating SWAT and APEX with data from the biophysical measurements.

Executive Summary – Feedstock Logistics

The Feedstock Logistics objective focuses on developing systems and strategies to enable sustainable and economic harvest, transportation and storage of feedstocks that meet agribusiness needs. The team also investigates novel harvest and transport systems and evaluates harvest and supply chain costs as well as technologies for efficient deconstruction and drying of feedstocks.

Co-Project Directors

- Kevin Shinners, University of Wisconsin, kjshinne@wisc.edu, 608.263.0756.
- Stuart Birrell, Iowa State University, sbirrell@iastate.edu, 515.294.2874.

Accomplishments – Year 3

Although the large round bale (LRB) will likely be the dominant package for perennial grasses, as yield increases, so does the number of bales per unit area and the aggregation costs. We investigated a "giant round baler" (GRB) concept that created bales that weighed 3 to 4 times that produced from the largest commercially available round baler, with as much as 2 tons of DM per bale. The GRB handled as well as conventional LRB and in some cases maintained their shape and weathered better than conventional LRB.

Although the LRB will likely be the dominant package form for perennial grasses, round bales have some disadvantages compared to large square bales (LSB). Chief among these are lower density and less favorable cross-section –both of which lead to less than optimum transport weight. We have developed a process that compacts the LRB and reshapes it into a parallelepiped or cuboid shape similar to a LSB. We have collected force and pressure data to calculate the energy input and provide needed design data for future compression devices. The mechanism is able to reshape a round bale into a roughly square cross-section and increase the density from 9.5 to 13.5 lbs/ft^3. Power requirement for compaction is considerably less than with a LSB because densification occurs at a much slower rate.

A baler was modified to accumulate and strategically place bales at harvest. We have conducted additional data collection comparing alternative methods of handling bale-gathering logistics to aggregate bales. Different accumulation schemes were compared with regard to aggregation time and wheel traffic. Although bale accumulation and strategic bale placement significantly reduced time, distance, and fuel consumption compared to random bale placement, the benefits were reduced as crop yield and number of bales per acre increased.

Single-pass balers (SPB) are now commercially available to harvest crop residues from the rear of the combine harvester. These balers are substantially different from conventional balers, so they cannot be used to harvest windrowed crops like perennial grasses. Because crop residues like corn stover and perennial grasses will both be harvested in the late fall; modifications to the

SPB that facilitate either baling with the combine or baling windrowed crops would allow greater utilization and dilution of capital costs. Therefore, modifications to a SPB have been made so baling either with the combine or with windrowed crops like perennial grass can seamlessly occur.

Work continued on quantifying energy requirements for size reducing perennial grass biomass. Gross size-reduction at the baler and keeping bales dry prior to grinding significantly reduced the energy required for grinding. Comparison of grinding energy of different biomass materials (corn stover, wheat straw; soybean straw) with that for perennial grasses was also quantified.

Planned Activities, Outcomes and Impacts – Year 4

Storage characteristics of perennial grasses as affected by storage scheme, bale size-reduction at harvest, and storage duration will be investigated. Comparisons will be made with corn stover because considerable literature on stover storage exists. Storage effects will be quantified by losses, compositional changes and grinding effectiveness and energy requirements.

If the market for perennial grasses is weak because of excess supply, then an alternative market could be developed if ruminant fiber digestibility of very mature grasses could be increased by amendment application. Therefore, we will be conducting small-scale experiments to determine the feasibility of increasing ruminant fiber digestibility of mature grasses.

Work will continue on bale compaction and re-shaping to quantify power requirements, productivity, bale density, bale expansion rate, and, and storage characteristics. Work will also continue to quantify the performance of a SPB when harvesting either crop residues with the grain combine harvester or windrowed crops like perennial grasses.

Final work on bale-size and biomass size-reduction will be completed and techno-economic modeling of different bale size, pre-cut and storage schemes will be conducted for comparison purposes.

Executive Summary – System Performance Metrics, Data Collection, Modeling, Analysis and Tools

This objective provides detailed analyses of feedstock production options and an accompanying set of spatial models to enhance the ability of policymakers, farmers, and the bioenergy industry to make informed decisions about which bioenergy feedstocks to grow, where to produce them, what environmental impacts they will have, and how biomass production systems are likely to respond to and contribute to climate change or other environmental shifts.

Co-Project Directors

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- Jason Hill, hill0408@umn.edu, 612.624.2692.

Accomplishments – Year 3

Our two most significant accomplishments this year were the publication of a featured policy piece "Federal agency models offer different visions for achieving Renewable Fuel Standard (RFS2) biofuel volumes" in Environmental Science and Technology (http://dx.doi.org/10.1021/es402181y) and the hosting of a workshop titled "Enhancing Mississippi Watershed Ecosystems with Perennial Bioenergy Crops," held jointly with the Mississippi River/Gulf of Mexico Nutrient (Hypoxia) Task Force" (https://www.biorenew.iastate.edu/watershedworkshop/).

Other major accomplishments include the successful defense of two doctoral students, the dissertations of whom covered ecosystem services related to water and a regional assessment of switchgrass production costs and returns. We also submitted for publication our research on regional changes in the biophysical exchange of carbon and water due to increased bioenergy production in the Midwest.

We also completed our first large scale scenario using the detailed SWAT model for the Upper Mississippi River Basin and the Ohio Tennessee River Basin with USGS 12-digit subwatersheds. The purpose of this modeling is to provide the ability to perform enhanced scenarios including greatly refined targeting scenarios to study placement of switchgrass and other biofuel crops in the landscape to evaluate to evaluate the water quality and carbon effects at the landscape level. This modeling system identifies the most cost-effective locations to target conservation investments, including the development of perennial feedstocks, to address the Gulf of Mexico hypoxic zone.

Planned Activities, Outcomes and Impacts – Year 4

We plan to continue our highly successful work on understanding the environmental impacts of the switchgrass-to-biofuel system both from a landscape perspective and from a life cycle perspective. We will (1) adapt existing biophysical models to best represent field trials and other data, and (2) adapt existing economic land-use models to best represent cropping system production costs and returns

Specifically, we are looking at the landscape level and wish to understand how placing switchgrass and other biofuel crops in the landscape affects environmental issues such as water quality and carbon flux. We will build on our recently completed large-scale scenario using the detailed SWAT model for the Upper Mississippi River Basin and the Ohio Tennessee River Basin with USGS 12-digit subwatersheds. The purpose of this modeling is to provide the ability to perform enhanced scenarios including greatly refined targeting scenarios. We will also continue our strong tradition of educating future bioenergy leaders in fields related to policy, water quality and the use of perennials in the landscape.

Executive Summary – Feedstock Conversion and Refining: Thermo-chemical Conversion of Biomass to Biofuels

The Feedstock Conversion and Refining Objective focuses on developing a detailed economic analysis of the performance of a refinery based on pyrolytic processing of biomass into liquid fuels. It also produces and provides biochar to other CenUSA researchers. The team concentrates on four primary goals:

- Develop a lignin catalytic (ZSM5) pyrolysis response model for various temperatures and catalyst to biomass ratios;
- Integrate the response data into a technoeconomic analysis model to assess the potential of converting perennial grasses, lignin and other biorefinery co-products to value-added fuels and identified chemicals via catalytic pyrolysis; and
- Provide technical and market targets to stakeholders of the commercialization objective; and
- Develop high value markets for the biochar co - product of biomass pyrolysis.

Co-Project Director

- Robert Brown, Iowa State University. 515.294.7943.

Accomplishments – Year 3

- Mild catalytic pyrolysis experiments indicate potential for biofuel yield improvements by improving the conversion effectiveness of both biomass monomers and oligomers.
- Bio-oil co-firing fuel (BCF) could reduce coal-fired power plant GHG emissions below the Clean Power Plan requirements at a competitive minimum electricity-selling price.
- Titanium hydrides and zeolite catalysts could in combination improve hydrocarbon yields from lignin catalytic pyrolysis.
- Zeolite-based catalytic fast pyrolysis can yield aromatic hydrocarbons from lignin-derived monomers as effectively as carbohydrate-derived monomers.
- Transportation fuels derived from herbaceous biomass fast pyrolysis have a lower estimated biofuel cost ($2.70/gal) than woody biomass catalytic pyrolysis derived fuels ($3.65/gal).

- Inorganic phases including calcite and sylvite were found to be present in acid-washed biochars by X-ray diffraction. The evidence that these mineral phases were not removed from the biochar by the acid washing treatment suggests that some inorganic phases may become occluded inside of biochar. Such occluded mineral phases may slow or prevent the release of some (a small fraction) plant nutrients that are present in biochar.

- Anion exchange capacity (AEC) of various biochars was found to vary from 0.602 to 27.76 cmol kg^{-1}. The AEC generally increased with decreasing pH and increasing with pyrolysis temperature. High AEC biochars have the potential to be used for high value industrial and environmental applications; hence development of a capacity to produce high AEC biochar would add value to a pyrolysis plant.

- Research on the impact of oxidation treatments on the anion exchange capacity (AEC) of biochars was completed. Biochars produced at 700 °C exhibited a lower decline in AEC following the oxidation treatments in contrast to biochars produced at 500 °C. The AEC of an alfalfa meal biochar produced at 700 °C did not change significantly following oxidation. Stability of AEC in the high temperature alfalfa meal biochar is attributed to the highly condensed aromatic character of carbon in this biochar. Developing biochars with high AEC that is stable under harsh conditions is important for many potential industrial and environmental applications.

Planned Activities, Outcomes and Impacts – Year 4

- Conduct techno-economic analysis on scenarios including pyrolysis of perennials and biorefinery co-products.

- Micro-scale mass balance analysis to determine the monomeric and oligomeric composition of lignin fast pyrolysis bio-oil.

- Zeolite acid site characterization to analyze their effect on pyrolysis coking and depolymerization phenomena.

- Zeolite catalyst development to improve lignin conversion yields and selectivity. Characterization of aluminum moieties formed in pyrolysis. The aluminum-amended biochars have potential use as a Claus catalyst, which is industrially important for the removal of hydrogen sulfide from natural gas and various petroleum products.

- Investigation of potential high-value applications for high anion exchange capacity (AEC) biochars. High AEC biochars also have the potential to be utilized in potable water treatment for removal of various contaminants such as low molecular weight organic acids, which are known to contribute to the formation of toxic by-products in water distribution systems.

- Continuation of a cooperative study with the City of Des Moines, Iowa Water Works (DMWW). We have determined that acetate is a major downstream organic contaminant. We will investigate the use of high AEC biochars for removal of acetate from potable water.

Planned Research Impacts

- Determine economic feasibility of and highlight cost improvement opportunities for pyrolysis and catalytic pyrolysis biorefineries.
- Determine methods to convert lignin into biofuels and bio-based chemicals effectively using the catalytic pyrolysis pathway.
- Identify potential high value applications for the biochar co-product of bioenergy production.

Planned Research Outcomes – Publications on the following topics

- Applications of metal hydride as a lignin deoxygenating catalyst
- Effects of zeolite acid site morphology on the catalytic pyrolysis of lignin
- Lignin catalytic pyrolysis with zeolite catalysts modified with metal promoters
- Characterization of aluminum moieties formed in pyrolysis
- Potential high-value applications for high anion exchange capacity (AEC) biochars
- Stability of biochar anion exchange capacity in harsh oxidizing conditions

Executive Summary – Markets and Distribution

The Markets and Distribution objective recognizes that a comprehensive strategy to address the impacts to and requirements of markets and distribution systems will be critical to the successful implementation and commercialization of a regional biofuels systems derived from perennial grasses grown on land unsuitable or marginal for the production of row crops. To develop this strategy the team focuses on two unifying approaches:

- Evaluation of farm-level adoption decisions, exploring the effectiveness of policy, market and contract mechanisms to facilitate broad scale voluntary adoption by farmers; and
- Estimate threshold returns that make feasible biomass production for biofuels.

Co-Project Directors

- Dermot Hayes, Iowa State University, dhayes@iastate.edu, 515.294.6185.
- Keri Jacobs, Iowa State University, kljacobs@iastate.edu, 515.294.6780.

Accomplishments – Year 3

In Year 3, we made progress on multiple fronts, including investigations into threshold returns of perennial grasses, incorporating real option values into analyses of returns to switchgrass production, and continuation of survey efforts of producers to understand adoption decisions. Specifically, we had the following major outputs:

- Richard Perrin and a graduate student completed a study of the potential impact of higher grain and hay prices on the allocation of crop acreage (Megeressa, 2013, *Impact of Biofuel Demand on Land and Water Use in the Great Plains*). The study finds that substantial incentives will need to be paid to grass biomass producers to divert significant acreages from current row crop rotations.
- Keri Jacobs presented CenUSA project information and objective findings at the 2013 Integrated Crop Management conference and administered a survey to participants to elicit information about knowledge of perennial grasses and willingness to adopt practices. The survey findings were presented at the CenUSA annual meeting.
- Jacobs delivered the CenUSA webinars: *Competition for land use: Why would the rational producer grow switchgrass for biofuel?* to three separate audiences.
- Hayes (Co-PD) published project-related research in Energy Policy, Economics Research International, and Biomass & Bioenergy.

Planned Activities, Outcomes and Impacts – Year 4

In Year 4, we will continue to explore the market for perennial grass production using updated production costs and returns, land-competition factors, and potentially available incentives and programs designed to increase participation in the market. In particular, we plan to exploit survey information from producers and existing federal conservation program data to estimate the biomass production potential under various pricing and contract scenarios in the central United States. In this analysis, we account for trade-offs in land use change and producers' potential willingness to accept lower returns from perennial grass production when environmental and conservation benefits are accounted for in the decision. Additionally, we will continue work with Rob Mitchell (Co-PD of Objective 2, Feedstock Production) to develop a decision tool that producers use to evaluate the potential for their land under perennial grass production when corn, soybean, and hay are alternative crops.

Executive Summary – Health & Safety

The production of bioenergy feedstocks will have inherent differences from current agricultural processes. These differences could increase the potential for workforce injury or death if not properly understood and if effective protective counter measures are not in place.

The Health and Safety team addresses two key elements in the biofuel feedstock supply chain:

- The risks associated with producing feedstocks; and
- The risks of air/dust exposure.

Co-Project Directors

- Chuck Schwab, Iowa State University, cvschwab@iastate.edu, 515.294.4131.
- Mark Hanna, Iowa State University, hmhanna@iastate.edu, 515.294.0468.

Accomplishments – Year 3

We have complied an extensive listing of actions that outlines the various steps to produce biofeedstock that will be the foundation of any risk assessment approach. While additional actions can always be added to the compiled list, we deemed our efforts complete enough to begin risk assessment modeling.

Saxon Ryan, a new graduate student joined the team replacing the existing Ph.D. student. He will be working primarily on the developing the risk model comparing differences between the two production operations, collecting the model data, and performing the risk calculations.

We adopted a standardized procedure of using three sources for injury data from risk assessment procedures by EPA. We have started validating the risk model terms and procedures to known standards was started.

The air sampling equipment was identified and the few sites for sampling have been identified. Human subject's approval for the second year was obtained.

Planned Activities, Outcomes and Impacts – Year 4

- Injury and exposure database will be populated with data from three sources and specific logic filters will be crafted to create necessary values needed for risk model calculations.

- Multiple risk model calculations will be performed and analyzed with results shared in a professional conference presentations and a possible paper.
- We will continue refinement of our baseline assessment of potential hazards.
- Specific modifications to the human subjects study will be made and approval pursued. The necessary air sampling equipment from vendor will be placed into service. Human subjects to participate in the study will have been recruited.
- The Master Gardeners' safety precautions for storing, handling and applying biochar publication will be integrated into one or more communities of practice (CoP) with eXtension with the target CoP being Ag Safety and Health and master gardeners second.
- We will continue to our develop relationship with NewBIO project collaborators from Penn State University (another USDA NIFA AFRI-CAP project) in the safety objective.

Executive Summary – Education

The Education Objective seeks to meet the future workforce demands of the emerging Bioeconomy through two distinct subtasks, as follows:

- Develop a shared bioenergy core curriculum for the Central Region of the United States.
- Provide interdisciplinary training and engagement opportunities for undergraduate and graduate students.

Co-Project Directors

- Raj Raman, rajraman@iastate.edu, 515.294.0465.
- Patrick Murphy, ptmurphy82@gmail.com, 765.494.1175.

Major Accomplishments – Year 3

- **On-line Curriculum Development.** We developed content for two modules in the markets and distribution objective area and two modules in the feedstock development objective area. We continued evaluation activities for existing modules, including analyzing data collected during Year 2.

- **Undergraduate Internship.** We successfully placed and mentored 16 undergraduate students at CenUSA institutions: Iowa State University (8 interns); University of Nebraska, Lincoln (4 interns); University of Minnesota (1 intern); Purdue University (2 interns); Archer Daniels Midland (1 intern) from May 28 – August 2, 2014.

- **Graduate Research Webinar Series.** The seminar series required students to explain how their research fits into the broader goals of the project, thereby creating a transdisciplinary-learning environment for graduate students involved in the project.

Planned Activities, Outcomes and Impacts – Year 4

- **On-line curriculum course modules.** Content for modules in the sustainable production systems, feedstock logistics and conversion objectives areas will be developed this year. Evaluation activities for the existing curriculum will be summarized in a case-studies article.

- **Continue the summer internship program.** In 2015, the program plans to host 20 undergraduate interns, with a diverse group of students representing institutions from throughout the country.

- **Graduate Intensive Program.** Working with objective leaders at the University of Wisconsin – Madison, offer a one-day condensed graduate intensive program add-on to the annual meeting. Plans include a proposed career-fair or similar activity with industry, tailored to grad students, plus other proposed high-value activities such as a tour of some GLBRC facilities and research plots. The graduate students will see a range of biomass research that is quite different from that in CenUSA, covering a range of topics from production/sustainability all the way to conversion processes.

- **Revamp the graduate research webinar series into a panel-based series entitled Conversations About Critical Issues.** Restructure and refocus the delivery of research webinar content. Consider four 1-h sessions spread over the academic year. Each session would have several CenUSA objective leaders or collaborating faculty discuss an issue meant to be mildly controversial so that multiple viewpoints can be presented. We are essentially hoping to stimulate intra-project conversations with a grad-student audience to illuminate the various approaches to critical issues within the project.

Executive Summary – Extension and Outreach

The Outreach and Extension Objective serves as CenUSA's link to the larger community of agricultural and horticultural producers and the public-at-large. The team delivers science-based knowledge and informal education programs linked to CenUSA Objectives 1 - 8 and 10.

Co-Project Directors

- Jill Euken, jeuken@iastate.edu, 515.2946286.
- Sorrel Brown, mailto:sorrel@iastate.edu, 515.294.8802.

Accomplishments – Year 3

The Extension Staff Training/eXtension/Communications Team produced the following from August 1, 2013 through July 31, 2014.

Fact Sheets

- Switchgrass (*Panicum virgatum*) for Biofuel Production
- Control Weeds in Switchgrass (*Panicum virgatum*) Grown for Biomass
- Plant Breeders Create New and Better Switchgrass Varieties for biofuels
- Successfully Harvest Switchgrass Grown for Biofuel
- The Economics of Switchgrass for Biofuel
- Competition for Land Use: Why would the rational producer grow switchgrass for biofuel?

Research Summaries

- Near Infrared (NIR) Analysis Provides Efficient Evaluation for Biomass Samples
- Research Find Strong Genetic Diversity in Switchgrass Gene Pools
- Minnesota Watershed Nitrogen Reduction Planning Tool
- Storing Perennial Grasses Grown for Biofuel
- Biofuel Quality Improved by Delaying Harvest of Perennial Grasses

Instructional Video

- Enhancing the Mississippi Watershed with Perennial Bioenergy Crops

Webinars

- The Renewable Fuel Standard and RINS Markets
- Anticipating Impacts of RFS 2014 Volumes on Corn and Soybean Prices

The team also produced three issues of BLADES newsletter (February, April, June).

During Year Three of the project, these materials, and those produced in Years 1 and 2, have had the following usage:

- CenUSA Fact Sheets and Research Summaries have had 3,492 views by 2,203 viewers
- Vimeo: CenUSA videos have had 693 plays and 9,335 loads
- YouTube: CenUSA videos have had 6,158 views
- CenUSA web site and Facebook: 3,047 visitors/followers

The **Producer Research Plots/Perennial Grass/Producer and Industry Education Team** has:

- Worked with producers/farm managers to maintain nine on-farm demonstration plots in Iowa, Minnesota, Nebraska, and Indiana.
- Collected data from the plots to share with CenUSA research team.
- Held field days/tours of the plots for a total of 277 participants.
- Hosted informational meetings for producers, reaching a total of 1,180 agricultural producers/consultants/industry leaders.

The **Economics and Decision Tools Team** has developed and released the *Watershed Nitrogen Reduction Planner Spreadsheet* and has the made significant progress on the web-based enterprise budget calculator.

The **Public Awareness/4-H and Youth Team** has:

- Developed an iPad app (C6) and piloted its use with over 350 youth/adults.
- Developed C6 curriculum/iBook/revised app and piloted with 330 youth/adults.
- Planned and executed 4-H science workshop and 4-H Round Up sessions.
- Developed and implemented switchgrass demonstration plots and learning materials at the Indiana FFA Center.
- Developed 4-H curriculum and school-based lessons and acquired licenses and software to host on-line youth education modules.

The **Public Education/Master Gardener Program** has:

- Established and maintained five biochar demonstration gardens.
- Collected data on various horticultural crops in the Extension Master Gardener demonstration gardens and developed exhibits/blogs/fact sheets/research summaries with data.
- Reached more than 5000 participants with garden tours, educational programs and exhibits about the CenUSA project and biochar.

The CenUSA Extension Administration team has:

- Provided leadership for the joint meeting held with the Mississippi River Hypoxia Task Force.
- Renegotiated budgets with each CenUSA Extension program in order to provide over $350K from the Extension line to support the CenUSA new commercialization objective.
- Developed four new outreach components as recommended by the CenUSA Advisory Board (feedlot trial with CenUSA switchgrass, evaluation of value proposition for alternative uses of switchgrass, and national training summit for Extension Educators, and CenUSA demonstration plots/outreach program at Vermeer Global Headquarters).
- Coordinated efforts of the various CenUSA Extension/outreach teams.
- Developed evaluation instruments for all the CenUSA Extension teams, summarized survey results and developed research reports and published results.
- Wrote Extension sections for CenUSA reapplication and quarterly and annual reports.

Planned Activities, Outcomes and Impacts – Year 4

- 75 extension educators and industry professionals will gain awareness and knowledge in bioenergy topics at the Extension Energy and Environment Summit September 23-26, 2014.
- Develop, produce and post additional CenUSA fact sheets, research summaries, videos, newsletters, blog posts and maintain twitter and Facebook accounts.
- 1,000 producers, industry leaders, educators, and agency personnel and 500 horticultural producers and industry leaders will gain awareness and knowledge regarding environmental, economic, and public relations impacts of transitioning marginal cropland to perennial grass and will understand the impacts of biochar as a soil amendment.

- Hold 20 educational meetings, conferences, workshops, field days, media events, and networking activities regarding perennial biomass production BMPs, biomass logistics, safety, processing, economics and BMPs for using biochar as a horticultural soil amendment.
- Utilize "citizen science" program to promote shared learning about the impacts of perennial grass agriculture on ecosystems; promulgate best management practices (BMPs).
- Finalize C6 curriculum, iBook app and youth learning modules re: perennial grasses, carbon cycling, and biochar utilization. Train 100 adults in use of the materials; 1000 youth will utilize the materials and will demonstrate increased learning about renewable energy and STEM careers.

Agro-ecosystem Approach to Sustainable Biofuels Production via the Pyrolysis-Biochar Platform (AFRI-CAP 2010-05073)

Annual Report: August 1, 2013 – July 31, 2014

Project Administration, Project Organization and Governance

Ken Moore (Professor, Iowa State University) continues as the CenUSA Bioenergy Project Director with Anne Kinzel as the Chief Operating Officer. Jill Cornelis (ISU Bioeconomy Institute) provides assistance with project financial matters.

Beginning in Year 4 we will operate under our revised organization chart (See Fig. 2) that reflects the addition of Objective 10 (Commercialization). Our team plan-of-work includes continuing our regularly scheduled Co-Project Director meetings, holding our annual all-hands meeting, and scheduling and holding the Advisory Board meeting. We will also continue our multi-modal/media communication plan that we strengthened in Year 3. This includes a mixture of social media, an enhanced web site, and the quarterly publication of BLADES.

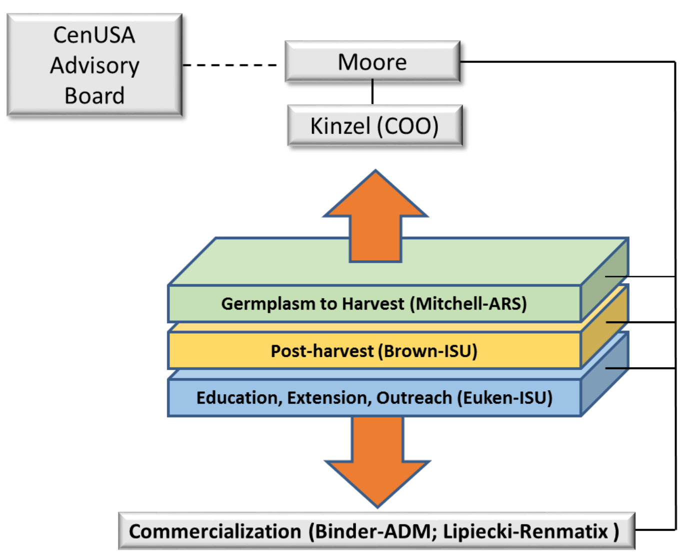

Fig. 2. Revised CenUSA Organizational Chart

Anticipated outcomes for Year 4 include the continuation of what has proven to be a successful and effective administrative plan that encourages and values team contributions, an enhanced public profile, and actions taken on the advice of the Advisory Board.

Featured Activities

- We submitted the Year 4 reapplication package in late May 2014.
- CenUSA Co-Project Directors have worked to host the Year 3 Annual Meeting in Chaska, Minnesota (July 29- August 1, 2014).
- We continued preparing for the formation of the new Commercialization Objective (Objective 10) that debuted August 1, 2014.

▪ **Year 4 Reapplication**

We submitted our reapplication package in late May 2014 with the assistance of Lynn Jelinski (Sunshine Consulting), the grant specialist who had aided the team for the filing of the initial CenUSA application. While the work involved was extensive, the process allowed us to make necessary midcourse corrections and add a new Commercialization Objective (Objective 10). Tom Binder (ADM) and Frank Lipiecki have agreed to serve as Co-Project Directors for the new objective. (See Exhibit 5)

▪ **2014 CenUSA Annual Meeting**

The Year 3 Annual Meeting was held at the Minnesota Landscape Arboretum (Chaska Minnesota, July 30 - August 1, 2014). The focus was on our Extension and Outreach objective and the new Commercialization Objective. Extension Master Gardener "Citizen Scientist" volunteers led by CenUSA Collaborators Julie Weisenhorn and Lynne Hagen hosted the event.

The event was well attended, as 11 out of 14 Advisory Board members were present along with 42 CenUSA personnel. Thirty-three undergraduate and graduate students/post docs also attended . Fen Hunt, a USDA-NIFA Division of Bioenergy National Program Leader represented the funding agency. Mark Petri, director of the Iowa Energy Center and 10 Minnesota Extension Master were our guests (See Exhibit 6).

Having already held "all-hands" meetings in 2011 (Ames, Iowa), 2012 (Lincoln, Nebraska) and 2013 (West Lafayette, Indiana) we decided to change the format for our fourth meeting. The goal was to feature the work of our undergraduate students and our Extension and Outreach collaborators in a way that allowed for maximum interaction between all the different groups present at the meeting —the Advisory Board, twenty something undergraduate students and graduate students, CenUSA collaborators from both the Extension and academic environments, and members of the interested public as represented by the Extension Master Gardeners. We chose an informal "trade-show" format to maximize interaction. Our extension personnel staffed booths and our undergraduate student interns presented posters detailing their summer project (See Fig 3). The format did prove to be engaging as indicated by the annual meeting participant evaluation (Exhibit 7).

Fig. 3 CenUSA "Trade Show"

- **CenUSA Bioenergy Advisory Board**

In our third year we have been able to add two new advisory board members. Christopher Clark (EPA Global Change Research Scientist) adds significant expertise in the area of water quality and watershed management and Tom Shannon, Research Technical Leader (Kimberly Clarke Corporation) will provide commercialization expertise from the commercial pulp industry. We have asked the Advisory Board to share their impressions of the Annual Meeting and the state of the project as we enter our fourth year. Their input will be provided via a written set of comments that we will share in September 2014 at which time we will hold a virtual meeting with the CenUSA Co-Project directors and the Advisory Board (September 26, 2014).

- **Coordination, Collaboration, and Communication**

  - **Communication Team.** We have completely re-vamped our communications strategy by creating a dedicated Communication Team. Pam Porter from our Extension and Outreach Objective is the team leader. Team members include Extension and Outreach collaborator Amy Kohmetscher and undergraduate interns Kristin Peterson and Charlie O'Brien (Iowa State University) and Anne Kinzel (CenUSA COO).

    The team has created a communications strategy to make the project more visible among the biofuels/bio-products research community, commercial firms and the interested public. The key elements of the plan include:

    ✓ **BLADES.** The BLADES virtual newsletter for distribution to the interested public. The newsletter has been professionally designed and will be published bi-monthly. We use the Constant Contact communications platform to manage newsletter distribution. BLADES is directly emailed to a list that currently numbers 650 individuals and organizations. The newsletter is also available via the CenUSA website. Three issues have been distributed to date (February, April and June 2014) and have been well received. Our goal is to have 1000 interested individuals on our mailing list by December 31, 2014 (See http://blades-newsletter.blogspot.com/p/).

    Since publishing our first issue of *BLADES*, traffic to our web site has increased 261% over baseline and traffic to our video/webinar sites has increased by 111% as well. Analysis also shows BLADES has been significant in attracting additional visits to our website, YouTube and Vimeo webinar/video distribution channels as well as to our Twitter account and Facebook page.

    Our updated plan on adding the following outreach/communications efforts in the first and second quarters:

    ✓ A complete redesign of the CenUSA website.

    ✓ Creation of CenUSA Infographics.

    ✓ Monthly press releases on significant CenUSA activity to a growing regional media list.

- ✓ Expand and refine CenUSA Media List
- ✓ Develop short videos with CenUSA collaborators and students to share the CenUSA story on social media.

- **Executive Team Meetings and CenUSA Research Seminar.** The Co-Project directors representing each of the now ten objectives will continue to meet monthly with Ken Moore and Anne Kinzel via online meetings held in CenUSA's dedicated Adobe Connect meeting room. The virtual meeting room allows for documents to be viewed by all participants, enhancing communications and dialogue between participants. Tom Binder, the Advisory Board chair also attends these meetings, to ensure there is an Advisory Board presence during these important project gatherings.

- **Financial Matters.** The Administrative Team continues to monitor all project budgets and subcontracts to ensure adherence to all sponsor budgeting rules and requirements. We will also be working to implement the new Commercialization Objective budget.

Germplasm to Harvest

Objective 1. Feedstock Development

Feedstock Development focuses on developing perennial grass cultivars and hybrids that can be used on marginal cropland in the Central United States for the production of biomass for energy. In 2014, the focus is on the establishment of new breeding and evaluation trials.

1. Significant Accomplishments Summary

This research provides important information on the arthropods associated with bioenergy grasses and valuable information on the host suitability of switchgrass and other bioenergy grasses to four aphids within a system that has been largely overlooked and indicates that there are genetic differences among switchgrass populations for resistance. The ultimate goal of this project is to develop effective and sustainable management strategies for the key arthropod pests affecting switchgrass.

2. Planned Activities

- **Breeding and Genetics – ARS-Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**

- Conduct routine plot maintenance on all field trials and breeding nurseries.

- **Feedstock Quality Analysis (Bruce Dien – ARS Peoria and Akwasi Boateng – ARS Wyndmoor)**
- Complete processing the first 50 switchgrass samples (e.g. collected by Kenneth Vogel's laboratory) for ester and ether linked hydroxycinnamic acids (e.g. ferulic acid).
- Begin to apply hydrothermal biochemical assay to switchgrass samples.
- Conduct rechecks on prior year sample set as warranted by discussions with collaborator (A. Boateng).
- Submit manuscript with Gautam Sarath on relationships between germplasm properties and product yields.
- Switchgrass samples from Mike Casler's group will be analyzed by py-GC/MS. There are additional plans to understand the relationship between mineral content/ash content in the biomass and pyrolysis product yield. Analysis of mineral content in all switchgrass samples will be performed by ICP-OES.
- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
- A total of 160 pitfall and sticky board traps will be collected every two weeks from May to September in Nebraska and Wisconsin.
- Process samples to identify potential pests and beneficial arthropods and characterize their seasonal abundance.
- Complete screening studies for big bluestem and Indiangrass.

3. **Actual Accomplishments**

- **Breeding and Genetics – Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**

  Conduct plot maintenance on all field trials and breeding nurseries.

- **Feedback Quality Analysis (Bruce Dien and Akwasi Boateng)**
- Completed processing first 50 switchgrass samples (collected by Kenneth Vogel's laboratory) for ester and ether linked hydroxycinnamic acids (e.g. ferulic acid).
- Developed hydrothermal biochemical assay for switchgrass samples.

- Completed rechecks on prior year sample set.
- The manuscript written with Sarath was submitted to Bioresource Technology.
- Switchgrass samples from Mike Casler's group have been analyzed for non-catalytic and catalytic pyrolysis products by py-GC/MS. Ash content has been determined for all samples and ICP has been conducted on all samples to determine mineral content.
- **Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
- Currently sampling nurseries for insects and other arthropods (May – September).
- Processing samples from sampling Year 3 (8/1/2013 -7/31/2014) to identify potential pests and beneficial arthropods and characterize their seasonal abundance.
- Completed screening of big bluestem and Indiangrass cultivars and experimental lines for their susceptibility to greenbugs and sugarcane aphids.

4. Explanation of Variances

None to report.

5. Plans for Next Year

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**
- Conduct 2014 harvests for 12 field trials planted in 2012.
- Oversee harvest and data collection from 24 field trials planted at remote locations.
- Make selections and produce seed on 12 selection nurseries of switchgrass and big bluestem.
- **Feedstock Quality Analysis (Bruce Dien and Akwasi Boateng)**
- Analyze set of biomass samples that have and have not been pelleted to better understand the effect of pelleting on chemical composition.
- Begin to work on new samples as they become available.
- Continue analysis of switchgrass set for biochemical conversion using hydrothermal pretreatment.
- Prepare new manuscripts on switchgrass pyrolysis.

- Continue to analyze new diverse switchgrass samples to assist in the establishment of an NIR model.
- **Pathology and Entomology (Tiffany Heng-Moss and Gary Yuen)**
- Complete insect sampling for Year 3.
- Finish processing samples from Nebraska and Wisconsin to identify potential pests and beneficial arthropods and characterize their seasonal abundance.

6. **Publications / Presentations/Proposals Submitted**

- Boateng, A.A., Mullen, C.A., Saathoff, A.J., Sattler, S.E., Mitchell, R.B., K.P. Vogel & G. Sarath. (2014) Pyrolysis products in switchgrass germplasm bred for differences in biomass quality. Submitted to Bioresource Technology.
- Casler, M.D. 2014. Heterosis and reciprocal-cross effects in tetraploid switchgrass. Crop Sci. 54:2063-2069.
- Jahufer, M.Z.Z. & M.D. Casler. (2014). Application of the Smith-Hazel selection index for improving biomass yield and quality of switchgrass. Submitted to Crop Sci.
- Nichols, V.A., F.E. Miguez, M.E. Jarchow, M.Z. Liebman & B.S. Dien. (2014) Comparison of cellulosic ethanol yields from Midwestern maize and reconstructed tallgrass prairie systems managed for bioenergy. Submitted to Bioenergy Research

Objective 2. Sustainable Feedstock Production Systems

The Sustainable Feedstock Production Systems objective focuses on conducting comparative analyses of the productivity potential and the environmental impacts of the most promising perennial grass bioenergy crops and management systems using a network of 14 fields strategically located across the Central United States. The overarching goal is to produce a quantitative assessment of the net energy balance of candidate systems and to optimize perennial feedstock production and ecosystem services on marginally productive cropland while maintaining food production on prime land.

- **Iowa State University**

The establishment and growth of corn, switchgrass, and native perennial plants for the system plots on the Armstrong Research and Demonstration Farm system was monitored through the summer 2014. Greenhouse gas emissions from the system plots were monitored on a regular basis during the summer 2014. Soil moisture was monitored at four depths in each subplot every half hour throughout the 2014 summer season.

- **Emergence**

  We monitored plant emergence twice in May 2014 by using frequency grids and noting the presence/absence of grasses and dicots in 100 grid squares, with two replications counted in each treatment-plot. Shown below is plant emergence from 16 May. The results suggest that grass emergence was much higher in May 2014 than May 2013. Switchgrass plots (SG), which had a near-0% emergence in 2012 and were reseeded in 2013, exhibited similar or higher grass emergence than the high diversity (HD) and low diversity (LD) plots. Biochar treatments had little or no effect on emergence in 2014. As perennial grasslands establish, native plants should become more evident and produce appreciable amounts of biomass.

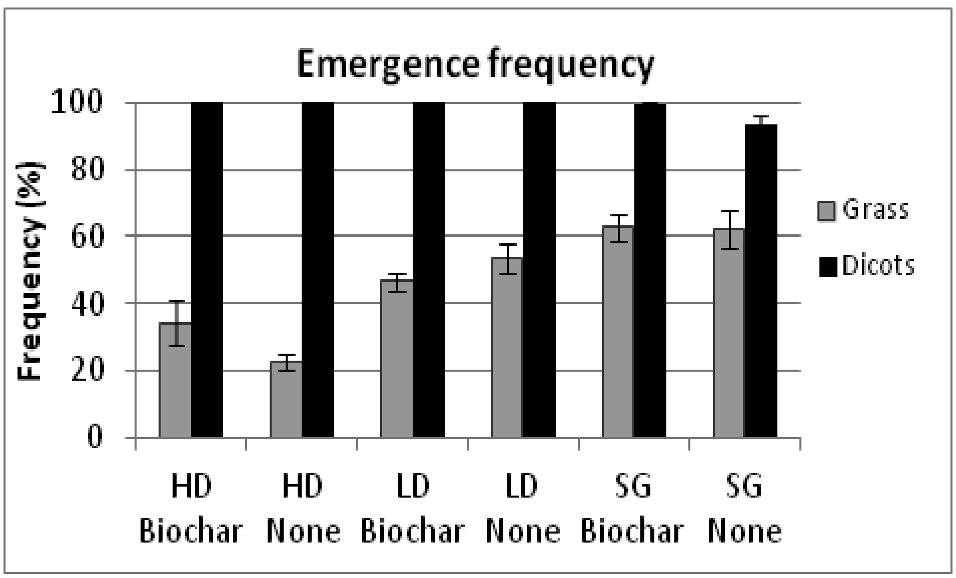

Fig. 4 Plant Emergence Frequency

- **Plant Species Composition**

  The relative percent cover of individual species was measured every 15 days, from the end of May through the beginning of June by randomly placing 0.25m^2 quadrats in plots. The results from four quadrats were averaged together, and two replications of this metric were taken in each treatment-plot. The results from the 13 June sampling are shown below. Compared to one year ago, the percent cover of weedy species is down in HD and LD plots. Sown species relative cover has increased in all plots, but particularly in switchgrass, which has caught up to the low diversity plots in spite of having to be replanted in spring 2013. High diversity plots have much lower sown species cover, and much of the sown cover is contributed by native dicots, with relatively few sown grasses present at this point. Similar to the emergence data, there appears to be no effect of biochar on general species composition.

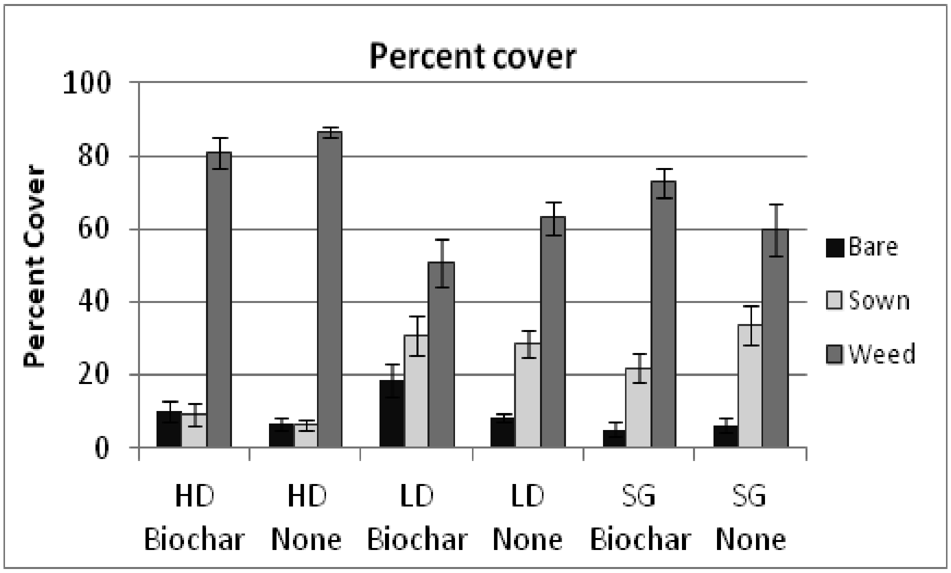

Fig. 5. Percent Cover

- **Light Transmission and Height**

Light transmission and canopy height were measured on 15 July in all plots, including maize. Light transmission was measured using an Accupar light bar. This measurement calculates the amount of light that passes through the canopy to reach the soil surface. Four readings were taken in each treatment-plot. Canopy height was taken at eight points in each plot. Shown below are the results. While corn was the tallest plant, it had only slightly higher rates of light transmission (more light reaching the soil). Native plant treatment or biochar had no apparent effect on canopy height or light transmission.

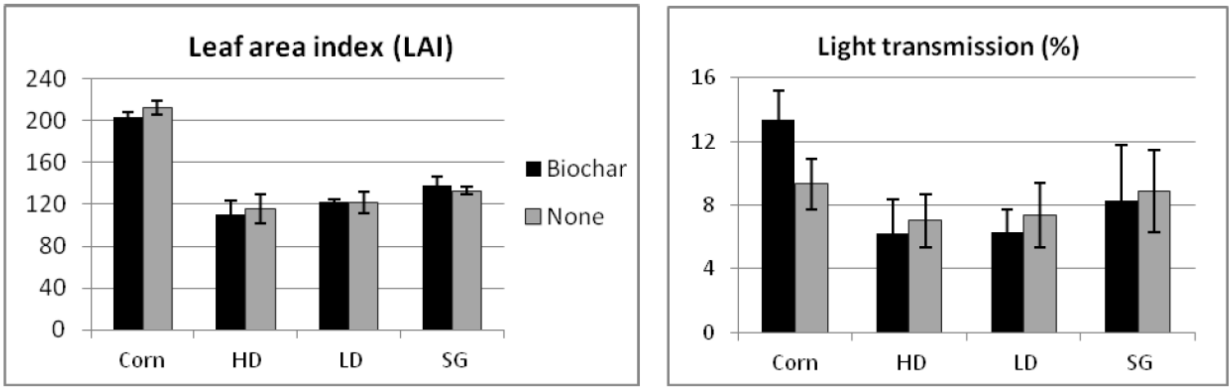

Fig 6. Leaf Area Index & Light Transmission

- **Peak Biomass**

Peak biomass was collected on August 8. Two, 0.25-m^2 areas were randomly selected, and plants were hand harvested, sorted to sown forbs, sown grasses, and unsown weedy species, then dried. Dry weights are shown below. Sown species composition has had a large impact on peak biomass. Weed biomass was much higher than sown biomass in high diversity plots, while in low diversity plots, grass biomass reached or exceeded weed biomass. In switchgrass plots, switchgrass biomass was almost 3-5 times higher than weed species biomass. However, there is no consistent effect of biochar on yields.

Work on plant establishment will continue into the fall, with a post-frost harvest planned that will estimate plant biomass available for biofuel purposes. While weed pressure remains high in the more diverse plots, native grasses in the low diversity and switchgrass plots are establishing and increasing in cover and biomass. Because of high weed pressure the high diversity plots were mowed at 16-inch height on August 19. This decision will greatly reduce 2014 post frost biomass yield but should reduce weed pressure during 2015. A decision was also made to spry the low diversity plots for weeds in spring 2015.

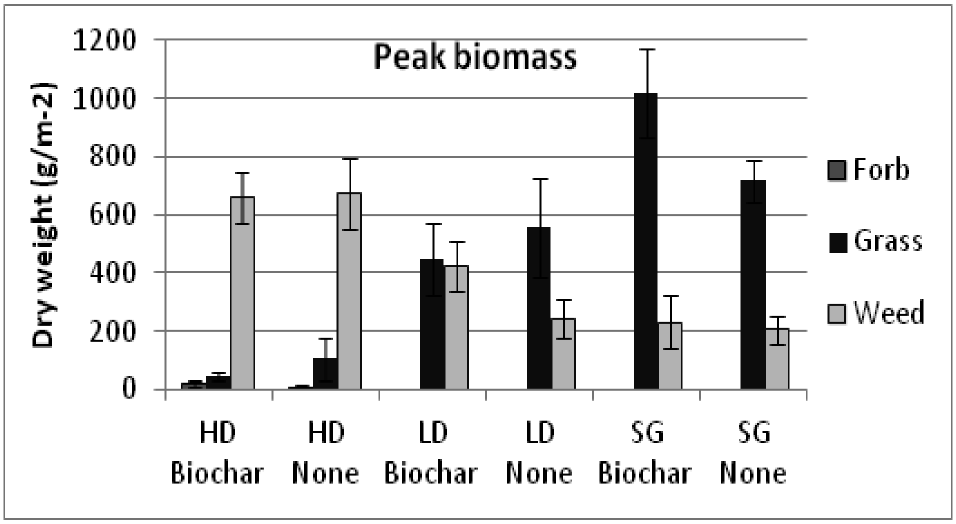

Fig. 7. Peak Biomass

- **Greenhouse Gas Emissions**

Four greenhouse gas-sampling pans were installed in each subplot in April 2014, and gas samples were collected 2-4 times per month, as appropriate, for a total of 14 sampling dates thus far. Gas samples will be collected at least one more time during the growing season, for a total of at least 15 sampling dates. Cumulative N_2O and CO_2 emissions were compute through July, and at that time it appeared that the effect of cropping system was significant, but the effect of biochar was not. N_2O emissions were positively correlated with N application rates, with the exception of the high and low diversity grass plots, which received the same amount of fertilizer as the switchgrass plots but exhibited significantly lower N_2O emissions.

Statistical analyses are ongoing, however, and other effects may yet be detected as data collection and analysis progress through the remainder of the season. The figures below (8a and b) show cumulative N_2O and CO_2 emissions averaged over each treatment (dashed lines indicate no biochar, solid lines indicate biochar; CC = continuous corn, SG = switchgrass, LD = low diversity, and HD = high diversity treatments).

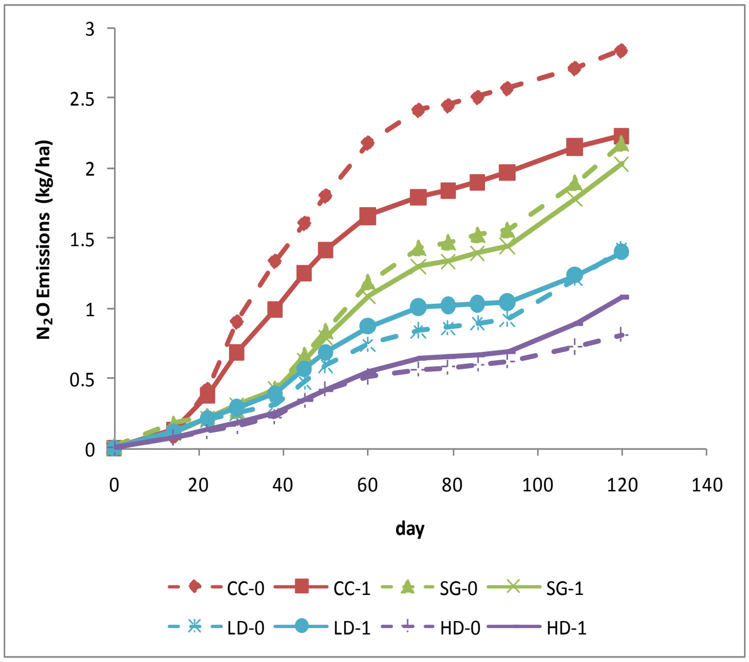

Fig. 8b N_2O Emissions

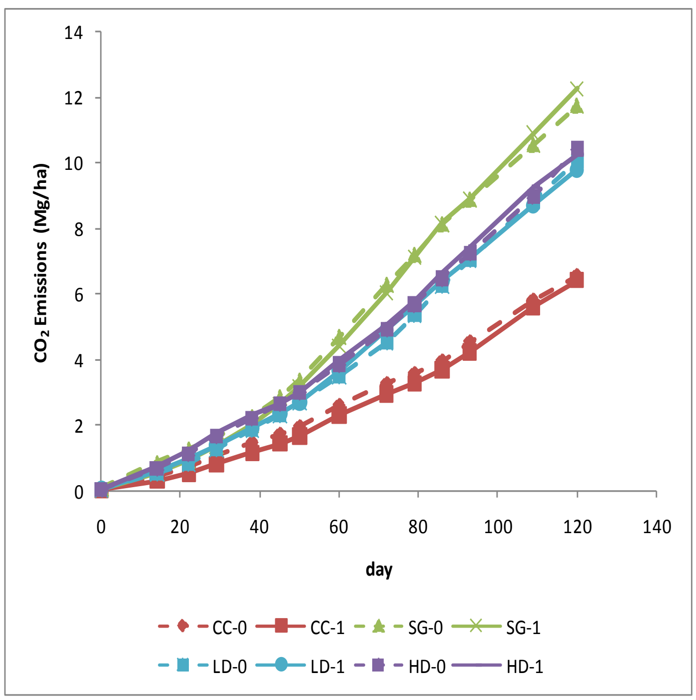

Fig. 8b CO_2 Emissions

- **Soil Moisture**

Moisture sensors were installed in each subplot at four depths (4, 10, 17, and 24 inches) during spring of 2013. The monitoring system is recording soil moisture content, temperature, and electrical conductivity every half hour. About 10% of the sensors failed during the 2013 growing season and several data loggers were damaged over the winter by deer. The failed sensors were replaced and the damaged data loggers were repaired during the spring, although a few additional sensors have failed during the 2014 season.

Figures 9a-d show average volumetric soil moisture content for the 4-inch soil depth from 6/1/13 through 7/1/14. The four cropping systems and biochar (1/green) and no biochar (0/red) treatments are distinguished. The gray region indicates standard errors for the biochar treatments estimated using a bootstrapping resampling (n=500) technique. Among the different cropping systems, the biochar treatment effect was significant only for corn. Monitoring of soil moisture is continuing and statistical analysis of other soil depths, cropping system and biochar effects is underway.

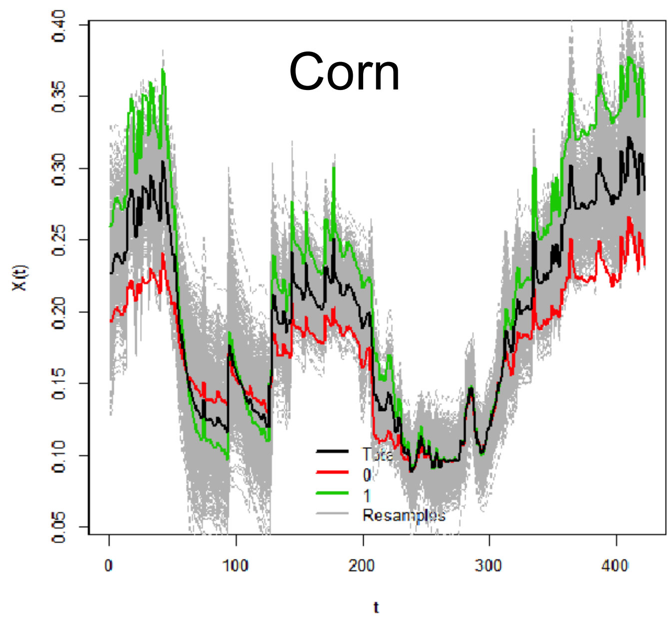

Fig. 9a Corn

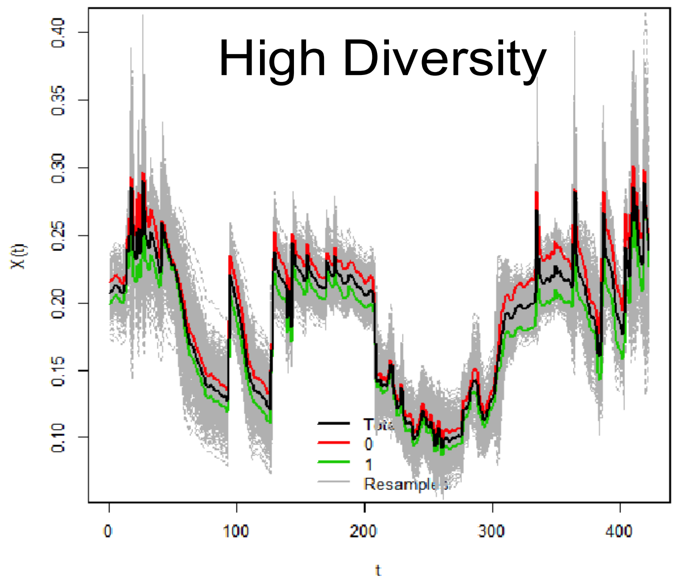

Fig. 9b High Diversity

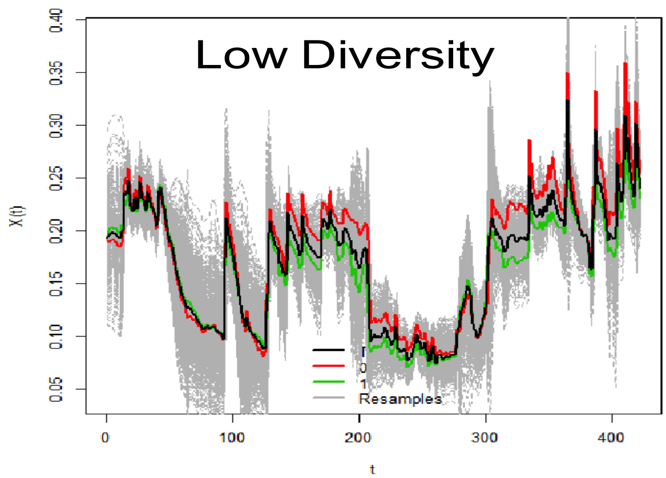

Fig. 9c Low Diversity

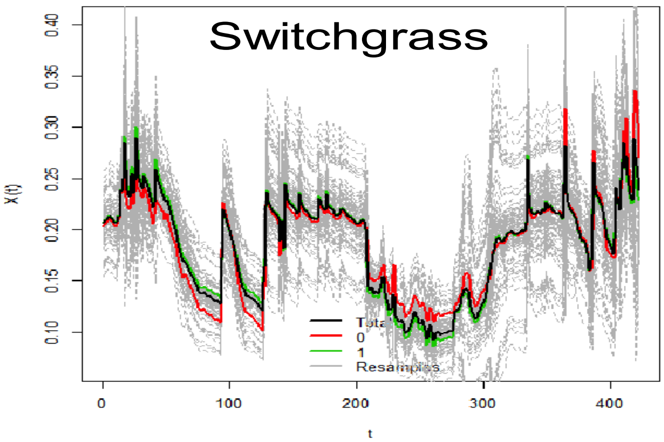

Fig. 9d Switchgrass

The figures 9a-d show average volumetric soil moisture content for the 4-inch soil depth from 6/1/13 through 7/1/14. The four cropping systems and biochar (1/green) and no biochar (0/red) treatments are distinguished. The gray region indicates standard errors for the biochar treatments estimated using a bootstrapping resampling (n=500) technique. Among the different cropping systems, the biochar treatment effect was significant only for corn. Monitoring of soil moisture is continuing and statistical analysis of other soil depths, cropping system and biochar effects is underway.

- **Purdue University**

Recent completion of mineral analysis permits evaluation of the relationships among soil and tissue nitrogen (N), phosphorus (P) and potassium (K) concentrations and productivity of understudied biomass systems. In addition, knowing biomass yield we are able to calculate nutrient removal in biomass; an important factor for understanding future fertilizer needs of these systems even when short-term effects of nutrients on yield are modest.

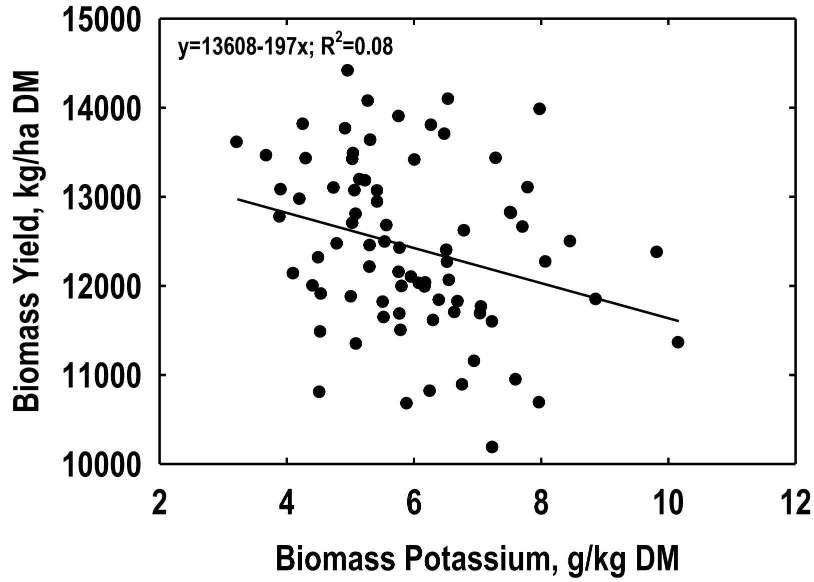

Fig 10. Impact of potassium (K) concentration in biomass on switchgrass biomass yield in 2013. Although there were large differences in tissue K concentrations, these were not closely related to biomass yield of switchgrass at Throckmorton Purdue Ag Center in 2013. Linear regression results are provided for informational purposes (not significant).

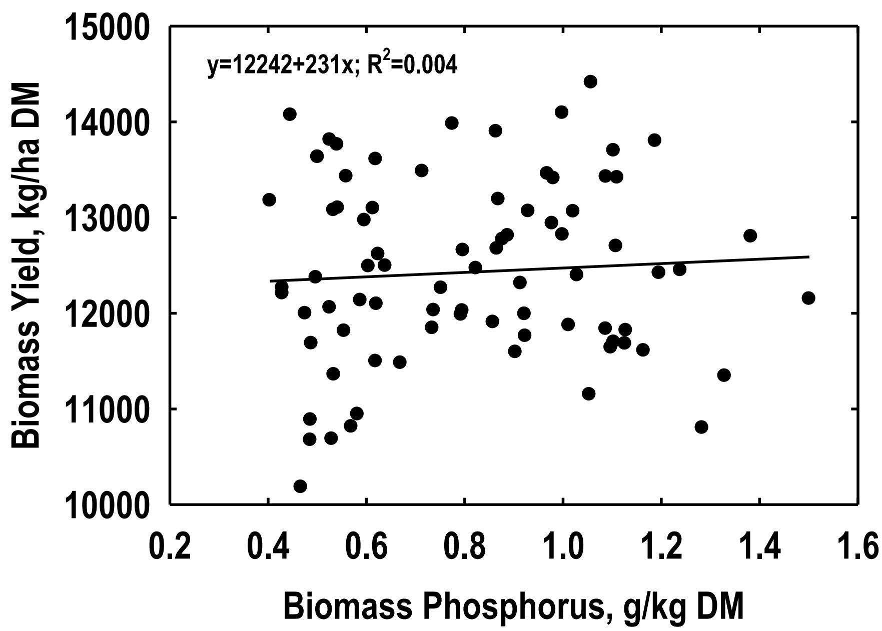

Fig. 11. Impact of phosphorus (P) concentration in biomass on switchgrass biomass yield in 2013. Although there were three-fold differences in tissue P concentrations, these were not closely related to biomass yield of switchgrass at Throckmorton Purdue Ag Center in 2013. Linear regression results are provided for informational purposes (not significant).

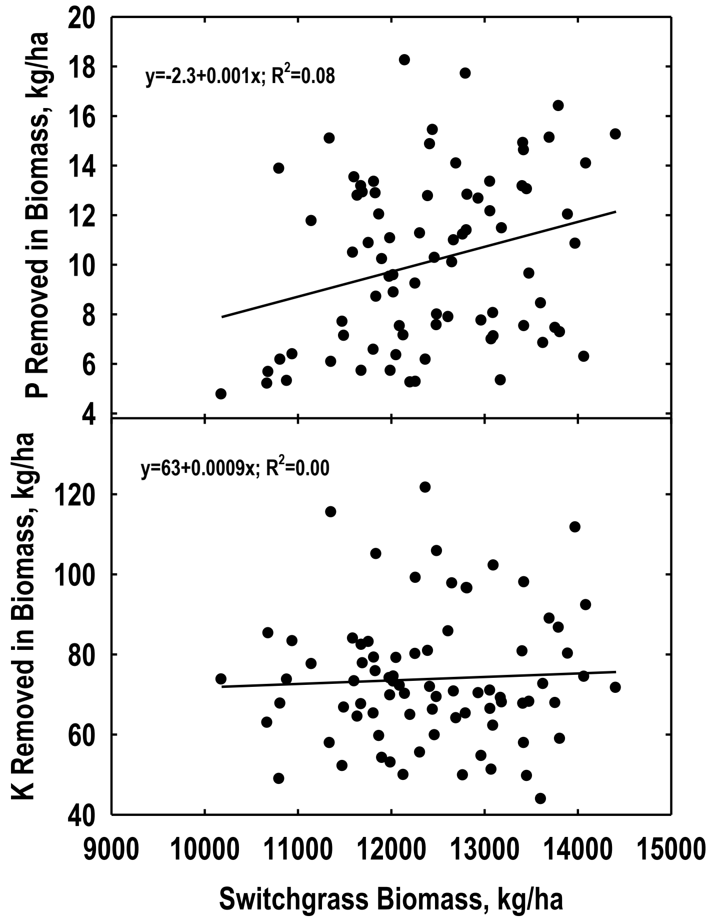

Fig 12. Impact of switchgrass biomass yield on removal of phosphorus (P) and potassium (K) in the biomass in 2013. Although there were large differences in yield, this was not an important factor influencing P and K removal and potential replacement via fertilizer application at Throckmorton Purdue Ag Center in 2013. Linear regression results are provided for informational purposes (not significant).

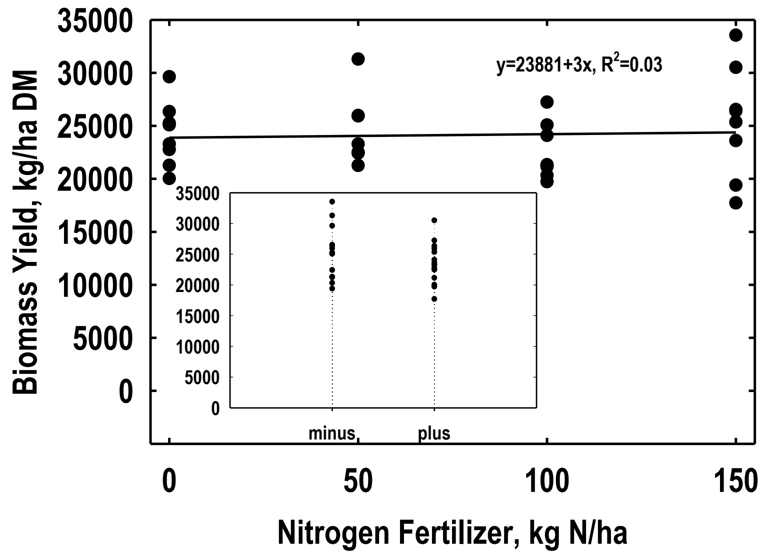

Fig. 13. Impact of nitrogen (N) fertilizer application on *Miscanthus* biomass yield in 2013. Insert shows the main effect of phosphorus (P, 75 kg/ha annually) and potassium (K, 300 kg/ha annually) fertilizer application ("plus") on biomass yield of *Miscanthus* averaged over N fertilizer rates. Although biomass yield varied nearly two-fold, these differences were not associated with fertilizer application at Throckmorton Purdue Ag Center in 2013. Linear regression results are provided for informational purposes (not significant)

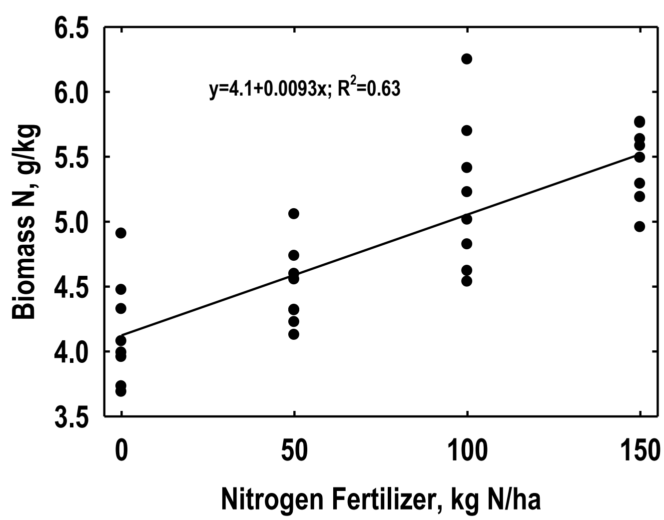

Fig. 14. Impact of nitrogen (N) fertilizer application on tissue N concentrations of *Miscanthus* biomass at the Throckmorton Purdue Ag Center in 2013. As expected, biomass N increased in a linear fashion as fertilizer N application increased from 0 to 150 kg N/ha/yr. Linear regression results indicate that 63% of the variation in tissue N was associated with N fertilizer rate.

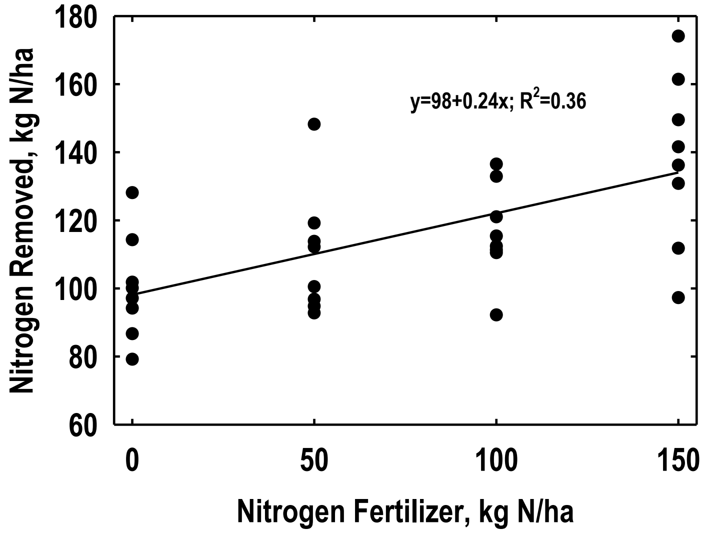

Fig 15. Impact of nitrogen (N) fertilizer application on N removal in *Miscanthus* biomass at the Throckmorton Purdue Ag Center in 2013. The N removal increased in a linear fashion as fertilizer N application increased from 0 to 150 kg N/ha/yr; a response associated with higher tissue N concentrations and not higher biomass yields. Linear regression results indicate that 36% of the variation in N removal in biomass was associated with N fertilizer rate.

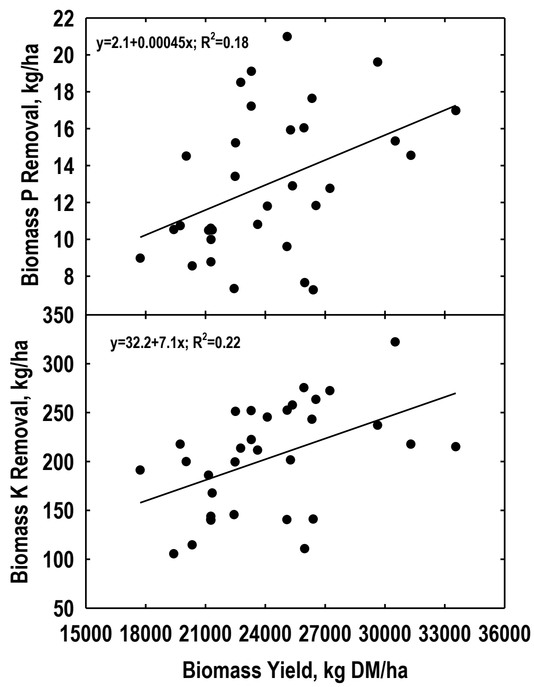

Fig 16. Relationship between *Miscanthus* biomass yield and removal of phosphorus (P) and potassium (K) in biomass at the Throckmorton Purdue Ag Center in 2013. For both nutrients, removal increased in a linear fashion as biomass yield increased, but these linear relationships accounted for a modest proportion (approximately 20%) of the variation in total nutrient removal in this biomass production system.

- **University of Illinois Urbana-Champaign**

  - **Factor Analysis Plots**

    ✓ Stand counts were measured in May 1, 2014 for both 2012 (reseeded in 2013) and 2013 plantings.

    ✓ Biomass was harvested in August 28, 2014. Only the "H1" plots (post anthesis stage) were harvested at this time.

    ✓ The next harvesting is planned for "H2" (after killing frost), and "H3" (Alternate H1 and H2 plots) within two weeks after the killing frost this fall.

Fig. 17. Harvesting H1 (post anthesis stage) plots for both 2012 & 2013 plantings were done August 28, 2014

  - **Comparison Field Trial**

    ✓ Plant height and light interception data were continued to take in the comparison field trial of Kanlow switchgrass (SW), IL ecotype big bluestem (BB), four populations of prairie cordgrass (20-107, 46-102, 17-109, 17-104), and Miscanthus x giganteus (Mxg).

    ✓ The plots will be harvested in late October 2014 with a combine harvester.

    ✓ Dry biomass will be calculated and tissue samples will be collected for chemical composition analysis.

  - **Abiotic Stress Trial**

    ✓ Growth measurements were periodically taken for prairie cordgrass and switchgrass growing on salt affected soil (EC>20 dS m^{-1}) in Salem, Illinois.

- ✓ The growth measurements were also taken in two poorly drained locations in Pana and Urbana, Illinois.
- ✓ Biomass will be harvested in late October 2014 in all three locations and the dry biomass weight as well as the chemical composition will be determined.

- **University of Minnesota**

The early harvests at Lamberton and Becker were completed on August 14 and 19, 2014, respectively.

- **Factor plots at Becker, MN**

Only H1 plots were harvested at Becker this year. Visually, growth was much better than last year as a result of abundant early and mid-season rainfall.

However, prior to harvest, we applied a moderate amount of irrigation to facilitate soil sampling for our metagenomic research. Sampling the loamy sand at Becker can be nearly impossible unless somewhat moist, and the very dry conditions in the weeks prior to harvest would have made soil sampling prohibitive without irrigation.

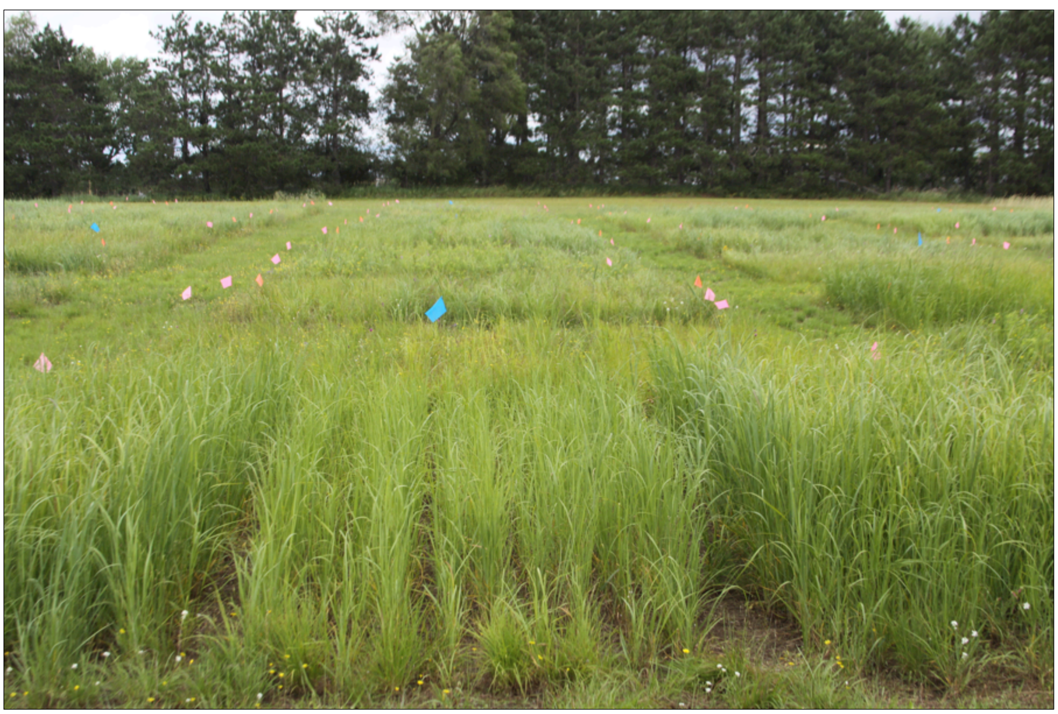

Fig 18. Becker plots on 17 July, prior to the start of a long dry period

Factor plots at Lamberton, Minnesota

Both H1 and H3 plots were harvested at Lamberton this year. Visually, growth was abundant and the grasses looked good.

Fig. 19. Factor plots at Lamberton, MN, immediately prior to August 19 harvest.

- **USDA-ARS, Lincoln**
  - **Factor Analysis Plots**
    - ✓ Fertilizer treatments were applied as scheduled.
    - ✓ Anthesis harvest treatments and sample collection were completed as scheduled.
    - ✓ Feedstock samples collected in 2012 and 2013 from Nebraska have been processed, scanned, and are being predicted.
  - **System Analysis Plots**
    - ✓ Fertilizer treatments were applied as scheduled.

- ✓ Broadleaf weeds in the perennial grasses required herbicides. The feedstock samples collected in 2012 and 2013 from Nebraska have been processed and are awaiting scanning and prediction.
- ✓ Greenhouse gas (GHG) sampling for the 2014 growing season continues. Soil water content and GHG have been sampled at weekly intervals in the System Analysis plots to compare the perennial grass feedstocks and N rate to continuous corn. 2013 data are being summarized.
- ✓ Growing season harvests in the harvest height and harvest date study have been completed.
- ✓ Visual obstruction measurements for the 2014 growing season continue.

- **Biochemical and Thermochemical Evaluation.** Biochemical and thermochemical evaluation of switchgrass, big bluestem, and low diversity mixture pellets is in process to compare the composition of baled and pelleted material. Additional pellet projects are being conducted and others are being considered.
- **Loadrite**. Loadrite loader scale has increased bale-weighing precision and efficiency. We have expanded dialog with Loadrite to determine how commercialization may benefit them and are seeking additional collaborations.
- **New Demonstration Sites.** Planted and managed two herbaceous perennial feedstock research and demonstration sites in cooperation with Vermeer Manufacturing near Pella, Iowa.
- **New Feedstock Biomass Trial.** Planted an annual feedstock biomass trial to address potential for growing teff and biomass sorghum in a cropping system with wheat and oats.
- **Undergraduate Interns.** Four CenUSA interns collaborated on research with ARS Lincoln:
  - ✓ **Joel Bauer, Iowa State University.** Project title: *N2O Emissions of Perennial Grasses & Corn. Summary: Big bluestem had the lowest emission rates*. Based on Figure 20, N_2O emissions were 2.7, 3.4, & 5.1 times greater for corn than for SW, LDM, and BB, respectively (See Figure 20).

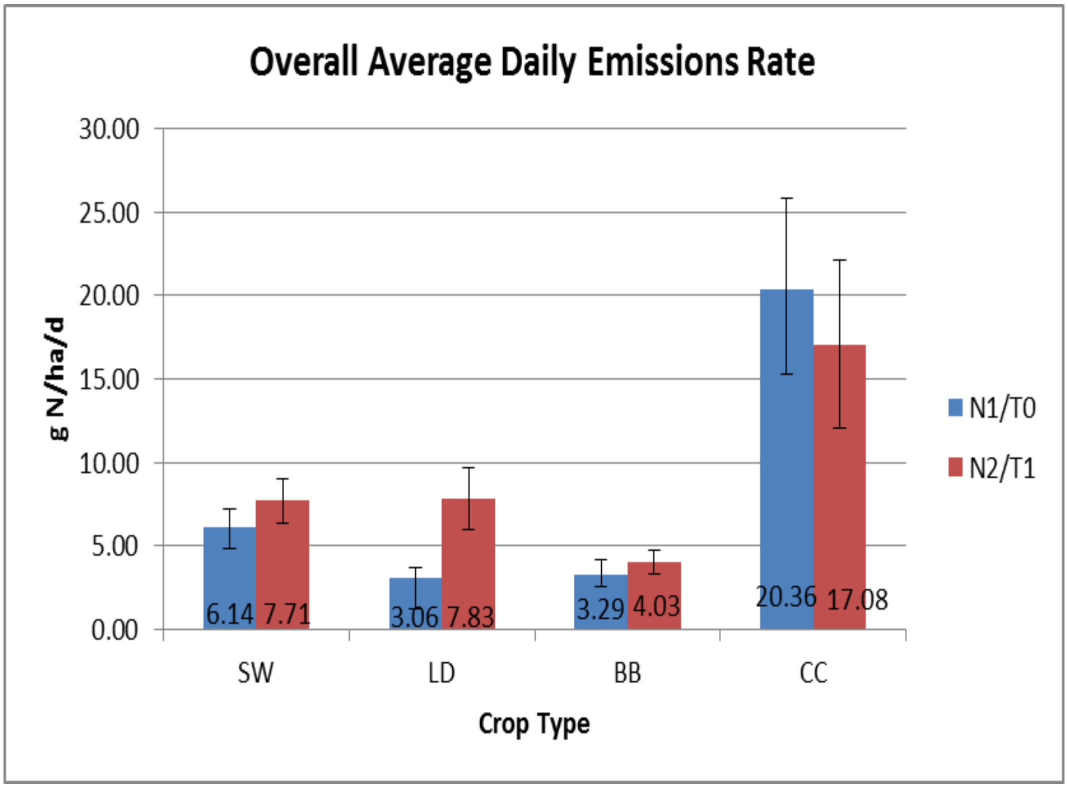

Fig. 20. Average daily N_2O emission rates for switchgrass (SW), low diversity grassland mixture (LD), big bluestem (BB), and continuous corn (CC) grown on marginally productive cropland in eastern Nebraska

- ✓ **Haley Chatelaine, College of St. Benedict.** Project title: *NUE of Switchgrass Grown on Marginal Cropland.* Summary: In 14 production years, August harvests had lower NUE & N economic efficiency (NEE) than harvesting after frost. Applying 60 kg N/ha had greater NUE and NEE than applying 120 kg N/ha. Applying 60 kg N/ha & harvesting after frost had the greatest NUE (89.5 kg of biomass per kg of N) & NEE ($5.63 of biomass for each dollar of applied N). See Table 1 for additional data.

Table 1. Nitrogen use efficiency (NUE) and nitrogen economic efficiency (NEE) for 14 production years of switchgrass grown for bioenergy in eastern Nebraska

Harvest Date	N Rate kg/ha	Biomass: Kg N	$ Biomass: $ N
August	60	57.6	3.62
August	120	47.7	3.00
Post frost	60	89.5	5.63
Post frost	120	66.5	4.18

- ✓ **Jackson Hambrick, University of Missouri.** Project title: *Farm to Pump: Nitrogen Fertilizer's Effect on Switchgrass Yield and Emissions.* Summary: Based on the GREET model, producing ethanol from switchgrass resulted in GHG emission reductions below the 60% threshold established by EPA for 0, 60, and 120 kg N/ha fertilizer rates. See Figure 21.

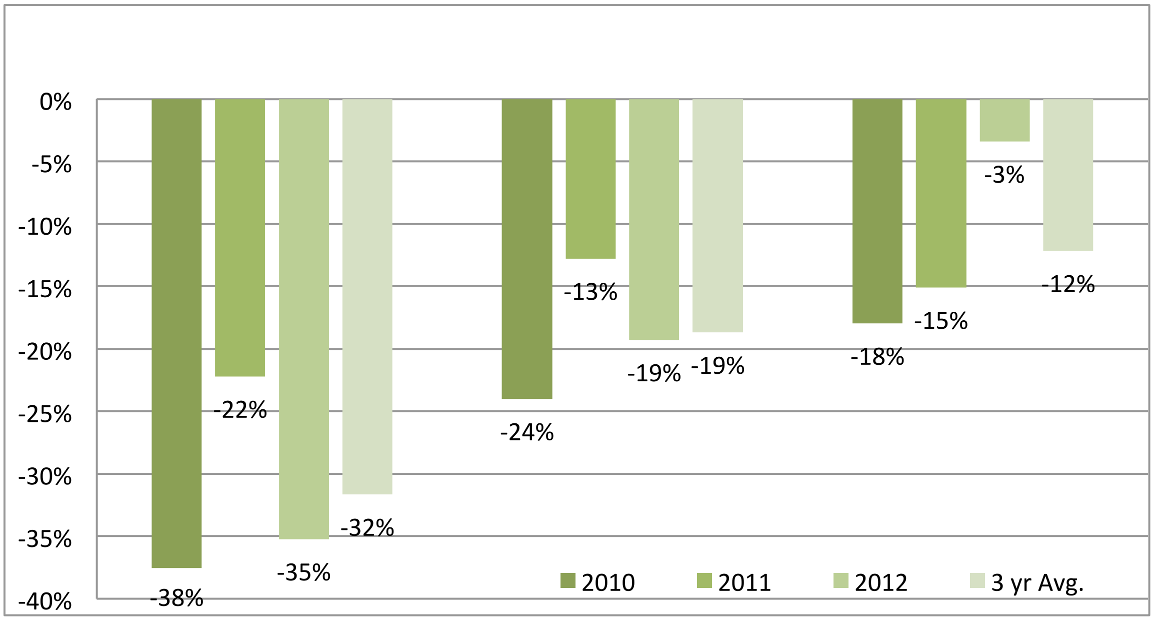

Fig. 21. Average greenhouse gas (GHG) emission reductions below the EPA 60% threshold for field treated with 0 (left), 60 (middle), or 120 (right) kg N/ha in eastern Nebraska.

- ✓ **Julie Juarez, University of California, Berkeley.** Project title: *Soil Matric Potential of Switchgrass Grown on Marginal Cropland.* Summary: Later harvest dates allow plants to grow for a longer period of time, resulting in greater soil water depletion and higher dry matter yields than early harvests. Annual variability in frequency and magnitude of precipitation and drought events will affect how harvest management decisions interact with soil water availability and switchgrass production.

- **Plans for Next Year**
  - ✓ Conduct field-scale harvests in the System Analysis plots, weight and transport bales.
  - ✓ Harvest Factor Analysis plots.
  - ✓ Plant triticale cover crop in continuous corn System Analysis plots.
  - ✓ Continue grinding, scanning, and predicting 2012 and 2013 biomass samples.

- ✓ Ship the first installment of biomass samples to Renmatix.
- ✓ Submit switchgrass and corn stover samples from long-term study for mineral analysis.
- ✓ Harvest Vermeer demonstration plots near Pella, Iowa.
- ✓ Harvest annual feedstock biomass trial and plant winter annuals.
- ✓ Harvest and ship switchgrass bales to Iowa feedlot feeding trial.

- **Publications, Presentations, and Proposals Submitted**

None

Objective 3. Feedstock Logistics

The Feedstock Logistics objective focuses on developing systems and strategies to enable sustainable and economic harvest, transportation and storage of feedstocks that meet agribusiness needs. The team also investigates novel harvest and transport systems and evaluates harvest and supply chain costs as well as technologies for efficient deconstruction and drying of feedstocks.

University of Wisconsin

1. **Planned Activities**

Planned research activities included:

- Submission of manuscripts concerning results of grass drying systems and bale aggregation/logistics;
- Collection of post-storage size-reduction energy requirements of bales focusing on precision-cut chopping;
- Evaluation of compaction and re-shaping system for round bales;
- Field evaluate a large-bale size for packaging grasses; and
- Field operations to insure successful establishment of Liberty switchgrass at our research/demonstration field.

2. **Actual Accomplishments**

- We investigated a "giant round baler" (GRB) concept that would create bales that weighed about 3-4 times that produced from the largest commercially available round hay baler. The GRB produced very good bale shape from finely chopped grasses and other biomass. Bale shape was very good and bales could easily be handled without material loss from the bale face despite the finely chopped nature of the feedstock. Density of the GRB was 11.4 lbs/ft^3 at an average switchgrass moisture of 17% and average bale weight was 3550 lbs. We identified potential areas for improvement with the design and function of the GRB and shared these results with the manufacturer. The GRB bales are in storage and we are monitoring storage characteristics.

- We have developed a process that reshapes and compacts conventional size round bales into a parallelepiped or cuboid shape. We have begun bale compaction experiments to quantify compression forces, bale density, and bale expansion rate. Initial results have shown that less energy is required when the bale is compacted in both the vertical and horizontal directions as compared to trying to achieve the desired density by single axis compression. The material flow in the bale is more favorable during two-axis compression. Densities in excess of 18 lbs/ ft^3 were achieved in the press but the bale re-expanded to only 12 lbs/ft^3. This was still greater than the original round bale density of 9.5 lbs/ft^3 and the compressed bale had a more favorable square cross section, which will help use more of the transport trailer volume during shipping.

- Additional work was done to enhance the work done in 2013 on bale accumulation and bale size reduction. Experiments were conducted to investigate several variations of the bale accumulation schemes previously studied. Based on the results, the accumulation and aggregation schemes which produce the greatest benefit are those where large numbers of bales can be placed in strategic lines across the field. Random accumulation of groups of 3-4 bales do reduce aggregation time, but not to the extent that a line of 15-20 bales produces. Design work has started on a mechanism to unroll round bales so that they can be size-reduced with a forage harvester. We plan to test various biomass material using the precision-cut technique and compare energy requirements for grinding bales in a conventional tub grinder.

- Finally, we have rented 35 acres of marginal land in which establish mixtures of switchgrass, big bluestem, and indiangrass have been established. This land serves as a test site for our equipment and we have conducted outreach activities here as well. In this quarter we managed weeds and upgraded fertility on grasses established in 2013. Additionally, we established an additional 5 acres using the Liberty variety of switchgrass developed by cooperators Mitchel and Vogel. Weed control will be vital to improve this plot in 2015.

3. Explanation of Variance

We are slightly behind in completing manuscripts for publication. The manuscripts are written but additional data collected in this quarter need to be added to complete the conclusions.

4. Plans for Next Year

Our efforts in the next year will include:

- Submission of manuscripts concerning results of grass drying systems and bale aggregation/logistics;
- Continuing to collect post-storage size-reduction energy requirements of bales focusing on precision-cut chopping;
- Evaluating a compaction and re-shaping system for round bales;
- Conducting an extensive storage study comparing several different perennial grasses across several storage durations and storage methods; and
- To investigate amendments to switchgrass to enhance the feed value of the crop should market forces require that the grass be diverted from bioenergy uses.

5. Publications, Presentations, and Proposals Submitted

None

Iowa State University

In order to provide a continuous supply of biomass to biorefineries, harvest time and frequency must be optimized. Due to variation in harvest timing and frequency, the moisture content at the time of harvest may vary depending on the maturity stage of the crop. At young vegetative growth stage, moisture content of switch grass averaged 70% (wet basis) and declined to 40 to 50% (wet basis) after flowering and seed set stage. Moisture content can further decline to less than 10% (wet basis) after a killing frost. For safe biomass storage, moisture content of less than 18% is desirable.

1. Planned Activities

Planned research activities included:

- **Continued development of improved dry matter loss models.** Crop characteristics such as yield, stem diameter, leaf to stem ratio, and swath structure can increase or decrease the moisture migration during field drying. Faster drying rates are obtained during sunny days, high temperatures, and dry soil when there is a thin swath. Less favorable conditions and periodic rainfall delays the drying process. Generally field-drying time of grasses varies from 2 to 7 days. Drying time is reduced to 2 to 4 days when the grasses are spread in thin layers and weather conditions are favorable.

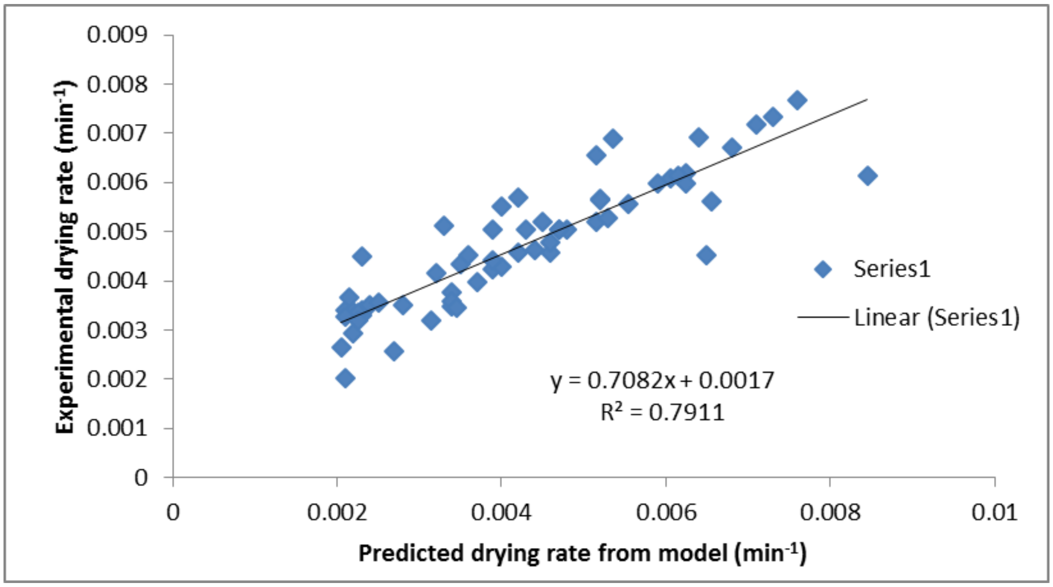

Fig. 22 Analysis of harvest and logistics data for large-scale harvest and transportation of biomass materials, including the effect of local and regional preprocessing of feedstock supplies. The Model predicted biomass-drying rates versus actual drying rate, based on Initial Moisture Content, Average Daily Solar Radiation, Wind Speed, Vapor Pressure Deficit and Material Density (i.e. Swath Density).

2. Actual Accomplishments

We have developed a model to predict the drying rate of biomass, based on environmental chamber data. A series of 27 drying rate experiments were performed based on past weather conditions in Iowa. The model included Initial Moisture Content, Average Daily Solar Radiation, Wind Speed, Vapor Pressure Deficit and Material Density (i.e. Swath Density) in the model. The model was successful in predicting the drying rate of biomass with a correlation coefficient of 0.79 (Figure 22). Field-testing of the model is in process for both switchgrass and corn stover to validate the model under field conditions.

Analysis of the effect of biorefinery scale on single and multiple source feedstock supply chain costs is continuing. The feedstock supply chain costs for refineries of different scales are being compared for single source supply chains (perennial grasses or corn stover) and multiple-source supply chains (perennial grasses and corn stover).

3. Explanation of Variance

We have experienced only minor variance in planned activities.

4. Plans for Next Year

Research activities planned during next year include:

- Field Testing and validation of the dry matter loss models in field harvest operations, including different field conditioning of biomass material.
- Analysis of field scale machine performance and logistics data for large-scale harvest and transportation of biomass materials.

5. Publications, Presentations, and Proposals Submitted

- Khanchi, A. & Birrell, S. (2014). Influence of rainfall level and crop density on dry matter loss from corn stover and switchgrass. Poster Presentation 2014 CenUSA Annual Meeting, July 30- August 1, 2014 Chanhassen MN.
- Prescott R. & Birrell, S. (2014). Analysis and Development of Biomass Densification Systems. Poster Presentation 2014 CenUSA Annual Meeting, July 30- August 1, 2014 Chanhassen MN.
- Khanchi, A. & Birrell, S. (2014). Influence of weather and swath density on drying rate potential of corn stover. Poster Presentation, Annual Midwest Post Doctoral Conference, May 2, Iowa City, IA.

Objective 4. System Performance Metrics, Data Collection, Modeling, Analysis and Tools

This objective provides detailed analyses of feedstock production options and an accompanying set of spatial models to enhance the ability of policymakers, farmers, and the bioenergy industry to make informed decisions about which bioenergy feedstocks to grow, where to produce them, what environmental impacts they will have, and how biomass production systems are likely to respond to and contribute to climate change or other environmental shifts.

We focus on four overarching tasks:

- Task 1. Adapt existing biophysical models to best represent data generated from field trials and other data sources
- Task 2. Adapt existing economic land-use models to best represent cropping system production costs and returns
- Task 3. Integrate physical and economic models to create spatially explicit simulation models representing a wide variety of biomass production options
- Task 4. Evaluate the life cycle environmental consequences of various bioenergy landscapes.

Iowa State University

1. Planned Activities

The first two broad tasks under the System Performance objective are to adapt existing biophysical models to best represent field trials and other data and to adapt existing economic land-use models to best represent cropping system production costs and returns.

2. Actual Accomplishments

We have completed our first large scale scenarios using the detailed SWAT model for the Upper Mississippi River Basin and the Ohio Tennessee River Basin with USGS 12-digit subwatersheds. A paper was accepted by the Journal of the European Agricultural Economics Association and was published this summer. In addition, the paper formed the basis for the plenary session of the world congress of the European Agricultural Economics Association held in Ljubljana, Slovenia in August. That paper describes the results of baseline and a conservation practice placement to evaluate the water quality effects at the landscape level. A second set of scenarios using the extended 12-digit model has been initiated using responses to a survey of farmers anticipated mitigation responses to climate change.

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Year

Continue to adapt existing biophysical models to best represent field trials and other data and to adapt existing economic land-use models to best represent cropping system production costs and returns. We are also developing scenarios of specific interest to the goals of CenUSA including the optimal placement of switchgrass to achieve a range of environmental improvements while producing energy.

5. Publications, Presentations, and Proposals Submitted

- Kling, C.L. (2014, July) Robust Optimization of Agricultural Conservation Investments to Cost-Efficiently Reduce the Northern Gulf of Mexico Hypoxic Zone. Presentation to the World Congress of Environmental and Resource Economists, Istanbul, Turkey.
- Kling, C.L., Panagopoulos, Y., Valcu, A., Gassman, P.W., Rabotyagov, S., Campbell, T., White, M., Arnold, J. G., Srinivasan, R., Jha, M.K., Richardson, J., Moskal, L. M., Turner, Gene & Rabalais, N. (2014). Land Use Model Integrating Agriculture and the Environment (LUMINATE): Linkages between Agricultural Land Use, Local Water Quality and Hypoxic Concerns in the Gulf of Mexico Basin. European Review of

Agricultural Economics, (2014): doi: 10.1093/erae/jbu009. Presentation to the World Congress of Environmental and Resource Economists, Istanbul, Turkey.

- Panagopoulos, Y., P. W. Gassman, R. Arritt, D. Herzmann, T. Campbell, M. Jha, C. Kling, R. Srinivasan, M. White & J. Arnold. (2014). Surface Water Quality and Cropping Systems Sustainability under a Changing Climate in the Upper Mississippi River Basin. Journal of Soil and Water Conservation. Forthcoming.
- Kling, C. L. Linking Externalities from the Land to their Consequences in the Sea: A Model of Land Use, Costs, Hydrology and the Gulf of Mexico Hypoxic Zone. Presentation to the Water Resources Conference, Saint Paul, Minnesota. Available on-line http://www.card.iastate.edu/presentations/linking_externalities_from_land_to_sea.pptx.
- Kling, C.L. (2013, October). Agricultural Water Pollution: Some Policy Considerations. Presentation to the Iowa Environmental Council Annual Meeting. Available at http://www.card.iastate.edu/presentations/iowa_enviornmental_council._oct_2013.pptx.
- Kling, C.L. (2013, August). Optimal placement of Second Generation Biofuels in a Watershed: Is Marginal Land the Answer? Presentation to the annual meetings of the Association of Agricultural and Applied Economics.
- Valcu, A.M. Agricultural Nonpoint Source Pollution and Water Quality Trading: Empirical Analysis under Imperfect Cost Information and Measurement Error. PhD dissertation, Iowa State University, 2013.
- Schilling, K.E., P.W. Gassman, C.L. Kling, T. Campbell, M. Jha, C.F. Wolter, & J.G. Arnold. (2013). The Potential for Agricultural Land Use Change to Reduce Flood Risk in a Large Watershed. Hydrological Processes. Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/hyp.9865

University of Minnesota

1. Planned Activities

Planned activities for this year include continued work on Task 1 (Adapt existing biophysical models to best represent data generated from field trials and other data sources), Task 2 (Adapt existing economic land-use models to best represent cropping system production costs and returns), Task 3 (Integrate physical and economic models to create spatially-explicit simulation models representing a wide variety of biomass production options), Task 4 (Evaluate the life cycle environmental consequences of various bioenergy landscapes), and Task 5 (Employ the modeling systems to study the design of policies to cost effectively supply ecosystem services from biomass feedstock production).

2. **Actual Accomplishments**

We continued wrapping up manuscripts on the topics of bioenergy crop yield gaps and switchgrass production costs. We submitted our manuscript on regional changes in the biophysical exchange of carbon and water due to increased bioenergy production in the Midwest.

3. **Explanation of Variance**

No variance has been experienced.

4. **Plans for Next Year**

Next year includes continued work on Tasks 1, 2, 3, 4, and 5.

5. **Publications, Presentations, and Proposals Submitted**

- Sun, J., Twine, T., Hill, J., & R. Noe. (In review) *Effects of crop expansion and conversion for corn ethanol on Midwest USA water and carbon budgets*. Submitted to GCB Bioenergy.
- Hill, J. "It really isn't easy being green: The Promise and Pitfalls of Building a Sustainable Bioeconomy" Oliver Smithies Lecture, Balliol College, University of Oxford, June 2014.

Post-Harvest

Objective 5. Feedstock Conversion and Refining: Thermo-chemical Conversion of Biomass to Biofuels

The Feedstock Conversion and Refining Objective will perform a detailed economic analysis of the performance of a refinery based on pyrolytic processing of biomass into liquid fuels and will provide biochar to other CenUSA researchers. The team concentrates on two primary goals:

- Estimating energy efficiency, GHG emissions, capital costs, and operating costs of the proposed biomass-to-biofuels conversion system using technoeconomic analysis;
- Preparing and characterizing Biochar for agronomics evaluations.

Sub-objective 1. Perform Technoeconomic Analysis

1. **Planned Activities**.

Further experimental studies will be conducted to generate input and assumptions for techno-economic analysis scenarios. Preliminary results indicate that lignin pyrolysis with zeolite catalysts could be improved with increasing hydrogenation activity. There are apparent limitations that constrain yields. Planned activities included:

- Conduct catalytic pyrolysis experiments with lignin model compounds to identify the limiting factors of using zeolites for lignin conversion; and
- Conduct experiments to understand the role of heat and mass transfer limitations of lignin catalytic pyrolysis using zeolites.

2. Actual Accomplishments

- **Lignin catalytic pyrolysis using metal hydride as a deoxygenating catalyst**

  This research demonstrated that the titanium hydride hydrogenation activity could convert most of the phenolics formed during lignin and creosol (phenolic monomer) pyrolysis. Titanium hydride thermo-gravimetric analysis (TGA) experiments indicate that hydrogen desorption occurs between 5250 °C and 6750 °C. The products of this process are mostly phenol, benzene and toluene. However, titanium hydride conversion yields to benzene, toluene and xylene (BTX) were lower than with zeolites. We were able to increase BTX yields by mixing titanium hydride with zeolites. Furthermore, the mixture of titanium hydride and zeolites improves the product H/C ratio due to the hydrogenation effect of titanium hydride. These results suggest that the combination of titanium hydride and zeolite catalysts could lead to improved hydrocarbon yields from lignin pyrolysis. Figure 23 shows the effect of mixing titanium hydride with zeolites in lignin catalytic pyrolysis.

- **Production of aromatic hydrocarbons from lignin using catalytic pyrolysis**

  This research demonstrates that lignin derived monomers are equally as effective as carbohydrate derived monomers in producing aromatic hydrocarbons via catalytic pyrolysis with ZSM5 zeolites. The summary for the in-situ and ex-situ comparison in the Frontier Tandem micropyrolysis reactor is as follows:

  ✓ No significant differences were observed for yields between in-situ and ex-situ runs for model compounds. While in some cases in-situ runs gave slightly lower yields, this may be due to mass transfer limitations inherent in the in-situ configuration.

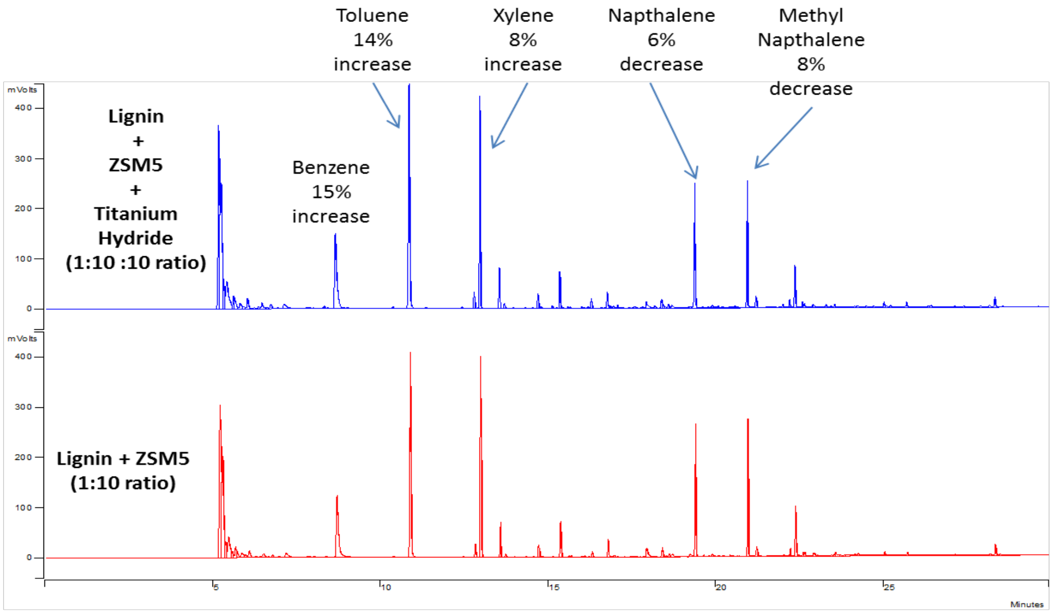

Fig. 23 Influence of titanium hydride in catalytic pyrolysis of organosolv lignin with ZSM5 zeolites at 700^{0}C

No significant thermal repolymerization effects were observed along the length up to the second bed in Tandem reactor.

Figure 24 shows the carbon yield comparison of lignin and carbohydrate monomers in zeolite catalytic pyrolysis experiments carried out in the Tandem micro pyrolysis reactor in both in-situ and ex-situ conditions.

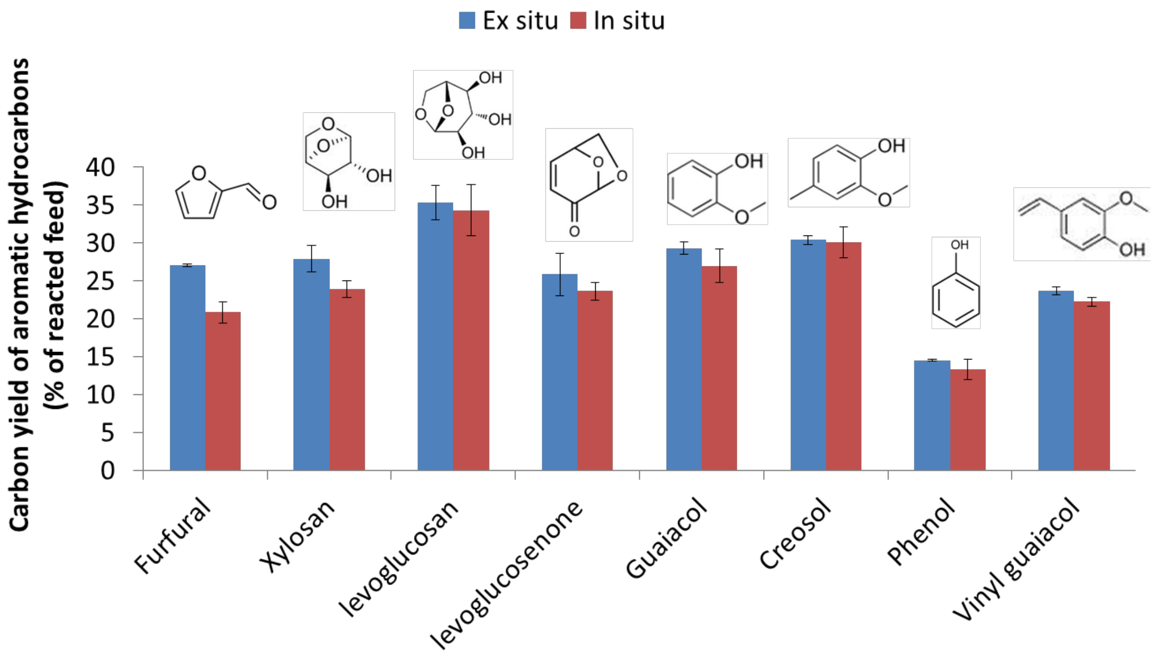

Fig. 24 shows the carbon yield comparison of lignin and carbohydrate monomers in zeolite catalytic pyrolysis experiments carried out in the Tandem micro pyrolysis reactor in both in-situ and ex-situ conditions

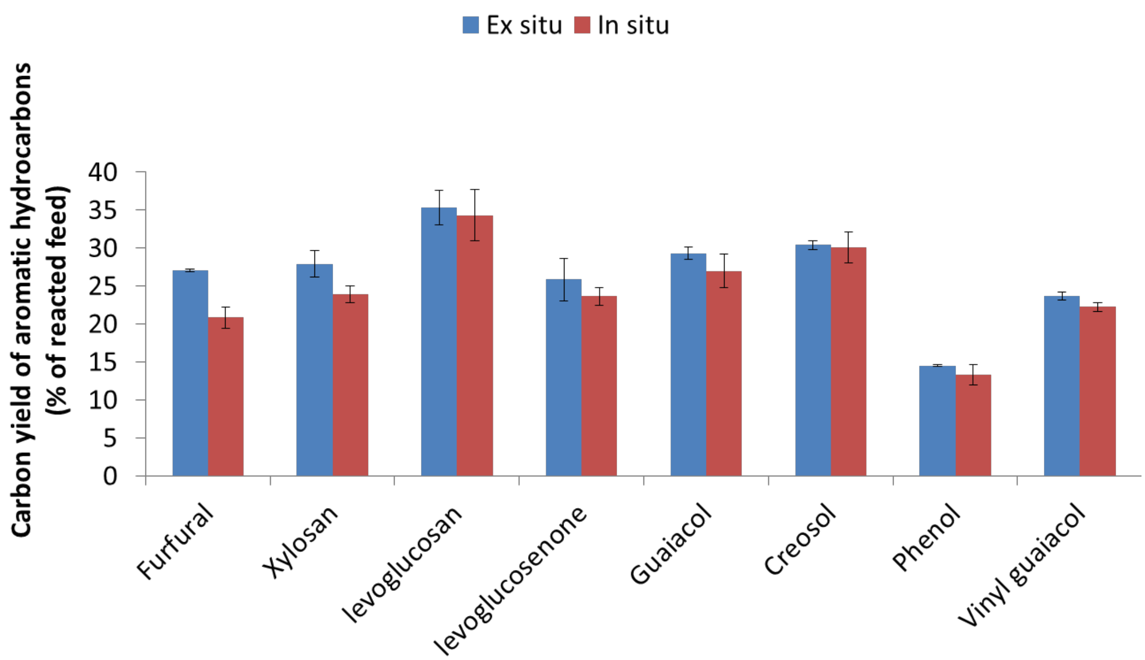

Fig. 25. Carbon yields comparison of lignin and carbohydrate monomers in catalytic pyrolysis with ZSM5 zeolites at 600^{0}C

3. Explanation of Variance

No variance has been experienced and accomplishments are on schedule.

4. Plans for Next Year

Micro-scale mass balance analysis will be conducted to determine the monomeric and oligomeric composition of lignin fast pyrolysis bio-oil. Zeolite acid site characterization will be completed to analyze their effect on pyrolysis coking and depolymerization phenomena. This will be critical in determining catalyst regeneration and life assumptions for techno-economic analysis.

5. Publications, Presentations, and Proposals Submitted

- **Presentations**

  Thilakaratne, R., Wright, M., Brown, R. Techno-Economic Comparison of Herbaceous Biomass Fast pyrolysis and Woody Biomass Catalytic Pyrolysis for Biofuels Production, CenUSA annual meeting poster presentation, July 2014.

- **Journal Publications**

  Thilakaratne R, Wright MM, Brown RC. A techno-economic analysis of microalgae remnant catalytic pyrolysis and upgrading to fuels. Fuel. 2014 Jul; 128:104-112

Sub-objective 2. Prepare and Characterize Biochar

1. Planned Activities

Plans for this quarter included: a) preparation of a manuscript on the work documenting the stability of AEC during oxidation of biochar, and b) investigations of the impact of iron and aluminum pretreatments on AEC of biochars.

2. Actual Accomplishments

Effects of Al and Fe pre-treatments of biomass on biochar

The effects of Al and Fe pre-treatments of biomass on biochar AEC were investigated. We obtained FTIR spectroscopic evidence of covalent bonding between Al and biochar C for biochars produced at 700 °C. Figure 26 shows FTIR spectra of biochars produced at 700 °C with the Al treatment and controls.

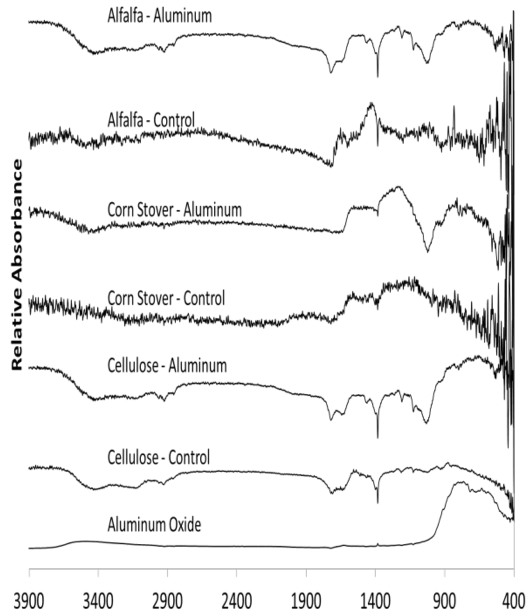

Fig. 26. FTIR spectra of biochars produced at 700 ^{0}C from alfalfa, corn stover, and cellulose.

Increased ether character is observed in aluminum-doped chars. The broad fingerprint band resembles spectra of oxidized biochars. Lacking is the OH stretching band present in the 500 °C biochars, but a band from 3500 to 3900 is observed. Higher pyrolysis temperature may have yielded a form of aluminum covalently bound to biochar carbon. Aluminum oxide was heated to 700 °C and exhibits no absorption from 1100-1300, yet the Al doped chars have increased absorption in this region which could be C-O stretching from a C-O-Al moiety (a hypothesis needing further testing).

X-ray diffraction indicated presence of calcite, sylvite, and quartz in the corn stover and alfalfa meal derived biochars. No evidence of any inorganic crystalline phases was detected in the Al-treated cellulose biochar, however this does not rule out the possibility of amorphous forms of aluminum oxide.

Magnetite is clearly evident in the cellulose biochar but not in the alfalfa or corn stover biochars. X-ray diffractometry does not reveal the forms of iron present in the alfalfa or corn stover derived biochars, however, evidence of quartz, sylvite, and calcite are observed.

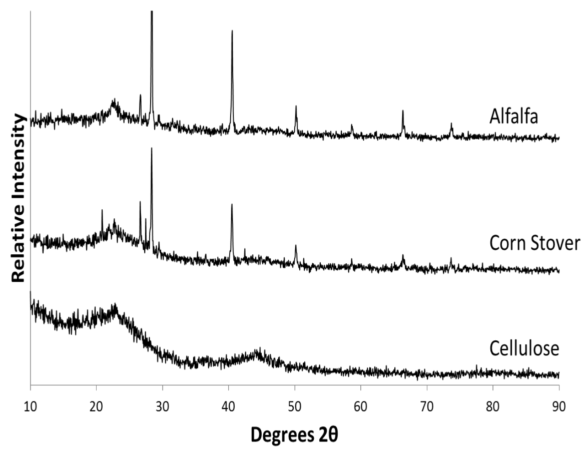

Fig. 27. XRD patterns of Al treatment 700 C biochars

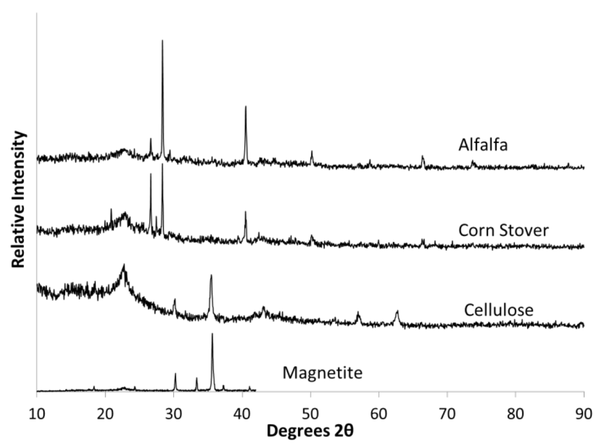

Fig. 28. XRD patters of Fe treated biochars prepared at 700 ^{0}C

Mossbauer spectroscopy (Table 2) confirmed the forms of iron in biochars produced at 700 ^{0}C. Seventy-nine percent (79%) of the iron in the cellulose biochar was present as magnetite which is supported by the XRD pattern. An unidentified peak which contributed 21% of the signal may be due to the small size effect of magnetite particles as observed in SEM micrographs. The decrease in intensity of the magnetite reflections in the XRD patterns of the corn stover and alfalfa-derived biochars is explained by the decrease in magnetite in these biochars. Most of the iron (73%) in the corn stover biochar was gamma iron oxide. An unknown peak contributing 10% of total intensity in the corn stover biochar may be due to a particle size effect. 52% of the iron in the alfalfa meal biochar was gamma iron oxide, 28% was zero-valent iron, and 20% was magnetite. The Mossbauer results demonstrate that diverse inorganic phases of iron are formed during pyrolysis of Fe-treated biomass and the type of iron phase is influenced by the nature of the feedstock. No evidence of covalent bonding between Fe and biochar C was observed.

The forms of iron detected in biochars by Mossbauer spectroscopy are shown in Table 2. Magnetite A – Fe (III), Magnetite B – Fe (II), gamma Fe_2O_3 is paramagnetic, alpha Fe_2O_3 is non magnetic amorphous.

Table 2. Forms of Fe in biochars produced at 700 °C as determined by Mossbauer spectroscopy

Biochar	CS	FWHM	INT (%)	QS	BHF (T)	Iron Specie
Cellulose-Iron	0.291(9)	0.53(3)	44(2)	-0.03(2)	49.44(7)	magnetite A-sites
	0.68(3)	0.92(9)	35(3)	0.00(5)	45.7(2)	magnetite B-sites
	0.80(5)	2.0(3)	21(2)	0	0	
Corn stover – Iron	0.36(9)	1.2(3)	17(3)	-0.2(2)	48.6(6)	magnetite A and B
	0.320(7)	0.73(2)	73(3)	0.93(1)	0	y-Fe2O3
	1.88(5)	0.7(1)	10(1)	0.88(7)	0	
Alfalfa - Iron	0.76(5)	0.3	5(1)	-.07(1)	45.1(4)	magnetite B-sites
	0.33(4)	0.6(2)	15(3)	-0.1(1)	49.2(3)	magnetite A-sites
	0.37(1)	0.77(4)	52(3)	0.87(2)	0	y-Fe_2O_3
	-0.05(8)	1.2(2)	28(3)	-0.01(15)	32.7(6)	zero valent iron
Iron (I,II) oxide (Magnetite)	0.374(7)	0.28(2)	25(1)	-0.19(1)	51.67(5)	a-Fe_2O_3
	0.660(4)	0.33(1)	50(1)	-0.003(8)	45.95(3)	magnetite B-sites
	0.279(6)	0.26(2)	25(1)	0.002(12)	49.11(4)	magnetite A-sites

The anion exchange capacity (AEC) of iron and aluminum treated biochar is shown in Table 3. As a general rule AEC increased with decreasing pH and was higher for the aluminum treated biochars than the controls. The AEC of the iron treated biochars showed no consistent trend relative to the controls. Thus the Al-treatments are effective for increasing the AEC of biochars and will add unique AL-OH functional groups on biochar surfaces. The Fe-treatments were not effective for increasing AEC of biochar but the observed novel chemistry may have other applications.

Table 3. Table of AEC values presented as mean (standard Deviation) of biochars at pHs 4, 6, 8

Feedstock	Treatment	HTT(^{0}C)	SA (m^2/g)	AEC (cmol(+)/kg biochar)		
				ph4	ph6	ph8
Cellulose	Aluminum	500	247	17.6(1.21)	2.90(1.21)	0.636(0.564)
Cellulose	Control	500	321	7.84(1.74)	2.63(0.189)	0.602(0.344)
Cellulose	Iron	500	373	5.23(0.922)	1.18(0.787)	0.306(0.0709)
Cellulose	Aluminum	700	305	28.0(2.46)	17.6(3.36)	15.5(5.61)
Cellulose	Control	700	229	24.2(5.32)	18.1(7.76)	4.11(0.166)
Cellulose	Iron	700	331	19.4(1.15)	11.9(0.768)	8.85(2.38)
Corn Stover	Aluminum	500	72	22.2(2.34)	6.18(1.38)	2.89(0.930)
Corn Stover	Control	500	150	17.5(5.19)	3.77(0.590)	1.05(0.184)
Corn Stover	Iron	500	159	13.9(5.58)	4.39(1.28)	1.12(0.778)
Corn Stover	Aluminum	700	309	44.0(2.80)	22.3(7.23)	11.6(1.07)
Corn Stover	Control	700	259	27.8(8.42)	13.8(3.78)	7.19(1.24)
Corn Stover	Iron	700	263	27.6(5.18)	16.4(2.86)	9.24(2.30)
Alfalfa	Aluminum	500	37	26.8(12.4)	15.2(4.17)	2.74(0.639)
Alfalfa	Control	500	39	10.9(1.83)	3.10(0.249)	0.938(0.302)
Alfalfa	Iron	500	54	17.3(9.23)	6.69(0.817)	2.92(0.436)
Alfalfa	Aluminum	700	298	52.9(1.87)	28.9(1.41)	23.5(4.96)
Alfalfa	Control	700	176	25.9(3.33)	9.64(0.961)	2.15(0.711)
Alfalfa	Iron	700	262	17.3(3.19)	18.2(0.241)	10.9(2.51)

3. Explanation of Variance

No variance noted.

4. Plans for Next Year

Characterization of aluminum moieties formed in pyrolysis. The aluminum-amended biochars have potential use as a Claus catalyst, which is industrially important for the removal of hydrogen sulfide from natural gas and various petroleum products.

Investigation of potential high-value applications for high anion exchange capacity (AEC) biochars. High AEC biochars also have the potential to be utilized in potable water treatment for removal of various contaminants such as low molecular weight organic acids, which are known to contribute to the formation of toxic by-products in water distribution systems.

Continuation of a cooperative study with the City of Des Moines, IA Water Works (DMWW). We have determined that acetate is a major downstream organic contaminant. We will investigate the use of high AEC biochars for removal of acetate from potable water.

5. **Publications, Presentations, and Proposals Submitted**

None submitted.

Objective 6. Markets and Distribution

The Markets and Distribution objective recognizes that a comprehensive strategy that addresses the impacts to and requirements of markets and distribution systems will be critical to the successful implementation and commercialization of a regional biofuels system derived from perennial grasses grown on land unsuitable or marginal for the production of row crops. To create this comprehensive strategy the team focuses on two unifying approaches:

- The study and evaluation of farm level adoption decisions, exploring the effectiveness of policy, market and contract mechanisms that facilitate broad scale voluntary adoption by farmers; and
- Estimate threshold returns that make feasible biomass production for biofuels.

1. **Planned Activities**

Our team's anticipated activities for the 4th quarter of year 3 (Y3 Q4) were:

- **Activity A.** Prepare and finalize survey results from the *Adoption of Switchgrass Production Survey* at the 2013 ICM Conference at ISU (Jacobs).
- **Activity B.** Continue to interact with industry on a BEI project to model the use of feedstocks as a fuel source for fast pyrolysis. The business model involves a distributed system of fast pyrolysis that provides as byproducts char and bio-oil. Char will be sold as a soil amendment, and bio-oil will be sold for use in furnaces for heat. The group includes soil scientists, chemical engineers and mechanical engineers (Hayes).
- **Activity C.** Continue modeling and analysis efforts of the regional supply curve for grasses and stover using a real options framework (Hayes). Present one of these at conference on this subject in 2013/2014. Publish two peer-reviewed papers in this area.
- **Activity D.** Construct the budgeting analysis of threshold returns necessary to make biomass production feasible under various yield regimes and land use alternatives (Perrin).

- **Activity E.** Continue a project to study the transportation economics of CRP when filter strips and grassy plantings are harvested for biomass.

2. **Actual Accomplishments**

- **Planned Activity A.** The survey findings were presented to project leaders and collaborators at the CenUSA Annual Meeting.
- **Planned Activity B.** Ongoing.
- **Planned Activity C.** Ongoing.
- **Planned Activity D.** Completed.
- **Planned Activity E.** Ongoing.

3. **Explanation of Variance**

None. All activities are moving according to the project schedule.

4. **Plans for Next Year**

- Prepare an outreach piece that compares the producer survey results over two years; this will summarize findings and identify implications for our project.
- Planned activities (B), (C), and (E) will continue.
- Prepare a report describing the use of CRP for perennial grasses. The feature of this report will be an exploration of the trade-off between offering higher biomass prices to procure more product closer to the plant and lower biomass prices with increased transportation costs under various participation (harvest/yield) rates. The comparison is made to the case of stover and a dual crop model is considered to estimate biomass production from grasses and stover.

5. **Publications, Presentations, and Proposals Submitted**

- Jacobs, K. "Competition for land use: Why would the rational producer grow switchgrass for biofuel?" CenUSA Summer Graduate Program Seminar, Iowa State University, June 20, 2014.

Objective 7. Health and Safety

- The production of bioenergy feedstocks will have inherent differences from current agricultural processes. These differences could increase the potential for workforce injury or death if not properly understood and if effective protective counter measures are not in place.

  The Health and Safety team addresses two key elements in the biofuel feedstock supply chain:

- The risks associated with producing feedstocks; and
- The risks of air/dust exposure.

1. **Task 1. Managing Risks in Producing Biofeedstocks**

   - **Planned Activities**

     Evaluation of the three risk assessment tools continued and the criteria rubric will be tested and reevaluated. Additional detail necessary for analysis in the other major headings Maintaining (weed control), Harvest, On-site processing and storage (stacking) and Transportation will occur.

   - **Actual Accomplishments**

     The three risk assessment tools (Frequency/Severity Analysis, Deviation Analysis, and Fault Tree Analysis) received continued evaluation and the resulting understanding developed from that evaluation caused a shift in how risk was going to be calculated. The current approach would provide a summative process of many actions that contain small estimating errors that would make it difficult to determine if there were any significant differences between the risks for one operation producing biofeedstocks over another producing corn, the primary question to be answered. The replacement risk model looks for differences between two operations and ignores the risks that are similar to both operations to reduce the errors accumulating in the final risk calculation.

     The standardization of this new risk assessment model for purpose of creating repeatable results is underway. Current projections indicate the expected outcome from this new risk model will be closer to other industry standards and better positioned for additional refinements as more data is collected.

     Data about exposures and frequencies for certain actions in the major headings have been collected. Additional facts necessary for the integration of the collected data into the new risk model for biofeedstock production were started to be collected. Specific coding procedures for data and those additional facts were defined.

The cooperative arrangement with the investigator at Penn State University yielded one paper in published for the Journal of Agromedicine and one in press for the Journal of Agricultural Safety and Health.

- **Explanation of Variance**

None to report.

- **Plans for Next Year**

The new risk assessment model evaluation will continue and preliminary calculations for the risk will be started for actions that currently have data. Additional data and detail necessary for analysis in the other identified action will be collected. Refinement of the current data sets for exposures and frequencies will be accomplished.

- **Publications, Presentations, and Proposal Submitted**

✓ Schaufler, D. H., A M. Yoder, D. J. Murphy, C. V. Schwab and A. F. Dehart. 2014. Safety and Health Hazards in On-Farm Biomass Production & Processing. Journal of Agricultural Safety and Health. (In Press).

✓ Yoder, A. M., C. V. Schwab, P. Gunderson, and D. J. Murphy. 2014. Safety and Health in Biomass Production, Transportation and Storage. Journal of Agromedicine. 19:83-86.

2. **Task 2 – Assessing Primary Dust Exposure**

- **Planned Activities**

Receive approval for modifications to the human subjects study. Have the air sampling equipment in hand and begin data collection for first few sample sites for harvesting operations and transporting materials.

- **Actual Accomplishments**

The annual approval for the human subjects was received, however the modifications to the human subjects study to include the transportation location and potential subjects was not completed during this quarter. It was more important to maintain the enforced human subject's approval than to lose the approval for human subjects for the upcoming year.

Additional details about the changes and sampling equipment were still being completed to assist in the new approval.

- **Explanation of Variance**

  None to report.

- **Plans for Next Year**

  Receive approval for modifications to the human subjects study. Purchase the air sampling equipment that was identified from vendor. Line up human subjects to participate in the study.

- **Publications, Presentations, and Proposal Submitted**

  No publication, presentations or proposal submitted from this task.

Education and Outreach

Objective 8. Education

The Education Objective seeks to meet the future workforce demands of the emerging Bioeconomy through two distinct subtasks, as follow:

- To develop a shared bioenergy curriculum core for the Central Region.
- To provide interdisciplinary training and engagement opportunities for undergraduate and graduate students

  Subtask 1 is **curriculum development**. Subtask 2A is **training undergraduates** via an 8-week summer internship program modeled on the highly successful NSF REU (research experience for undergraduates) program. Subtask 2B is **training graduate students** via a 2-week summer intensive program modeled on a highly successful industry sponsored intensive program in biorenewables the team led in 2009. Subtask 2C is **training graduate students via a monthly research webinar**. The next portion of this report is broken into subtasks.

Subtask 1: Curriculum Development

1. **Planned Activities**

   - **Module 5. Integrating Bioenergy Production into Current Systems**

Complete all revisions.

- **Module 6. Balancing Energy Demand with Food, Feed and Fiber Needs**

  Complete all revisions.

- **Module 7. Developing a New Supply Chain for Biofuels: Contracting for Dedicated Energy Crops**

  Complete all revisions.

- **Module 8. Biofuels Policy: How Does Policy Affect the Market for Biofuels?**

  Complete internal review and begin making revisions

- **Module 9. Enterprise budget**

  Complete draft of module content

- **Module 10. Genetics and Breeding of Perennial Grasses for Biofuel Production**

  Complete revisions.

- **Module 11 Introduction to Biofuel: Perennial Grasses as a Feedstock**

  Complete internal review and begin making revisions, if needed.

- **Module 12. Perennial Grass Seed: Protection, Certification and Production**

  Complete internal review and begin making revisions, if needed.

- **Evaluation tasks**

  ✓ Complete analysis of new evaluation data sets.

  ✓ Develop outline of journal article summarizing evaluation data sets.

2. Actual Accomplishments

- **Module 7. Developing a New Supply Chain for Biofuels: Contracting for Dedicated Energy Crops**

  Completed revisions.

- **Module 8. Biofuels Policy: How Does Policy Affect the Market for Biofuels?**

  Internal review in progress.

- **Module 9. Enterprise Budget**

  No work was completed on this module. An alternative content expert is being identified.

- **Module 10. Genetics and Breeding of Perennial Grasses for Biofuel Production**

  Continued making edits to content.

- **Module 11. Introduction to Biofuel: Perennial Grasses as a Feedstock**

  Continued making edits to content.

- **Module 12. Perennial Grass Seed: Protection, Certification and Production**

  Continued making edits to content.

- **Evaluation Tasks**

  ✓ Completed analysis of data sets.

  ✓ Rough draft of journal manuscript completed.

3. Explanation of Variance

No work was completed on Module 9 this quarter. A content developer new to the project has been identified for this module, but they did not begin revising the existing content. It is anticipated that they will complete the revision to the content by the end of Year 3 (July 2014)

4. Plans for Next Year

- **Modules**: Complete final editing of existing modules in feedstock development and economics areas.

- **Module 14: Biochemical Conversion of Bioenergy Feedstocks**

  Develop outline of module content

- **Module 15: Thermochemical Conversion of Bioenergy Feedstocks**

  Develop outline of module content

5. Evaluation Tasks

Continuing preparation of draft of journal manuscript

6. Publications, Presentations, and Proposals Submitted

None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. Planned Activities

- Finalize all logistics for student travel, lodging at Iowa State University and all four partner institutions (University of Minnesota, University of Nebraska – Lincoln, Purdue University, and Archer Daniels Midland) and administration of stipends.
- Provide mentor training using a 15-minute video (created by Raj Raman). Will share link with the internship mentors (faculty/grad student/post doc) in mid-May, followed by a combined face-to-face (for ISU-based mentors) and virtual (via WebEx for partners) meeting to clarify any questions and concerns.
- Launch the program on May 28, 2014 with the arrival of the students. Run the orientation at Iowa State from May 29 – June 1, 2014 and send students to appropriate lab placements for start date on June 2, schedule weekly meetings (June 4 – July 23) with student interns to discuss progress, face-to-face for ISU students and virtual (via WebEx) for partner-placement students.
- All partner-placed interns return to Iowa State On Tuesday, July 29, 2014 in preparation for travel to the CenUSA annual meeting in Chaska, MN on Wednesday, July 30 – 31.
- All undergraduate interns participate in the annual meeting as they actively engage in the Q&A sessions following research presentations by objective program directors and faculty leaders.
- All interns present their research during the research poster presentation on Thursday, July 31.
- Interns return to Iowa State University on July 31 for the close of the program on Friday, August 1.

2. Actual Accomplishments

- Finalized all logistics for all 16 student internship participants including the following: 1) student travel to Iowa State for the orientation on Thursday, May 29 – Sunday, June 1 as well as travel for the students with placements at four partner institutions, (University of Minnesota, University of Nebraska – Lincoln, Purdue University, and our first industry-based internship partner at Archer Daniels Midland. 2) housing for students placed at Iowa State as well as the partner institutions; 3) orientation events and speakers (safety training, ethics seminar with case studies, and lab tours) all scheduled; 4) and administration of stipend payments and cash advance provided during orientation.

- Recorded an updated version of the mentor training video (15-minute video created by Raj Raman). Shared video link with the internship mentors (faculty/grad student/post doc) on May 15 giving them ample time to view the video. Followed up with a combined face-to-face (for ISU-based mentors) and virtual (via WebEx for partners) meeting on May 21 to clarify any questions and concerns in preparation of the students' arrival.

- Launched the program on May 28 with the arrival of the students. Conducted orientation on Wednesday, May 29 – Sunday, June 1 that included an overview and expectations of the program, lab safety training provided by Iowa State University's Environmental Health & Safety personnel, lab research documentation training, an energy overview lecture by Raj Raman, a half day bioethics seminar and case studies by Dr. Clark Wolf of Iowa State University, and lab tours.

- Iowa State University's Research Institute for Studies in Education (RISE) administered a pre-program survey to assess students on May 29. This provided a baseline for program evaluation.

- The ISU-based interns participated in a team-building canoe trip on the Des Moines River on Saturday, May 31.

- Students placed at partner institutions (University of Nebraska, Lincoln working with Dr. Virginia Jin and Dr. Rob Mitchell; University of Minnesota working with Dr. Jason Hill; Purdue University working with Dr. Indrajeet Chaubey; and ADM working with Tom Binder) departed Iowa State University on June 2 to begin their host lab placements through July 29.

- Scheduled weekly meetings (June 4 – July 23) with student interns to discuss progress, face-to-face for ISU students and virtual (via WebEx) for partner-placement students.

- During weekly meetings, mentored students regarding research poster content in preparation for their research poster session during the CenUSA Annual Meeting hosted by the University of Minnesota, located at the Minnesota Arboretum in Chaska, MN.

- Interns placed at Iowa State University toured Iowa State's BioCentury Research Farm on June 6 and Lincolnway Energy (an ethanol refinery) on June 16.

- All CenUSA Bioenergy interns attended presentations by Dr. Keri Jacobs on markets and distribution, Dr. Rob Anex on lifecycle assessment, and Dr. Peter Keeling on innovations in the bioeconomy. They also attended a presentation on "Applying to and Getting into

Graduate School" co-presented by Dr. Raj Raman. All these presentations were delivered face-to-face for ISU-based students and virtual (via Webex) for partner-placed students.

- Coordinated the return of partner institution placed students to Iowa State University on July 29. Coordinated the CenUSA Annual Meeting logistics (registration, charter transportation, accommodations, poster session participation) regarding the 16 undergraduate interns attendance at the annual meeting.

3. Explanation of Variance

None.

4. Plans for Next Year

- All 16 interns will return to Iowa State University from the CenUSA annual meeting for the conclusion of the program
- On August 1, all CenUSA student interns will participate in the ISU university-wide undergraduate research poster session and reception. This poster session, the culminating event of the CenUSA Bioenergy Internship Program, will include all undergraduate research interns who have participated in summer research internships at Iowa State University. This event will showcase over 100 students.
- All students will complete a post-program survey conducted by Iowa State University's Research Institute for Studies in Education (RISE). The purpose of this assessment is to (1) assess the program's activities; (2) evaluate immediate program successes and challenges; (3) promote continued interest in the program by alumni after they complete their research experience; and (4) track the career paths of our graduates.
- On August 2, 2014 all student interns depart Iowa State University.
- Finalize and process all payments related to the internship program.
- Create a calendar and content outline for the summer 2015 program.

5. Publications, Presentations, and Proposals Submitted

None to report in this period.

Subtask 2B – Training Graduate Students via Intensive Program

1. Planned Activities

None. This is a PY4 activity, and forward planning will begin in summer 2014.

2. **Actual Accomplishments**

N/A

3. **Explanation of Variance**

N/A

4. **Plans for Next Year**

N/A

5. **Publications, Presentations, and Proposals Submitted**

N/A

Subtask 2C –Subtask 2C – Training Graduate Students via Monthly Research Webinar

1. **Planned Activities**

- Considering the heavy load we have with educational programming (16 undergraduate research interns) from May 28 – August 2, 2014 and the recuperation time of the Objective 7 project director, we are not delivering any CenUSA research seminars until the CoPd meeting scheduled on August 29, 2014.
- Since we have completed seminars on Objectives 1-6, we will consider picking up with Objective 7 in August 2014.

2. **Actual Accomplishments**

No graduate research webinars were hosted during this time period.

3. **Explanation of Variance**

None.

4. **Plans for Next Year**

Restructure the delivery of research webinar content.

- Propose four 1-h sessions spread over the academic year (probably October, November, February, April). Each session would have a couple of CenUSA objective leaders or collaborating faculty presenting on an issue listed below. The issues are meant to be mildly controversial so that multiple views can be presented. After the presentations, which should last no longer than 20 minutes total, we will move to Q&A, with questions from anyone and particularly encouraged from graduate students.

- Potential topics:
  - ✓ What are the most realistic approaches to reducing N and P export from the Corn Belt?
  - ✓ What kind of switchgrass yields are likely to be possible on marginal lands, and what would the cost of this material be?
  - ✓ How do yield increases and machinery changes impact cost and safety?
  - ✓ What is the most realistic scenario for the adoption of switchgrass (or other perennial) on marginal lands, and what policy changes would be needed to make this happen?

5. Publications, Presentations, and Proposals Submitted

None to report.

Objective 9. Extension and Outreach

The Outreach and Extension Objective serves as CenUSA's link to the larger community of agricultural and horticultural producers and the public-at-large. The team delivers science-based knowledge and informal education programs linked to CenUSA Objectives 1-7.

The following teams conduct the Outreach and Extension Objective's work:

- **Extension Staff Training/eXtension Team**

  This team concentrates on creating and delivering professional development activities for Extension educators and agricultural and horticultural industry leaders, with special emphasis on materials development (videos, publications, web posts, etc.).

- **Producer Research Plots/Perennial Grass Team**

  This team covers the areas of:

  - Production, harvest, storage, transportation.
  - Social and community impacts.
  - Producer and general public awareness of perennial crops and biochar agriculture.
  - Certified Crop Advisor training.

- **Economics and Decision Tools Team**

The Economics and Decision Tools Team focuses on the development of crop enterprise decision support tools to analyze the economic possibilities associated with converting acreage from existing conventional crops to energy biomass feedstock crops.

- **Health and Safety Team**

  This team integrates its work with the Producer Research Plots/Perennial Grass and the Public Awareness/Horticulture/eXtension 4-H and Youth teams (See Objective 7. Health and Safety).

- **Public Awareness/Horticulture/eXtension/4-H and Youth Team**

  This team focuses on two separate areas:

  - **Youth Development.** The emphasis is on developing a series of experiential programs for youth that introduce the topics of biofuels production, carbon and nutrient cycling, and biochar as a soil amendment.

  - **Broader Public Education/Master Gardener.** These programs acquaint the non-farm community with biofuels and biochar through a series of outreach activities using the Master Gardener volunteer model as the means of introducing the topics to the public.

- **Evaluation/Administration Team**

  This team coordinates CenUSA's extensive extension and outreach activities. The team is also charged with developing evaluation mechanisms for assessing learning and behavior change resulting from extension and outreach activities, compiling evaluation results and preparing reports, and coordination of team meetings.

1. Extension Staff Training/eXtension Team

- **Planned Activities**

  ✓ Host a webinar on May 23, 2014 featuring work done by Susan Rupp with CenUSA Co-project Director Rob Mitchell and Ken Vogel (Project Advisor) in relation to perennial grass production practices for bioenergy and wildlife habitat.

  ✓ Finish the plant pathology video featuring CenUSA researcher Gary Yuen.

  ✓ Gather footage for biochar videos at the 2014 CenUSA annual meeting in Minnesota.

  ✓ Make the CenUSA bioenergy open online, non-credit course available to the public.

  ✓ Develop eXtension Bio pages for CenUSA collaborators. These pages will rotate with others' bios on the eXtension Farm Energy Home Page.

- ✓ Publish fact sheets and research summaries:
  - *Economics of Switchgrass* – Richard Perrin.
  - *Biochar Science Review.*
  - *Storage of Two Perennial Grasses as Biomass Feedstocks* – Kevin Shinners.
  - *Switchgrass Nutrients* – Rob Mitchell, Ann Sawyer and Carl Rosen.
- ✓ Begin developing publications:
  - *Land Competition* – Keri Jacobs.
  - *Pyrolysis* – Akwesi Boateng.
- ✓ Continue maintenance of the index: *Resources from CenUSA – Sustainable Production and Distribution of Bioenergy for the Central USA* to include all CenUSA resources.
- ✓ Use eXtension Farm Energy Social Media sites to share information from CenUSA.
- ✓ Publish BLADES Newsletter in June; send to CenUSA e-mail list.

- **Actual Accomplishments**

The CenUSA Extension Training/ eXtension team reached 4303 people this quarter (3141 male; 1162 female) with the activities described below.

- ✓ Hosted webinar with Susan Rupp, *Perennial Herbaceous Biomass Production and Harvest in the Prairie Pothole Region of the Northern Great Plains* on May 23, 2014. The webinar is archived for further viewing on the eXtension CenUSA site.
- ✓ Finished and posted the plant pathology video on Vimeo/YouTube platforms in July 2014.
- ✓ Gathered footage at the CenUSA annual meeting for two videos and two archived presentations about biochar. An additional video related to the commercialization objective was captured for use in the upcoming September newsletter.
- ✓ Published CenUSA's BLADES newsletter in June and send to CenUSA email list via Constant Contact platform.
- ✓ Presented a video and provided eXtension handouts and business cards at the 2014 CenUSA annual meeting tradeshow.

- ✓ Publications (May 1 – July 31, 2014):
  - *Storing Perennial Grasses Grown for Biofuel* – Kevin Shinners
  - *The Economics of Switchgrass for Biofuel* – Richard Perrin
  - *Competition for Land Use: Why would the rational producer grow switchgrass for biofuel?* – Keri Jacobs
  - Completed *Resources from CenUSA-Sustainable Production and Distribution of Bioenergy for Central USA* (http://www.extension.org/pages/68136), which includes all CenUSA resources, including fact sheets, webinars, instructional videos, research summaries, and journal publications.
  - Developed eXtension Bio pages for several CenUSA collaborators. These pages rotate with other bios on http://extension.org/ and the eXt Farm Energy home age.
- ✓ Google analytics for CenUSA articles/fact sheets on eXtension Farm Energy site from February 1, 2014 - April 30, 2014:
  - 1,413 page views by 966 users; 80% of them new sessions; averaging 1.7 pages per visit. Compared to last quarter, usage is steadily increasing, as page views are up by 40% and users are up 42%.
  - Traffic sources are 77% search engines, 15% direct traffic and 8% referring sites.
  - Viewers were predominately from Minnesota, Texas, Pennsylvania, Michigan, Illinois, Nebraska, Iowa, New York, Wisconsin and Missouri with use throughout the U.S. and world.
- ✓ Impact of CenUSA Vimeo Channel:
  - From May 1 – July 3, 2014, the 33 CenUSA videos archived on Vimeo have had 143 plays, or users who viewed the video on the CenUSA Vimeo site, or on a web site that embedded a CenUSA video.
  - The 33 videos also had 1,340 loads; 1,044 of those loads came from our videos embedded on other sites. When a video is loaded, people see the video but they do not click "play." The embedded videos were played 40 times.
  - Vimeo videos were downloaded 9 times. This means the video was saved to a viewer's hard drive (users usually do this because they have limited Internet connectivity which does not allow for live streaming of video). Once the video is downloaded, it is available on their computer to watch at their convenience.

- ✓ Impact of YouTube Channel
  - CenUSA videos are also posted on YouTube, and those videos have been viewed 757 times between May 1, 2014 and July 31, 2014. 450 views were from the United States. Demographic analytics indicate an overall 73% male/27% female audience to date. Within the U.S., YouTube is also able to collect age range information. The reported ages of our YouTube audience in the U.S. are as follows: 18-25 years (12%); 25-34 years (25%); 35-44 years (13%); 45-54 years (13%); 55-64 years (33%); 65+ years (4.8%). The remaining 307 views do not have age and gender demographics associated with them.
  - YouTube also provides data related to how users access the videos. 90% of the videos were viewed on their associated YouTube watch page (each video has a unique "watch page"), while 7.7% of videos were viewed from embedded copies on another site. Users find our videos through various avenues, which are referred to as "traffic sources. Our top four traffic sources include: YouTube search, YouTube suggestions, direct links, and referrals from other websites. 38% of our views come from users searching directly on YouTube. The YouTube suggestion feature accounted for 23% of our views. Views from mobile apps or from direct traffic (links in an email or copying/pasting the direct URL) account for 12% of video views. Finally, referrals from outside YouTube (Google search or access through external web sites) account for 12% of video views.
- ✓ CenUSA Web Site

  The CenUSA web site had 677 visitors between May 1, 2014 and July 31, 2014. These visitors logged a total of 3,535 pageviews during 1,091 sessions. Pageviews are the total number of pages that visitors looked at during their time on the site. A session qualifies as the entire time a user is actively engaging with the site. If activity ceases for an extended period of time, and the use returns, a new session is started.
- ✓ CenUSA Social Media
  - Twitter traffic consists of followers who subscribe to our account and "follow" tweets (announcements). Followers can "favorite" a tweet or retweet it to share with their own followers. They can also "mention" CenUSA by tagging CenUSA Bioenergy's twitter account (@CenUSABioenergy) in their own tweets. This quarter, our tweets were retweeted a total of 47 times. Followers tagged CenUSA tweets as a favorite 143 times and mentioned us 75 times. CenUSA Bioenergy also has 352 followers currently, up from 278 last quarter.

- ✓ By the end of July, CenUSA's Facebook page had 176 likes, up from 142 the previous quarter. Some of our most successful posts this quarter were the three "intern spotlights" which reached 705, 615, and 540 people respectively. Our post with the highest engagement was the 2014 annual meeting photo album. 581 people clicked through the album from the annual meeting.
- ✓ BLADES newsletter: One CenUSA newsletter was produced and released this quarter, featuring stories related to research coming from CenUSA and other happenings in the world of perennial grass energy, including the industry sector. The BLADES newsletter was sent to 693 individuals. 39% opened the newsletter, and 25.4% clicked on a story. Our numbers of opened newsletters and stories clicked are higher than the newsletter industry" average.

a. Explanation of Variance

Additional contracts added by our video expert have delayed the plant pathology related video. For the publication *Storage of Two Perennial Grasses as Biomass Feedstocks*, we are waiting for second review to be completed. Review for the Hypoxia article is taking longer than expected; the article it is still with the final reviewer.

b. Plans for Next Quarter.

- ✓ Edit footage from the 2014 Annual Meeting to produce a Master Gardener Biochar video project summary and an intro to biochar video.
- ✓ Process presentations recorded at annual meeting and post them to Vimeo in place of webinars (due to significantly decreased webinar attendance and the need for biochar presentations).
- ✓ Publish BLADES Newsletter in September an email it to the list in Constant Contact.
- ✓ Photograph the Nebraska CenUSA field days in August 2014 to provide images for extension and outreach and communications team.
- ✓ Present at E3 Conference in Ames, Iowa (September 23-25, 2104).
- ✓ Continue development of Moodle LMS platform for future release of Bioenergy MOC.
- ✓ The biochar science review publication is is still in progress due to change in direction after discussion with contributors at the CenUSA annual meeting. A new format for the articles is being pursued to accommodate the current state of the research data and input from conference participants about the best way to

disseminate information about biochar. A series of one-page fact sheets about different aspects of biochar will be developed in input from David Laird and Kurt Spokas and published via Extension.

- ✓ Develop case studies about CenUSA biofuel industry affiliates showcasing markets for bioenergy feedstocks and biochar. Build on industry connections made with industry representatives at CenUSA annual meeting.
- ✓ Develop publication on pyrolysis with CenUSA Bioenergy Co-project director Robert Brown.
- ✓ Develop a fact sheet from existing plant pathology and entomology materials.
- ✓ Continue to add eXtension Bio pages for CenUSA collaborators. These pages will rotate with other bios on the http://www.extension.org/ and the eXt Farm Energy home page.
- ✓ Maintain index on eXtension site: *Resources from CenUSA – Sustainable Production and Distribution of Bioenergy for the Central USA* – to include all CenUSA resources.

c. Publications, Presentations, Proposals Submitted

- ✓ Listed below are peer reviewed publications on eXtension added this quarter (link to the publications at: http://www.extension/org/pages/68136
    - *Management Practices Impact Greenhouse Gas Emissions in the Harvest of Corn Stover for Biofuels* – Virginia Jin.
    - *Storing Perennial Grasses Grown for Biofuel* – Kevin Shinners.
    - *The Economics of Switchgrass for Biofuel* – Richard Perrin.
    - *Competition for Land Use: Why would the rational producer grow switchgrass for biofuel?* – Keri Jacobs.
    - *Biochar Commercialization* – Pam Porter and David Laird.
    - CenUSA Bioenergy Annual Meeting Tradeshow presentation.
    - *Plant Pathogen Risk Analysis for Bioenergy Switchgrass Grown in the Central USA* (Available at https://vimeo.com/100149975).
- ✓ Video presentation for Annual Meeting. (Available at https://vimeo.com/101362566, password: tradeshow).

Producer Research Plots/Perennial Grass/Producer and Industry Education Team

a. Planned Activities

✓ **Indiana**

- Chad Martin to provide presentation on CenUSA at the *Heating the Midwest Biomass* conference in Green Bay, Wisconsin.
- Chad Martin to provide presentation at the Montgomery County Ag Club regarding CenUSA and the status of second-generation biofuels.
- Chad Martin to provide presentation on CenUSA for the Indiana SARE Educator Committee.

✓ **Iowa**.

- Due to staffing changes (retirement of primary staff person who has managed the CenUSA demonstrations/outreach), only collection of data/management of plots was planned for this quarter.

✓ **Minnesota**

- Host tour of CenUSA plots as part of Crops Field Day in southwest Minnesota (Lamberton location).
- Continue with monthly grassland assessments according to CenUSA protocol.

✓ **Nebraska**.

- Burn 2013 established plot at Beaver Crossing.
- Fertilize Beaver Crossing and Dawson plot according to CenUSA protocol.
- Reinstall automated weather station and soil moisture sensors at Dawson and Beaver Crossing sites.
- Spray broadleaf weeds at both sites as needed.
- Capture stand counts at Beaver Crossing and Dawson site according to protocol.
- Mow walking alleys as needed at both locations.
- Work with CenUSA Extension team to develop a field day evaluation instrument.

b. Actual Accomplishments

- ✓ **Indiana**
  - Indiana (Purdue). Total contacts May 1 –July 31, 2014 for events listed below = 95 (70 male; 25 female).
  - Chad Martin provided a presentation about CenUSA to the Heating the Midwest Biomass conference in Green Bay, Wisconsin.
  - Chad Martin provided a presentation to the Montgomery County Ag Club regarding CenUSA and status of second generation biofuels.
  - Chad Martin presented a status update to the Indiana SARE Educator Committee on CenUSA and programs planned for the future.
- ✓ **Iowa**
  - Made stand counts at both Iowa sites in July 2014.
- ✓ **Minnesota**
  - Hosted tour of CenUSA plots as part of Crops Field Day at CenUSA Lamberton plots; provided overview of switchgrass-for-bioenergy, the CenUSA project, and UM research activities in particular (58 participants; 43 male and 15 female).
  - Completed monthly grassland assessments, per CenUSA protocol.
- ✓ **Nebraska**
  - Worked with CenUSA evaluator (Sorrel Brown) to develop field day evaluation instrument.
  - Burned 2013 established plot at Beaver Crossing.
  - Fertilized Beaver Crossing and Dawson plot according to CenUSA protocol.
  - Captured stand counts at Dawson site.
  - Reinstalled automated weather station and soil moisture sensors at Dawson and Beaver Crossing sites.
  - Sprayed broadleaf weeds at Beaver Crossing site.
  - Captured stand counts at Beaver Crossing site according to protocol.

c. Explanation of Variance

Because of the abnormally cool/wet weather conditions in the Midwest in March – May, growth of the grass was behind normal and therefore cultural practices were conducted later than normal for most of the demonstration plots.

Staff changes in Iowa (retirement of leader of demonstration plots) led to reduced activity this summer.

d. Plans for Next Year

- ✓ Indiana
  - o We will exhibit at the E3 Conference in Ames, Iowa (September 23-26, 2014).
  - o On farm demonstrations including:
    - ➢ October 28, 2014: Second generation Biofuels Harvesting and Marketing with CenUSA Demonstration Plot Tour at Sweeten Farm.
    - ➢ October 30, 2014: CenUSA Bioenergy Grass Demonstration Plot Field Day at the Indiana FFA Leadership Center, Trafalgar, Indiana.
- ✓ Iowa
  - o Apply N rate treatments to the demonstration plots.
  - o Evaluate grass stands.
- ✓ Minnesota
  - o Continue with monthly grassland assessments through October 1, 2014 and again prior to harvest, per CenUSA protocol. No outreach activities planned for next quarter.
- ✓ Nebraska
  - o Collect biomass samples each month at both locations.
  - o Develop the agenda for the Switchgrass Bioenergy Feedstock Field Days.
  - o Work with ARDC marketing and promotion staff to develop a marketing plan for Field Days scheduled for August 19-20, 2014.
  - o Reserve tents, caterer, garbage and portable toilet vendors for field days.
  - o Mow walking alleys as needed at each location.

- Secure custom operator to demonstrate harvest at field day.
- Communicate with field day trainers re: field day specifics and request storyboard content from each.
- Implement marketing plan (develop and distribute statewide and regional press releases), mail 5500 field day announcements to farm operators located at the field day site county and surrounding counties; contact radio and television stations; contact farm magazines.
- Develop storyboards.
- Secure field day supplies.
- Beautify field day sites.
- Make copies of field day handouts and develop a participant folder with copies inserted.
- Conduct field days on August 19, 2014 at Beaver Crossing and August 20, 2014 at Dawson.
- Attend CenUSA Annual Meeting July 30 – August 1, 2014.

e. Publications, Presentations, Proposals Submitted

- ✓ **Indiana.** Working on field day handbooks to be given out at October field days/tours
- ✓ **Minnesota:** Working on a summary of CenUSA research activities for distribution to parties who requested data at the Lamberton Crops Field Day and for future use.

2. Economics and Decision Tools

a. Planned Activities

- ✓ Host a spring field day at the ISU Southeast Research Farm in Crawfordsville, Iowa where a CenUSA switchgrass plot has been established; discuss economics of switchgrass.
- ✓ Update and improve the watershed nitrogen reduction planner spreadsheet. Start on a phosphorus equivalent spreadsheet. Continue work on the web-based crop enterprise budget calculator.

b. Actual Accomplishments

- ✓ The nitrogen spreadsheet has been updated and should be made available for downloading in October 2014.
- ✓ Working on the phosphorus spreadsheet and the budget calculator.

c. Explanation of Variance

The field day in Iowa did not materialize due to retirement of lead CenUSA staff person.

d. Plans for Next Year

- Release nitrogen spreadsheet.
- Continue work on the web-based crop enterprise budget calculator.
- Include discussions of perennial grasses in Iowa Farm leasing meetings in August and September 2014.

e. Publications, Presentations, Proposals Submitted

None.

3. Health and Safety

See Health and Safety Objective report, above.

4. Public Awareness/Horticulture/eXtension/4-H and Youth Team

a. Youth Development

- ✓ **Planned Activities**
  - **Indiana**
    - Plan and execute 4-H science workshop and 4-H Round up sessions.
    - Execute Trafalgar activities.
    - Continue to pilot test CenUSA elementary curriculum.
    - Finalize text for display at Trafalgar, including editing and construction of signage.
    - Continue development and editing of on-line youth modules.
  - **Iowa**

- ➢ Coordinate and mentor three CenUSA interns to develop CenUSA C6 curriculum, C6 BioFarm app game, C6 STEM career videos and C6 iBook.
- ➢ Schedule meetings for interns with scientists, engineers, editors, and videographers to provide technical support needed for development of the materials.
- ➢ Develop biorenewables core concept activity for pre-K/elementary groups
- ➢ Pilot the materials with several youth groups during the summer, including Iowa 4-H/Youth Conference.

✓ **Actual Accomplishments**

- **Indiana**
  - ➢ 24 adult leaders (8 male, 16 female; 2 Hispanic; 18 white; 4 black); and 213 youth were involved in CenUSA 4-H Science Workshop and CenUSA 4-H Round Up sessions (116 male, 97 female; 40 Hispanic, 131 white, 42 black).
  - ➢ Trafalgar (Indiana FFA) demonstration plots were established and evaluated for sign installation. Production of signs for demonstration plots is underway.
  - ➢ Educational programming development of electronic modules on tablets to supplement signage at Trafalgar plots is complete.
  - ➢ Pilot test of elementary curriculum was completed in May 2014.
  - ➢ Electronic educational modules for 4-H Curriculum are under development.
  - ➢ Curriculum development and 4-H experts have reviewed 4-H (beginner/intermediate/advanced) materials. Content experts will review the materials by next quarter.
  - ➢ High school (FFA) curriculum is complete and has been reviewed by curriculum development experts and is in review with content experts.
  - ➢ High school classroom pilot teach participants have been identified for the fall semester pilot to take place September – December, 2014.
- **Iowa**
  - ➢ The Iowa CenUSA C6 team developed and tested the necessary algorithms for an education game that uses an agricultural production scenario to introduce

the concepts relating to the carbon economy and biorenewables. The game continues under development.

- A supporting iBook was framed and two chapters finished in draft form. Chapter 1 is out for technical review. Curriculum for use in grades 7-12 science and agriculture classrooms was framed and aligned with standards for STEM and agriculture.
- A coloring sheet was developed for use with pre-K/elementary students to introduce core concepts in biorenewables. It was piloted at a county fair.
- Five videos were produced that highlight careers that link to the bioeconomy and feature engineers, crop insurance agents, agronomists and educators. The videos are being edited by a professional videographer for release in November 2014.
- We developed and launched a new website (http://c6biofarm.weebly.com/) to allow access to the materials as they are released.
- We developed C6/BioFarm promotional/marketing pieces (See Exhibit 8).
- The draft materials were piloted with several groups late summer: 7 adult leaders were involved in piloting/reviewing the materials (5 male, 2 female -- all white); 333 youth participated in C6 pilot activities (143 male, 190 female; 59 Hispanic, 113 white, 25 black, 27 Asian, 2 Native Hawaiian/Pacific Islander).

✓ **Explanation of Variance**

None

✓ **Plans for Next Quarter**

- **Indiana**
  - Finish and install demonstration plot signage at Trafalgar (October 2014).
  - Pilot test supplemental electronic modules for Trafalgar demonstration plots.
  - Send completed curriculum (x4) to editor and graphic designer.
  - Electronic modules for beginner 4-H curriculum will be completed.
  - Teachers will begin pilot of high school (FFA) curriculum.

- 4-H pilot participants will be identified.

- **Iowa**

  - C6 Curriculum, C6 BioFarm Game and C6 iBook will be shared at the Fall Conference for Iowa Math and Science Teachers on October 22, 2014.
  - C6 Materials will be shared at the Iowa 4-H Youth Fest, a professional development workshop for Iowa 4-H Youth staff in November 2014.
  - C6 Team will plan and host a "hackathon" September 27, 2014 for ISU undergraduate students to aid in the development of the C6 BioFarm game as well as develop corollary tools supporting the CenUSA Outreach goals.

✓ **Publications, Presentations, Proposals Submitted**

- **Indiana**

  - CenUSA annual meeting presentation.
  - Presentation accepted for NSTA Regional meeting, November 2014.
  - Presentations accepted for Extension Energy and Environment (E3) conference, September, 2014.

- **Iowa**

  - C6 promotional pieces (See Exhibit 7).
  - CenUSA 2014 annual meeting.
  - Presentation accepted for Extension Energy and Environment (E3) conference (September 2014).

b. Broader Public Education/Master Gardener Program

✓ **Planned Activities**

- **Iowa**

  - Pot up and deliver plants and discuss garden preparation and planting with demonstration site managers.
  - Contact Extension Master Gardener volunteers to help with data collection and planting.

- Order CenUSA biochar ball caps to distribute to Extension Master Gardener volunteers.
- Hold meeting to update Denny Schrock and Cindy. Haynes on project May 22, 2014.
- Hold conference call with Objective team on June 9, 2014.
- Attend Upper Midwest Gardener Conference and present on biochar plots to tour group on June 27, 2014.
- Attend CenUSA annual meeting July 30 and 31, 2014.
- Present on biochar plots at Horticulture Research Farm Garden Field Day on July 23, 2014.

- **Minnesota**
  - Finalize garden rotation design.
  - Install interpretative signage and plant labels.
  - Coordinate individual crop teams for each site.
  - Procure biochar for the relocation of the Cloquet (Native American) site.
  - Plant four gardens and schedule maintenance.
  - Collect data on plants at designated times.

✓ **Actual Accomplishments**

- **Iowa**
  - Iowa (total participants in tours this quarter = 83; 34 male and 49 female; 2 Hispanic, 80 white, 1 black).
  - Potted up and delivered plants and discussed garden preparation and planting with demonstration managers.
  - Contacted MG volunteers to help with data collection and planting at the three Iowa sites.
  - Received CenUSA biochar ball caps and distributed to Master Gardener volunteers and demonstration farm managers.

- Held meeting to update Denny Schrock and Cindy Haynes on CenUSA project on May 22, 2014.
- Attended Upper Midwest Master Gardener Conference and presented on biochar plots in Muscatine to tour group on June 27, 2014.
- Attended the CenUSA Annual Meeting on July 30 and 31, 2014, which included a tour of one of the MN biochar demonstration gardens.
- Presented on biochar plots at the ISU Armstrong Farm Demonstration Garden Field day on July 21, 2014.
- Presented on biochar plots at Horticulture Research Farm Garden Field Day on July 23, 2014.

- **Minnesota**
  - The CenUSA Master Gardener Volunteer project leaders reached 77 people between May 1 and July 31, 2014.
  - Julie Weisenhorn completed the garden design, which took into consideration the need for rotating solanaceae crops such as potatoes, peppers and tomatoes.
  - Interpretive signage and plant labels were installed at all four sites (see photograph). An additional directional sign was made for the Andover site directing visitors in the Bunker Hills Park to the garden.
  - All crop teams were coordinated at each site, meaning sub-groups of volunteers are responsible for 4-5 crops each.
  - Biochar for the Cloquet site was once again donated by Royal Oak Charcoal Company and payment for shipment of the biochar was covered by grant funds.
  - Gardens were planted in all four sites in early June. Due to the cool wet weather, the planting was delayed from late May. In the Cloquet site at the Fond du Lac Tribal Community Center, a new site was established which included amending the soil with biochar and installing a deer resistant fence.
  - The lettuce and carrots struggled with germinating so the data will be inconclusive on those crops. Collecting is an ongoing process that will be completed in September. The results will be posted in the annual report

- ➢ The CenUSA annual meeting took place at the Minnesota Landscape Arboretum. Twenty-five Minnesota Extension Master Gardener volunteers attended a portion of the event and provided a guided tour for one of the CenUSA Biochar Demonstration Gardens located at the Arboretum.
- ➢ A display with information representing the CenUSA Extension Master Gardener Biochar research project in Minnesota was set up in the public foyer of the Arboretum during the CenUSA annual meeting. Attendees and the general public had access to the display and an evaluation system was accessible that asked: "Please give us your opinion: Based on what you learned about Biochar today, if it were available on the market, would you be interested in applying it to your garden? Results of the survey were: 65 said yes, they would use biochar; 9 said maybe they'd consider using biochar; and 3 said no, they would not use biochar.

✓ **Explanation of Variance**

None

✓ **Plans for Next Quarter**

- **Iowa**
  - ➢ Complete harvest data collection.
  - ➢ Organize and summarize data.
  - ➢ Write blog post for site.
- **Minnesota**
  - ➢ Continue data collection.
  - ➢ Develop and staff a public display about the Extension Master Gardener role on the biochar project at the Minnesota State Fair on August 31, 2014 in the University of Minnesota building as a special one-day project.
  - ➢ Extension Master Gardener volunteer Meleah Maynard will write and post a blog about the biochar project in late August – describing the volunteer experience.
  - ➢ Julie Weisenhorn will present "How to Engage Volunteers in Research" as a module for the E3 conference in Ames, Iowa in September 2014.
  - ➢ Maintain gardens until hard frost.

- ➢ Clean up gardens to prepare for winter.
- ➢ Coordinate individual crop teams for each site.
- ➢ Procure biochar for the relocation of the Cloquet site.
- ➢ Plant four gardens and schedule maintenance at each one.
- ➢ Collect data on plants at designated times.

✓ **Publications, Presentations, Proposals Submitted**

None

5. Evaluation and Administration

a. Planned Activities

- ✓ Develop survey instruments, conduct analysis of surveys completed by participants, and produce reports summarizing impact of CenUSA Extension efforts.
- ✓ Support C6 team to develop educational materials targeting K-12 youth.
- ✓ Schedule and coordinate weekly meetings with CenUSA Extension interns.
- ✓ Recruit CenUSA Team members to exhibit at CenUSA Annual Meeting Trade Show; develop impact exhibits for CenUSA Annual meeting; prepare Extension presentation for CenUSA Annual meeting.
- ✓ Continue work on Extension Energy and Environment Conference (see: http://www.2014e3.org/agenda/).
    - o Make arrangements for conference tours.
    - o Follow up with plenary, breakout, and speed sharing speakers for the conference.
    - o Continue marketing the conference through various outlets.
- ✓ Recruit trucker and complete contract for trucking switchgrass from UNL to Iowa for the CenUSA beef feeding trial.
- ✓ Work with Vermeer:
    - o Publicize plot establishment.
    - o Work with Vermeer PR staff and a signage company to design, develop and install signage at Vermeer plots.

- Plan CenUSA outreach activities at Vermeer site.

✓ Provide input for CenUSA Extension teams.

✓ Collect information from CenUSA Extension teams and prepare reports.

b. Actual Accomplishments

✓ Revised data graphs of four survey result reports posted on CenUSA website

- *Adoption of Switchgrass Production*
- *Perennial Grasses for Bioenergy in Central U.S.*
- *Integrated Agricultural Landscapes for Profit Risk Management*
- *Establishing and Managing Perennial Grasses for Bioenergy*

✓ Developed impact banner for CenUSA trade annual meeting trade show.

✓ Developed evaluation instrument for CenUSA annual meeting.

✓ Represented CenUSA at June AFRI CAP Extension teleconference.

✓ Scheduled and coordinated weekly meetings with CenUSA Extension interns and meetings with technical experts, editors and videographers.

✓ Recruited CenUSA Team members to exhibit at CenUSA Annual Meeting Trade Show; Developed impact exhibits for CenUSA Annual meeting; prepared Extension presentation for CenUSA Annual meeting.

✓ Continued work on Extension Energy and Environment Conference (see: http://www.2014e3.org/agenda/)

- Make arrangements for conference tours.
- Follow up with plenary, breakout, and speed sharing speakers for the conference.
- Continue marketing the conference through various outlets.

✓ Recruited trucker and complete contract for trucking switchgrass from UNL to Iowa for the CenUSA beef feeding trial.

✓ Worked with Vermeer to:

- Publicize plot establishment.

- Work with Vermeer PR staff and signage company to design, develop and install signage at Vermeer plots (see attached pictures).
- Planed CenUSA outreach activities at Vermeer site to be held September 4, 2014 (see new banner prepared for the exhibit that highlight commercial targets for CenUSA project).

✓ Provided input for CenUSA Extension teams.

✓ Collected information from CenUSA Extension teams and prepared reports.

c. Explanation of Variance

None

d. Plans for Next Quarter

✓ Develop survey instruments, conduct analysis of surveys completed by participants, and produce reports summarizing impact of CenUSA Extension efforts.

✓ Support C6 team to continue development of educational materials targeting K-12 youth.

✓ Finalize plans for E3 conference, host conference, and conduct evaluation for conference.

✓ Prepare Vermeer Dealer Days exhibit, handouts and evaluation.

✓ Work with Iowa Extension to identify new lead for producer demonstration/outreach component of the project.

- **Publications, Presentations, Proposals Submitted**

None this quarter.

Exhibit 1

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WASHINGTON, D.C.
and

AGRICULTURAL RESEARCH DIVISION
INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
UNIVERSITY OF NEBRASKA
LINCOLN, NE

RELEASE OF LIBERTY SWITCHGRASS

The Agricultural Research Service (ARS), United States Department of Agriculture (USDA), and the Agricultural Research Division, Institute of Agriculture and Natural Resources, University of Nebraska (UNL) announce the release of Liberty switchgrass. Liberty switchgrass (Panicum virgatum L.) is a lowland type cultivar that is adapted to USDA Plant Hardiness Zones (HZ) 4, 5, and 6 in the Great Plains and Midwest, USA east of 100o W. longitude and potentially other regions where it has not been tested to date. It was developed for use as a perennial biomass energy crop and is the first high yielding biomass type lowland cultivar that is adapted to this region. It can produce greater biomass yields than upland or forage type switchgrass cultivars that have been developed previously for use in the region and has equivalent winter survival. It has significantly greater winter survival in its adaptation region than previously released lowland switchgrass cultivars that frequently have substantial winter damage and stand loss north of 40o N latitude in the USA.

Liberty was developed using population hybridization and multi-generation within population breeding procedures. Plants of two switchgrass cultivars, Summer and Kanlow were mated using paired plant crossing in the greenhouse in1996. Summer (S) is a tetraploid, upland cultivar that is based on germplasm collected in southeast Nebraska while Kanlow (K) is a tetraploid, lowland cultivar that originated from a collection in Oklahoma. Seed harvested from the Summer (S) plants was used to grow KxS F1 plants which were transplanted into field evaluation nurseries at the University of Nebraska's Agricultural Research and Development Center (ARDC) near Mead, NE in the spring of 1997. In 1999, fifty-one plants with the lowland phenotype were selected for vigor and survival and transplanted into an isolated polycross nursery which was used to produce Syn 2 seed by harvesting seed from all selected plants. The Syn 2 seed was used to establish a generation advance nursery using transplanted seedlings that produced Syn 3 seed. The two generations without selection were used to stabilize the population. The Syn 3 seed was used to grow 2900 seedlings in mini-pots in the greenhouse. Six hundred seedlings selected for their vigor at six weeks post-planting were transplanted to a spaced plant field selection nursery in 2002. Two years after transplanting to the field nursery, plants were evaluated for biomass yield and composition and 34 plants with the lowland phenotype were selected based on a selection index (NETO2) that weighted high biomass yield and low stem lignin concentration equally. Selected plants were transplanted in an isolated polycross nursery in 2006 to produce Liberty Syn 1 seed which was evaluated as the experimental strain KxS HP1 NETO2 C1.

Multi-year biomass evaluation trials were conducted at locations near Mead, NE (HZ 5), Dekalb, IL (HZ 5), and Marshfield (HZ 4), Arlington (HZ 4), and Spooner (HZ 3), WI during the period 2008 through 2011 in which cultivars and experimental strains including KxS HP1 NETO2 C1 were evaluated for biomass yield, plant survival, and other traits. Small plot trials were managed to maximize biomass yields and were harvested after killing frosts in 2009, 2010, and 2011. Stand persistence was also monitored during this period. Biomass yields of Liberty were 40 percent and 25 percent greater, respectively, at Mead, NE and Dekalb, IL (both HZ 5 locations) than the best available adapted upland cultivars. At Dekalb, IL, Liberty's biomass yields were also 25 percent greater than Kanlow or any other tested lowland switchgrass experimental strain. Some lowland experimental strains at Mead, NE had greater biomass yields than Liberty but had significant stand loss in space-planted evaluation nurseries during the winter of 2008-2009 while plants in the Liberty population had negligible winter damage. At Spooner, WI (HZ 3), Liberty had greater biomass yield than any released cultivar in the trial and maintained stands with 100 percent ground cover during a period in which Kanlow and Kanlow-based experimental strains had significant winter kill resulting in ground cover scores of less than 20 percent. Liberty also maintain excellent stands at both Marshfield and Arlington, WI where again Kanlow and Kanlow-derived experimental strains had significant winter damage. At Arlington and Marshfield, WI, Liberty had equivalent or greater biomass yield than switchgrass HZ 4 cultivars that have been released to date. Its primary merit for release is its ability to maintain stands and produce high biomass yields when managed as a biomass energy crop in the Midwest USA.

Liberty has the typical lowland switchgrass phenotype but because the female parent plants in the originating crosses was the upland cultivar Summer, it has upland cytoplasm that can be identified using chloroplast DNA markers. Switchgrass maturity as measured by heading date can vary with year and environment. Liberty is typically two to three weeks earlier in maturity than Kanlow, its lowland male parent cultivar, and can be distinguished from Kanlow and other switchgrass lowland cultivars by its earlier maturity and chloroplast DNA. It is 10 days to two weeks later in maturity than Summer, its female parent cultivar, and can be distinguished from Summer and other upland cultivars by its lowland phenotype. It is a tetraploid cultivar.

Liberty is a stable, improved random mated population and will be maintained and increased accordingly. Breeder seed will be jointly maintained and produced by USDA-ARS and the University of Nebraska-Lincoln with random-mated, isolated increase fields originating from Syn 1 breeder seed. Foundation seed production of Liberty will be managed by Husker Genetics, the Foundation Seed Division of the University of Nebraska-Lincoln, Lincoln, NE. Foundation seed will be made available for certified seed production on a non-exclusive basis to seed producers who contractually agree to produce and market the seed only as certified seed using the cultivar name Liberty. Certified seed production will be restricted to the USDA Plant Hardiness Zones 5 and 6. A technology development and transfer fee will be assessed by the University of Nebraska. Seed of Liberty will be deposited in the National Plant Germplasm System where it will be available for research purposes. Application will be made for U.S. Plant Variety Protection.

Individuals contributing to the development of the cultivar include K.P. Vogel (breeding and evaluation trials), R.B. Mitchell (evaluation trials), and G. Sarath (cultivar characterization and evaluation trials) all USDA-ARS, Lincoln, NE and M.D. Casler (evaluation trials) USDA-ARS, Madison, WI.

Signatures:

[signature] — 11/15/13

Dean and Director, Agricultural Research Division
University of Nebraska — Date

K Simmons — 11/27/13

Deputy Administrator, Crop Production and Protection
Agricultural Research Service, U.S. Department of Agriculture — Date

Exhibit 2

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FOR IMMEDIATE RELEASE
APRIL 1, 2014

LIBERTY, A NEW BIOENERGY SWITCHGRASS CULTIVAR THAT THRIVES IN NORTHERN CLIMES

Producing excellent yields of biomass for bioenergy, new switchgrass (*Panicum virgatum L.*) cultivar *Liberty* promises to revolutionize biomass production. It has pushed northward the agricultural zone where high-yielding switchgrass can be grown, and like the prairie grasses from which it was bred, *Liberty* prospers in marginal soils.

Dr. Kenneth Vogel, standing on tiptoes in Liberty *switchgrass before flowering*.

Lincoln, NE – Agricultural Research Services (ARS) today announced the launch of *Liberty*, a new switchgrass cultivar developed by the USDA-ARS Grass Breeding Program. "The development and testing of *Liberty* switchgrass was a multi-scientist, multi-location team effort," said Dr. Kenneth Vogel, who led the team of plant breeders and agronomists in the almost two decades-long process.

"*Liberty* demonstrates the power of combining top-notch science with the development of alternative fuel sources," said Dr. Kenneth Moore, director of CenUSA, a USDA-funded consortium devoted to the sustainable production of bioenergy and bioproducts in the

Midwest. ARS's Vogel is part of the consortium. "*Liberty's* biomass yields in trials in Nebraska and Illinois are about 25 - 40% greater than for the best previously released cultivars adapted to the region," Moore said, "making this a true breakthrough in the production perennial grasses for biofuels including for the pyrolysis conversion process."

Liberty overcomes winter survival problems that beset high-yielding lowland switchgrass cultivars such as *Kanlow*. Lowland cultivars are difficult to grow reliably north of 40^{o} N latitude, a line that runs across the Kansas-Nebraska border and near Champaign, IL, Indianapolis, IN, and St. Louis, MO. In fact, *Liberty* had excellent winter survival as far north as Spooner, WI (45.8^{o} N; USDA Plant Hardiness Zone 3), as far north as it has been tested.
In multi-year trials at Mead, NE and DeKalb, IL, both in USDA Plant Hardiness Zone 5, *Liberty* produced 8.2 and 7.3 tons/acre biomass, respectively, which was 1.6 tons/acre greater than the previously released upland cultivars adapted to the region. It has also produced high yields at testing sites in Wisconsin.

Vogel and his team developed *Liberty* using population hybridization and multi-generation within population breeding procedures. Beginning in 1996, plants of two switchgrass cultivars, *Summer*, whose germplasm originates from southeast Nebraska, and *Kanlow*, with germplasm from Oklahoma, were mated using paired plant crossing. First-generation offspring were transplanted into field evaluation nurseries, from which 51 plants were selected that had high vigor and excellent winter survival. Standard plant breeding methods were used over the next several years to stabilize the populations and to further select for a combination of high biomass yield and winter survival.

Field trials began in 2008, and continued until 2011. The end result, nearly two decades later, is a stable, improved random-mated population. Producing high yields of biomass, able to thrive in cold climates and prosper on lands marginal for farming, *Liberty* stands to greatly enhance the use of perennial grasses for biomass production for energy in the Midwest.
Liberty represents a lifetime achievement for its developer, Dr. Vogel, who in 2013 retired after a long and distinguished career with USDA-ARS. Says Dr. Kenneth Moore of CenUSA, "Vogel has been a leading grass breeder in the U.S. for decades and his contributions to science and agriculture have been extraordinary. It is immensely satisfying that his most recent cultivar, *Liberty*, is associated with CenUSA, to which he has provided such outstanding leadership and service."

Breeder seed will be jointly maintained and produced by USDA-ARS and the University of Nebraska-Lincoln. Husker Genetics, the Foundation Seed Division of the University of Nebraska-Lincoln, will manage foundation seed for production of certified seed of Liberty.

*   *   *

Based at Iowa State University, CenUSA is a USDA-NIFA sponsored research project focused on the creation of a sustainable biofuels and bioproducts system in the Midwest. Iowa State University's Dr. Kenneth Moore, Charles F. Curtiss Distinguished Professor of Agriculture and Life Sciences, is the lead investigator. The consortium of eight institutions includes Iowa State

University; Purdue University; University of Wisconsin, Madison; University of Minnesota, Twin Cities; University of Nebraska, Lincoln; University of Illinois; Champaign; University of Vermont; and the USDA Agricultural Research Service in Lincoln. CenUSA's mission is to develop a regional system for producing fuels and bioproducts from feedstocks derived from high biomass-producing herbaceous perennials such as switchgrass, using the pyrolytic conversion process.

Exhibit 2

cenusa bioenergy

An ambitious, University based, USDA sponsored research project investigating the sustainable production and distribution of bioenergy and bioproducts for the central U.S.

February | April | June | September

'Liberty' Switchgrass: Plant Breeding Superstar

"You can't make a good car go fast without a good engine. CenUSA Bioenergy is the car and Liberty is the good engine." This is Dr. Ken Vogel's analogy for his new switchgrass cultivar Liberty, which he helped to develop over almost two decades of plant breeding.

Vogel, University of Nebraska Professor and USDA ARS Research Geneticist, began working on Liberty in 1996 along with the USDA-ARS grass breeding program. Their goal was to develop a high-yielding, lowland-type switchgrass cultivar, widely adapted throughout the Midwest, to be grown as a biomass energy crop. The USDA released the new cultivar November 2013, in partnership with the University of Nebraska-Lincoln.

Liberty produces about two tons more biomass per acre than typical northern switchgrass cultivars, which is in keeping with CenUSA Bioenergy's mission of generating higher yields on marginally productive cropland. Rob Mitchell, research agronomist for the USDA-ARS believes that Liberty has the ability to greatly benefit farmers by increasing their net return per acre.

"Compared to other available cultivars like Shawnee, Liberty has increased yield by more than 40 percent in eastern Nebraska. If biomass sells for $70 per ton, Liberty could have a gross return of $175 per acre more than Shawnee," Mitchell said. "Liberty will be one of the most important cultivars for biofuels. Its ability to produce high yields is a critically important component for cellulosic bioenergy," he said.

Vogel sees the greater yield per acre as a big step for the CenUSA Bioenergy project. "This is the first true bioenergy switchgrass in the Midwest. The first one really adapted for the Midwest and for use as a bioenergy crop. It also improves the economic feasibility of using switchgrass as a biomass energy crop in the Midwest," he said.

When research began in 1996, the USDA-ARS Breeding Program crossed two switchgrass cultivars: Summer, an adapted cultivar developed from germplasm originating from southeast Nebraska, and Kanlow, a high-yield cultivar from Oklahoma.

One of the reasons for selecting these lowland cultivars was to improve winter hardiness. After three generations of breeding following the initial crosses, Vogel and Mitchell were able to retain the winter hardiness of Summer and the high yields of Kanlow. Due to this, Liberty has become the first high-yielding, lowland-type cultivar that can survive Midwest winters.

Vogel believes that Liberty could be grown in other areas besides the Midwest; it appears to be adapted to the eastern United States, all the way to the Atlantic Ocean. Extensive trials are underway to determine how well it performs in these areas.

The next step for Liberty is to increase seed production so that it can be made available to farmers. Seed producers can request seed for establishing certified seed fields through Husker Genetics at the University of Nebraska-Lincoln. Liberty will be available to farmers in spring, 2016.

Sustainable Production and Distribution of Bioenergy and Bioproducts for the Central USA

Stay Connected with CenUSA

Visit CenUSA website

CenUSA Bioenergy | Iowa State University | Bioeconomy Institute | 1124C Biorenewables Laboratory | Ames | IA | 50011-3272

CenUSA Bioenergy is supported by Agriculture and Food Research Initiative Competitive Grant No. 2011-68005-30411 from the USDA National Institute of Food and Agriculture.

United States Department of Agriculture National Institute of Food and Agriculture

Exhibit 3

Summary of Stakeholder Comments
12-26-13

Process: CenUSA Bioenergy Advisory Board members (Appendix I) received e-mail notification from Ken Moore that Jelinski would be contacting them via telephone to get their input on the Year 4 re-application process. In his note, (see Appendix II) Moore mentioned that CenUSA has decided to add an objective to the project on commercialization of biofuels and bioproducts produced from switchgrass.

All 12 Advisory Board members were reached and all engaged in extensive and free-ranging telephone interviews during the period 12-17 to 12-23-13. Advisory Board members were asked not to discuss negatives, but rather to offer their insight going forward. Jelinski listened and took copious notes, and avoided 'leading' the stakeholders. In general, stakeholders were highly laudatory of the research and development that has taken place over the past 3 years. Some members provided additional feedback via e-mail after the interview process. The following summarizes their main points in descending order of priority. It also mentions two important issues that were not raised by stakeholders.

Because the Advisory Board has representation from each of CenUSA's key stakeholder groups, this summary sets forth a fairly balanced view and serves as a strong genesis for a stakeholder-driven agenda for the Year 4 re-application.

9 of 12 Stakeholders Said: We Want to See Just One Real Application. The first statement from most stakeholders was an enthusiastic plea to provide a real-world, practical application, as that is the only way that people will see the value of the process, and the only way that unforeseen kinks could be worked out.

However, stakeholders had widely different views on how to accomplish this. Some advocated partnering with farm co-ops, where a co-op buys a machine and then shares the machine (such as the mobile pyrolyzer discussed below). There was strong feeling that the CenUSA project would play well into the infrastructure of co-ops, most of which have fuel stations, and could be tweaked and optimized on small and local levels. It was emphasized that, in general, co-op members are fairly unaware of CenUSA's accomplishments. For example, they "express blank looks when told about the opportunities of biochar" (see section below on recommendations on outreach).

Others said that there is more than one way to get to commercial applications. For example, several stakeholders suggested partnering with an existing cellulosic ethanol facility to get going. In addition to syngas and biochar, pyrolysis would provide process heat for ethanol fermentation.

Emphasis was on starting small, though, because there are big risks and challenges, and the project needs to get across the well-recognized 'Valley of Death' in which startups fail in infancy. It was thought that a 150 tons/day scale plant is probably needed, but maybe a pilot plant as small as 50 tons/day could help with the learning curve. It was emphasized that it takes a lot beyond research to make this happen, and the marketplace needs to participate. We were reminded that DuPont and Poet invested in pilot scale development for their cellulosic ethanol plants.

9 of 12 Stakeholders Said: We Need to Look Broader than Switchgrass, Examine Multiple Feedstocks and Multiple Markets. The value proposition for switchgrass and other energy crops varies by region,

CenUSA Bioenergy is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture. (http://www.cenusa.iastate.edu)

and land prices also factor into this ‘patchwork quilt’. A number of stakeholders expressed the downside of switchgrass --- specifically, it requires a farmer to plant it and then be committed to it for 10 years. This was deemed an issue for people who rent land, rather than owning it. It was also mentioned that maybe Iowa isn’t so suited for growing switchgrass --- that corn and soybeans are too profitable and perhaps warmer areas like KY and TN would be more suitable.

Some stakeholders suggested looking beyond switchgrass, perhaps to corn stover, which we already know how to harvest, deliver and convert to ethanol. Another growth area is cover crops like rye grass. Some suggested growing miscanthus to provide, for example, bioenergy for a poultry plant or for a university power plant.

Stakeholders also stressed the need for multiple markets (e.g., safety nets) for switchgrass, and mentioned how switchgrass pellets could be used for co-fired coal plants for reduction of emissions, or used for heating and liquid fuels, and how one outfit in PA is shipping compressed switchgrass to Europe for oil spills. As an existence proof, MFA Oil is using perennial grasses to burn directly and has an agreement with a 9-county region in MO (see BCAP program in MO). Stakeholders wanted a better identification of other end markets and alternative uses for switchgrass. (See also section on *We Need to Look Broader than Transportation Fuels* for recurrence of this theme.)

Others discussed the possibility of other uses for switchgrass, for example paper, specialty chemicals and cellulosics. They also stressed that biomass must be usable by farmers and landowners. Some suggested looking at these grasses to see how well they perform under other conversion processes (e.g., cellulosic ethanol).

8 of 12 Stakeholders Said: We Want to See a Value Proposition. Economics was an overarching issue for most stakeholders. They haven’t seen the economic opportunity yet and wanted to know: What is sellable and how do we sell it? The question most had was: How do we produce value for the farmer? Most stated that the economics need to make the numbers work, and the value proposition wasn’t clear to them. It was very telling that Harding, who represents 150,000 farmer families (80% of farmer families in Iowa) is cautious about overpromising. He is reluctant to splash CenUSA’s accomplishments to his members until the economics are worked out.

Another telling question from a stakeholder was: “Do the principals [of the project] think this is possible?” Another said, “Show me a viable plan.” And yet another said “Their own research shows economics aren’t there,” and further advising that so far CenUSA has shown the value of biomass; now is time to show the how of reaping economic value from switchgrass. This is what it will take, stakeholders cautioned, to get industry interest. There was a plea to have a robust technology analysis, and to understand economies of scale. Having clear economic analyses would help.

Stakeholders expressed that in the end this project must enable small rural communities, and that we are right now seeing a functional disconnect between the farmer and the end user. Others mentioned that there also appears to be a disconnect between stakeholders and scientists, but that they wanted to see the science first. To solve the disconnect problem, some suggested that we get more stakeholders to the table now (see Management Section, for recurrence of this theme).

8 of 12 Stakeholders Said: We Need to Look Broader than Transportation Fuels. Industry is right now interested in products other than transportation fuels from biomass --- for example, in pulp and chemicals and biopolymers, where the economics are clearer. (For example, ISU’s Center on Bioplastics and Biocomposites was highly touted.) One stakeholder said, “Biofuels might be what the project is supposed to be about but maybe we need to look at low-hanging fruit.”

Part of the need to look beyond transportation fuels is because of uncertainties introduced by the capricious nature of government in relaxing the renewable fuel standards (RFS) guidelines. Said one stakeholder, “To say our government flip flops is an oxymoron.”

Stakeholders also acknowledged the issue of competition from shale oil and natural gas, which at least temporarily drives down the demand for biofuels. One person said, “CenUSA is up against big oil and ethanol and there is a big disconnect. We must prove our product and prove that it is functional.”

In addition to transportation fuels, biomass can lead to gasification, steam heat and power generation. Should we be working on biomass for fuel, or biomass for energy generation? Or for cellulosic ethanol generation? The bottom line is that stakeholders were not clear on what the best end product is on the processing side.

6 of 12 Stakeholders Said: We See an Academia ‘Push’ and not an Industrial ‘Pull.’ A recurring theme was that industry needs to be more involved, and that industry needs to want this. Said one stakeholder, “Industry must drive the agenda.” Several stakeholders were concerned about the lack of industrial representation at the last annual meeting, and questioned whether industry is doing this themselves in secret, or are they waiting for more information? Others noted the lack of involvement by co-op representatives, as well. The need was expressed for involvement of others to work out unforeseen kinks.

With respect to this particular stakeholder-identified issue, it is important to note that on the flip side, stakeholders expressed their appreciation for the unbiased aspect of information coming from academia.

6 of 12 Stakeholders Said: The Whole Issue of Harvesting and Logistics for Switchgrass is Tough. “Transportation is a huge issue,” stakeholders said, “and the transportation economics isn’t working even though Stuart has done a great job looking at cost of transportation.” Stakeholders emphasized that getting the logistics clear is important for business, and not to forget that logistics transcends the particular application. For example, logistics is setting the foundation for biomass competing with natural gas. Stakeholders questioned whether bales and pelletizing could be used at scale. They emphasized that the cost to harvest on the flat (e.g., land near Ames) is low, but on on a 10 % slope, the cost to harvest goes through the roof.

5 of 12 Stakeholders Said: We Need to Grow the Industry by Focusing on Job Creation. Stakeholders were enthusiastic that the jobs created in this industry will be of high quality, and will also increase the ‘number of jobs/acre,’ a ratio that is low for corn and soybean. It was emphasized that job creation would help reverse the loss of rural communities. They noted that a service industry will grow up for parts and service for the biofuel plants, and machinery dealers will move nearby, just like happened for ethanol. Stakeholders thought that we should promote rural development. “We need some homegrown renewable energy,” said one. “Love to see smaller community projects --- small and self-funded where people can utilize their own waste streams. This sends a strong message. Small success stories will energize others.”

5 of 12 Stakeholders Said: We Need Better Information about Biochar. Stakeholders expressed some confusion about biochar. One wanted to know how we certify that biochar is high-quality. Another wanted to know if the minerals and salts are bioavailable. Another wanted to see data to show how effective biochar is.

On the plus side, biochar adds value to the process, and the biochar market looks promising. Is CenUSA going to take biochar to the marketplace, maybe bag it? One thought it was good to get Master Gardeners involved in biochar (however, see pushback on Master Gardeners in section below).

5 of 12 Stakeholders Said: We Should Explore Mini Biofuel Plants or Pyrolyzers on a Semi Truck. Some thought that CenUSA should investigate this possibility, and suggested using a mobile pyrolysis unit through a co-op. In this way the end user can use the bio-diesel product in their own communities, and this helps with local sustainability (see topic below). However, one stakeholder expressed concerns about emissions and explosion and fire risks associated with mobile pyrolysis units and said "I can't see it."

5 of 12 Stakeholders Said: We Need Better Coordination among Objectives and Need to Tweak the Management Plan. Several stakeholders pointed out the need for better coordination among Objectives, citing that in a report at the Annual Meeting, one Objective used 12-15 tons/acre in its calculations, and another used 2 tons/acre. Another said, "The price for the feedstock and cost of land rental was seemingly grasped out of the air with no real justification. Working with the same or similar values would lend credibility to the project."

Because the stakeholders are very busy people and because travel to in-person meetings is time consuming, some expressed the desire to have more virtual meetings.

As we go into the Year 4 re-application process, the stakeholders expect to see more industrial representation on the Advisory Board. New Board members are needed on the "front end" and "back end" of the process, and representatives were suggested from DuPont and Poet.

One stakeholder suggested that in the future, Annual Meetings be held at an industrial site (e.g., Poet or ICM), and not at a university test plot.

4 of 12 Stakeholders Commented on Extension and Outreach. Extension was praised because it can be trusted and isn't corporate hype. However, stakeholders expressed the need to get the information out there. Said one stakeholder, "The Extension network is in place. Use it!"

There was some push-back from the Master Gardener project as being too 'full of fluff' and 'feel good,' and wanted to see hard information. It was felt that Extension and Outreach are needed to garner support from constituents, and that focus on youth is not warranted because they have a long way to go before they vote. Instead of youth, stakeholders suggested educating co-ops and people who can get involved and help. [One stakeholder said that too much budget is going to Extension and Outreach, but Moore and Kinzel remind us that Extension and Education are required to receive 1/3 of the funds and that we are very close to that line. The new Objective could fall under Outreach, and therefore Extension.]

3 of 12 Stakeholders Said: We want to be Good Stewards of the Land. Some stakeholders began their interview with "Sustainability is important." Some were concerned because so far we don't know if switchgrass for transportation fuel is sustainable, and cautioned that we don't want to go the route of corn and ethanol. One expressed concern about switchgrass as a monoculture and suggested that this is setting up for production loss. We were also cautioned that the recent drought was an eye-opener, where less productive species survived and more productive species did not. One stakeholder thinks that farmers should be willing to give up 0.5 ton/acre in order to ensure sustainability.

Sustainability of healthy wildlife populations was also mentioned, and one stakeholder encouraged people to reach out to their respective wildlife biology departments to gauge interest. He also suggested that that state's fish and game agency and possibly other wildlife groups that are interested in this work could be invited to future meetings.

3 of 12 Stakeholders Said: We Need a Better Definition of Marginal Land. Even though the words 'marginal land' are in CenUSA's vision statement, the definition of marginal land needs to be clarified. One stakeholder said that CenUSA not being critical enough of itself. Highly erodible land would greatly benefit from perennial grasses. It is not clear how many acres of marginal land are out there. It was felt that if we had a common definition, there would be a more candid conversation about the environmental plusses and minuses of the project. At least one stakeholder acknowledged that some land is in row crop production that shouldn't be.

2 of 12 Stakeholders Said: Why Haven't we Heard the Word EPA? Or Local Restrictions? One stakeholder cautions that EPA should be involved in this project from the get-go. EPA could be providing hints so we don't go down the road of failure. Another mentioned that all sorts of restrictions kick in when involving the Soil Conservation Commission --- do we know how legislative restrictions might impair progress?

2 of 12 Stakeholders Said: We Should Look at the Transition from Row Crop to Alternative Crop Production. The transition from row crop to alternative crop production is something that could be modeled at ISU. We were warned that the next 5 years are going to be different from the last 5 years. If a farmer invests in this transition, and it takes 2-3 years to get the crop established, what will the markets be several years out? Are there properly scaled systems for switchgrass and miscanthus? It is a chicken and egg problem, as it takes 2-3 years to establish switchgrass plots.

1 of 12 Stakeholders Said: Has Anyone Looked at the Stability and Corrosiveness of Bio-oil/Bio-diesel? One stakeholder cautioned that stability and corrosion of bio-fuels, from what he reads on the internet, are real problems. Corrosive, unstable biofuel would be more difficult to market and to use.

1 of 12 Stakeholders Said: Perform a True Cost Analysis. One stakeholder suggested developing a metric with which to compare the different ethanol feedstocks. He recommended a rating according to "sustainability" or "societal benefit" because using only dollars and cents is easy but can be misleading. He mentioned that such a rating may also help us to determine what kinds and levels of supports (subsidies) may be needed in order to compete.

0 of 12 Stakeholders Mentioned Education. In Sherlock Holmes' *The Hound of the Baskervilles*, the clue came from the dog that didn't bark. It was curious that no one brought up the fact that the universities involved in this project are educating future leaders in the bioenergy field.

0 of 12 Stakeholders Mentioned Intellectual Property. Patents and licenses are often used as metrics for success in tech-related projects. It is curious that no one mentioned intellectual property.

Appendix I

2013 CenUSA Bioenergy Advisory Board

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Appendix II
e-Mail Sent to Advisory Board from Ken Moore 12-17-13

Friends:

It has been a busy and interesting time for the project since we met in Indiana. As you are aware, Bill Goldner has been actively encouraging us to be more proactive in demonstrating the commercial potential of our vision for the past year and a half. In a conference call last month he indicated very strongly that our reapplication for next year's funding would be evaluated with this expectation.

To address this concern, we have decided to add a new objective area to the project that focuses on commercialization of biofuels and bioproducts produced from perennial grasses grown on marginal land. Recognizing that this will be a major shift in direction, we have engaged Lynn Jelinski to assist us with writing the application. Lynn worked with us on the original proposal and has an amazing ability to communicate ideas and explain why what we are doing is important. I want to give you a heads up that she will be contacting you for your thoughts and ideas.

One of the best things we have going for us as a project is all of you. You have been with us through it all and have always been forthcoming and honest with your comments and suggestions. I encourage you to be the same with Lynn.

My very best wishes for the Holidays.

Ken

What happens when undergraduate students tackle the research question: Can switchgrass grown on marginal land be used to produce bioenergy and bioproducts?

That's the high-profile question that CenUSA, one of Iowa State University's largest USDA-funded projects, is working to answer. "Who better to work with professors and technical staff," said Anne Kinzel, the project's chief operating officer, "than bright and energetic summer interns? They learn science and engineering in ways that only hands-on research can provide."

At the conclusion of their 10-week, paid internships, Kinzel was surprised to hear how powerful the out-of-class learning experiences were. As expected, students gained research experience and honed their critical thinking and communications skills. But even more important, in their own words, were the life lessons and personal growth that came from being nudged out of their comfort zones.

Hear what CenUSA summer interns from across the United States, David Carlson, Michelle Apolaro, and Beth Lowry, have to say about their experiences. Like Kinzel, you will be surprised.

Spotlight on Intern David Carlson

"I got to call the shots in my research project, which was an exciting experience most 20 year-olds don't get," said David Carlson, an undergraduate in agricultural business and marketing at the University of Minnesota.

> *I got to call the shots in my research project, which was an exciting experience most 20 year-olds don't get.*
>
> - David Carlson, CenUSA Summer Intern

Carlson's project, carried out at CenUSA's partner Agricultural Research Services at the University of Nebraska, demonstrated that non-destructive, in-field biomass testing could accurately predict biomass yield. Carlson showed that simple measurements such as elongated leaf height and visual obstruction could replace the current time-intensive and destructive quadrat sampling technique.

"His research is significant," said his mentors and project collaborators Drs. Virginia Jin, Rob Mitchell, and Marty Schmer, "because rapid biomass estimation techniques will be critical in assessing feedstock availability in variable landscapes."

CenUSA intern David Carlson, mixing herbicides.

In addition to his research accomplishments, Carlson said he learned a lot about leadership, workplace interactions and people skills.

Because Carlson is an Air Force ROTC cadet, these skills augur well for success during his four-year (at least) commitment to the Air Force.

Carlson's mentors are equally enthusiastic. "Interns like David give us the opportunity to engage students in hands-on experiences that we hope will contribute to their educational and professional development," they said. "Plus, it's fun! Our interns have been fantastic - we hope that they have gotten as much enjoyment out of their experiences with us as we've had in hosting them."

Little do his mentors know how much fun Carlson had. He recounts one of his favorite memories, when he and three teammates were out installing water sensors at different depths in the field, in the rain. Because there were two young women and two young men on the team, and it takes two to install the watermark sets, a natural race ensued. He blames his multi-tasking male partner for being bested by the young women. At least that was his excuse. He said of the experience, "But anyway, we're out in this cornfield, in the rain, racing to see who can install them fastest, laughing and joking, everyone getting covered in mud. It was a great moment!"

Spotlight on Intern Michelle Apolaro

"Months later, and all I talk about is my time at Iowa State University for the internship," said Michelle Apolaro. "The experience was the single most defining factor in my career plans for the future."

> *The experience was the single most defining factor in my career plans for the future.*
>
> \- Michelle Apolaro, CenUSA Summer Intern

Apolaro, an agricultural engineering major at the University of Florida, worked with Professor Stuart Birrell, whose research focuses on precision agriculture at Iowa State University. Apolaro's project involved creating a working definition of the term 'marginal land' for the entire CenUSA project so the team of scientists could compare apples to apples, or better, switchgrass land to switchgrass land.

Apolaro's mentor is equally enthusiastic about the internship. He cites her self-motivation and ability to work independently as the reason she accomplished so much during her summer internship.

She found a paper in the literature that defined 'marginal land' in a logistical manner and adapted the definition to fit the CenUSA project. Using USDA databases, she tested the new definition on two parcels of land in Boone County, IA. Using statistical analyses, she found that many of the variables originally thought to be important for defining marginal land were in fact negligible.

"This is significant," Birrell said, "because it would lead to a more efficient and cost-effective way to identify marginal cropland that would be a candidate for perennial grass."

Thanks to CenUSA, I got a job in the plant biotech industry.

- Michelle Apolaro, CenUSA Summer Intern

Beyond creating a working definition of 'marginal land' for the entire CenUSA project, Apolaro said that the internship taught her a new vocabulary. Now, she says, she feels much more comfortable talking to people in the agricultural industry.

"I truly have never been more excited about a career in agriculture," said Apolaro. After her summer in Ames, IA, she said, her goal is to get back to the Midwest to work in the agricultural industry. "I can't wait to move out there....even if it is in two years!"

Spotlight on Intern Elizabeth Lowry

I got a lot of good input and feedback [at the CenUSA Annual Meeting] and got the big picture of how my work fits in.

- Elizabeth Lowry, CenUSA Summer Intern

No stranger to internships, Elizabeth (Beth) Lowry knew she wanted to spend a summer performing applications-driven research, moving closer to commercialization than the basic research in plant biology she had performed the summer before. Lowry, who recently graduated as a major in biological systems engineering from Kansas State University, worked with Iowa State University professor Robert Brown, a pioneer in the use of pyrolysis – thermal conversion – of biomass to produce bioproducts, biofuel and bioenergy.

"Lowry's project," says Dr. Brown, "has given us important insights into how we might convert biomass into a renewable fuel. One of the challenges in converting biomass into molecules that resemble gasoline and diesel is a relative deficiency of hydrogen in biomass," Brown said, "so Beth and her team investigated ways to pyrolyzer biomass in the presence of waste plastic to make up this deficiency and yield more useful products."

Beth Lowry defends her poster, Co-pyrolysis of Biomass and Polymers: the Effect of Catalysts*, at the CenUSA Annual Meeting at Purdue University.*

Lowry used bench-scale batch pyrolyzers, or micropyrolyzers, to study the effect of catalysts on the co-pyrolysis of biomass and polymers. She, like the other interns, had the opportunity to present her work at CenUSA's Annual Meeting at Purdue University. There, she says, "I got a lot of good input and feedback. I also got the big picture of how my work fits in with the overall project."

As part of a large and active research team, Lowry learned about consensus-building and give-and-take. She describes one point during the summer when there was contention for use of the micropyrolyzer. "The lab manager sat all seven of us down, and everyone had a coherent and mannerly discussion of what we needed to do and what columns and other accessories we needed. In the end the lab manager made sure that everyone's needs were being met and we could all do our research."

The summer internship, combined with her current internship with DuPont Pioneer, helped Lowry clarify her career goals. She plans to go for a Ph.D. degree in molecular biology, and wants to specialize in the genetic transformation of corn (maize) so it can better address issues of sustainability, whether for food, feed, or energy.

For More Information on CenUSA's Summer Internships

CenUSA (http://www.cenusa.iastate.edu/) will begin taking applications for internships on February 1, 2014 for the summer of 2014. The deadline is March 1, 2014. Locations of internships are Iowa State University, the University of Nebraska, Lincoln, Purdue, ARS in Wyndmoor, PA, and the University of Minnesota.

For complete applications information, see
http://www.cenusa.iastate.edu/Education/CenusaInternshipProgram

Exhibit 5

Specific outcomes will be: 1) 1,000 agricultural producers, agricultural industry leaders, educators, and agency personnel and 500 horticultural producers and industry leaders will gain awareness and knowledge regarding environmental, economic, and public relations impacts of transitioning marginal crop land to perennial bioenergy grasses; and will understand the impacts of biochar as a soil amendment (indicator measured by post-event surveys); 2) 800 4-H, FFA, and K-12 science students will gain awareness and knowledge of biomass production, biofuels production, carbon and nutrient cycling topics and careers in bioenergy STEM fields as a result of participating in youth activities (indicators measured by pre/post activity surveys and open-ended questionnaires).

Objective 10. Commercialization

Note: Because Objective 10 is new, it is described in much greater detail than the other Objectives, and over a period of two years.

New in Year 4, Objective 10 is a collaboration between ADM and ISU, and between Renmatix and ISU. Tom Binder (ADM) and Frank Lipiecki (Renmatix) will co-lead Objective 10. Robert Brown (Iowa State University) will coordinate and collaborate.

Our goals are to:

- Explore the use of perennial grasses as an alternative to crop residues in ADM's modified Acetosolv process;
- Assess the potential of fast pyrolysis and solvolysis to produce and capture high value compounds from the acetic- and sugar-rich co-product streams, and lignin streams from ADM's modified Acetosolv process;
- Characterize the chemical and physical characteristics of perennial grasses and cornstover (as a baseline) and correlate these parameters with their performance as feedstocks in Renmatix's Plantrose™ process; and
- Concomitantly, evaluate the potential for lignin streams from Renmatix to produce high value compounds via fast pyrolysis and solvolysis.

A highly important outcome from Objective 10 is expanding the potential of biomass available in the Midwest beyond crop residues. This will answer the stakeholder-identified demand for additional markets and thereby lower the risk to farmers associated with developing an industry based on a single feedstock and will increase farmer participation. A second major outcome is demonstrating feedstock flexibility, which will reduce risk to the biorefinery.

10a. Perennial grasses as an alternative to crop residues in ADM's modified Acetosolv process

Lead Institution: Archer Daniels Midland Company, Tom Binder, Senior Vice President of Research, 217-451-4228

Partner Organization: Iowa State University, Robert C. Brown, Distinguished Professor of Mechanical Engineering, Director, Bioeconomy Institute (BEI) and Center for Sustainable Environmental Technologies (CSET), Iowa State University, 515-294-7934, rcbrown3@iastate.edu.
ADM has developed and built a 1 ton per day integrated biorefinery and used it to demonstrate a modified Acetosolv process to fractionate biomass into cellulose, hemicellulose and lignin streams using pressurized acetic acid and a unique solvent precipitation step. See figure left. ADM's modified Acetosolv process.

This modified process is particularly attractive from an environmental standpoint because solvents can be recycled in total. This process has been developed using agricultural residues as feedstock. In this project ADM will explore the use of feedstocks such as switchgrass in their biorefinery processes.

ADM will process various samples of switchgrass, big bluestem and low diversity mix prairie grasses in its pilot modified Acetosolv processing plant. Other feedstocks available from CenUSA that would provide the highest diversity of cellulose, hemicellulose and lignin content will also be tested to provide directions for future breeding. From this testing ADM will provide fractions back to CenUSA for pyrolysis and solvolysis testing in Objective 10b. ADM will provide fraction yields, pulp and lignin quality information, and enzyme digestibility of the pulp fraction to CenUSA.

Tasks:

10a-1: CenUSA will provide ADM with switchgrass, big bluestem and low diversity mix grasses at 500 kg each for runs in its pilot plant;

10a-2: ADM will provide information on fraction yields, pulp and lignin quality information, and enzyme digestibility to CenUSA; and

10a-3: ADM will provide CenUSA with acetic- and sugar-rich streams, as well as lignin for subsequent pyrolysis and/or solvolysis.

Timetable and Milestones: Objective 10a

	Federal Fiscal Year 2014		Federal Fiscal Year 2015				Federal Fiscal Year 2016			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 10a-1			a							
Task 10a-2							b			
Task 10a-3									c	

a) Feedstock from CenUSA size reduced and dried as required for conversion in the Acetosolv process
b) Acetosolv fraction yield and composition data provided to CenUSA
c) Acetosolv fractions delivered ISU for further testing of recovery of high-value products via pyrolysis and solvolysis

Key outcomes from task 10a:

- This project will establish that viability of alternative markets for perennial grasses, thereby reducing risk to farmers.
- This project will establish the difference in product yield and composition between conversion of agricultural residues and perennial grasses using the Acetosolv process.

10b. Recovery of high value products from ADM's biorefinery co-product streams

Lead Institution: Iowa State University, Robert C. Brown, Distinguished Professor of Mechanical Engineering, Director, Bioeconomy Institute (BEI) and Center for Sustainable Environmental Technologies (CSET), Iowa State University, 515-294-7934, rcbrown3@iastate.edu; Xianglan Bai, Assistant Professor of Mechanical Engineering, Iowa State University, 515-294-7669, bxl9801@iastate.edu

Partner Organization: Archer Daniels Midland Company, Tom Binder, Senior Vice President of Research, 217-451-4228

Initial tests at ISU suggest recovery of high concentrations of acetic acid via pyrolysis of ADM's acetic and sugar rich streams can be achieved. Optimized acetic acid recovery and processes for recovery of sugars or furfural from the acetic and sugar rich streams will be developed. Production and recovery of high value compounds from ADM's lignin streams via pyrolysis and solvolysis will also be assessed. The resulting biochar will be analyzed to determine the bioavailability of nutrients, including potassium and phosphorus.

Researchers at ISU have developed a proprietary process, low temperature, low-pressure (LTLP) hydrogenation, to stabilize phenolic oligomers produced from pyrolysis of biomass. These compounds, derived from lignin in biomass, are extremely reactive even at room temperature, making them difficult to process into products. This stabilized material not only has potential as heating oil, but also as a refinery blendstock and starting material for polymers and carbon fibers. The LTLP process will be used with lignin streams from ADM's biorefinery processes to determine if high value products can be generated. Bench scale catalytic upgrading tests will be conducted to assess the potential of this material as an intermediate for the production of drop-in hydrocarbon fuels.

Hypotheses to be evaluated include:

- Staged pyrolysis of acetic and sugar rich streams allow separate recovery of acetic acid and furfural;
- Solvolysis of sugar rich streams allows for recovery of high concentrations of sugars or furfural;
- Thermochemical conversion of lignin streams allows for recovery of high value compounds, specifically phenolic monomers;
- Utilization of ISU's LTLP stabilization technique is effective in conversion of lignin streams into high value products, such as phenolic monomers, refinery blendstocks, and intermediates for polymer and carbon fiber production;
- Pyrolytic recovery of sugars from co-product streams results in a concentrated sugar solution that can be readily hydrolyzed and fermented; and
- Thermochemical conversion of acetic and sugar rich streams and lignin streams produces a biochar that provides bioavailable nutrients to the soil.

Tasks:

10b-1: Test the concept of staged pyrolysis of acetic- and sugar-rich streams for recovery of high value products such as acetic acid, phenolic monomers, sugars, and furfural using the Frontier double-shot micropyrolysis unit;

10b-2: Test the effectiveness of catalytic pyrolysis of acetic- and sugar-rich streams for recovery of high value products such as acetic acid, phenolic monomers, sugars, and furfural using the Frontier Tandem micropyrolysis unit;

10b-3: Test the effectiveness of solvolysis of sugar rich streams for recovery of high value products such as sugar and furfural using solvolysis microreactors;

10b-4: Test the effectiveness of pyrolysis and catalytic pyrolysis of lignin streams for recovery of high value products such as phenolic monomers using the Frontier Tandem micropyrolysis unit;

10b-5: Test the effectiveness of solvolysis of lignin streams for recovery of high value products such as phenolic monomers using solvolysis microreactors;

10b-6: Assess potential of ISU's LTLP stabilization technology to convert lignin streams into high value intermediates or end products;

10b-7: Conduct exploratory upgrading tests of stabilized lignin streams from Task 10b-6. These tests will be carried out using laboratory slurry or fixed bed reactors;

10b-8: Conduct continuous flow pyrolysis, staged pyrolysis, and catalytic pyrolysis using down-selected conditions from micropyrolysis trials. These tests will be carried out using a laboratory scale pyrolysis reactors with capacities ranging from 100 g/h to 2 kg/h;

10b-9: Conduct larger scale semi-batch or continuous trials using down-selected conditions from solvolysis microreactor trials. These tests will be carried out using laboratory slurry or fixed bed reactors;

10b-10: Conduct bench top fermentation trials using recovered sugar streams; and

10b-11: Assess bioavailability of nutrients recovered in the biochar.

Timetable and Milestones: Objective 10b

	Federal Fiscal Year 2014		Federal Fiscal Year 2015				Federal Fiscal Year 2016			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 10b-1			a							
Task 10b-2				b						
Task 10b-3				c						
Task 10b-4				d						
Task 10b-5				e						
Task 10b-6				f						
Task 10b-7										g
Task 10b-8										h
Task 10b-9										i
Task 10b-10										j
Task 10b-11										k

a) Completion of double-shot micropyrolysis tests on sugar and acetate rich streams. Conditions for production and recovery of high value products in a pyrolysis or staged pyrolysis scenario down-selected. Test plan for lab scale proof of concept determined.
b) Completion of Tandem micropyrolysis tests on sugar and acetate rich streams. Conditions for production and recovery of high value products in a catalytic pyrolysis scenario down-selected. Test plan for lab scale proof of concept determined.
c) Completion of solvolysis microreactor tests on sugar and acetate rich streams. Conditions for production and recovery of high value products in a solvolysis scenario down-selected. Test plan for lab scale proof of concept determined.
d) Completion of Tandem micropyrolysis tests of lignin streams. Conditions for production and recovery of high value products in a pyrolysis or catalytic pyrolysis scenario down-selected. Test plan for lab scale proof of concept determined.
e) Completion of solvolysis microreactor tests of lignin streams. Conditions for production and recovery of high value products in a solvolysis scenario down-selected. Test plan for lab scale proof of concept determined.

f) Completion of lab scale stabilization tests. Mass balance, physical and chemical characterization, and thermal stability differences determined.
g) Completion of lab scale upgrading tests. Mass balance, physical and chemical characterization determined.
h) Completion of lab scale proof of concept tests for selected pyrolysis, staged pyrolysis, and catalytic pyrolysis conditions. Complete mass balance and product analysis
i) Completion of lab scale proof of concept tests for selected solvolysis conditions. Complete mass balance and product analysis
j) Measure organism growth using optical density to determine fermentability and toxicity of the pyrolytic sugars streams.
k) Completion of biochar characterization.

Key outcomes from task 10b:

- This project will establish the technical feasibility of producing value-added bioproducts (e.g., ethanol, lignin, biochar) via the pyrolysis and solvolysis platform.
- This project will establish the possible combinations and yields of end products and additional value thermochemical processing of biorefinery co-products.

10c. Characterize the chemical and physical characteristics of perennial grasses and cornstover, and correlate these parameters with their performance as feedstocks in Renmatix's Plantrose™ process

Lead Institution: Renmatix, Inc., *Frank Lipiecki*, Research and Development Director, 484-751-4013

Partner Organization: Iowa State University, *Robert C. Brown*, Distinguished Professor of Mechanical Engineering, Director, Bioeconomy Institute (BEI) and Center for Sustainable Environmental Technologies (CSET), Iowa State University, 515-294-7934, rcbrown3@iastate.edu; *Xianglan Bai*, Assistant Professor of Mechanical Engineering, Iowa State University, 515-294-7669, bxl9801@iastate.edu.

Renmatix, an early-stage company with substantial venture investments from BASF and Waste Management, converts biomass into C5 (hemicellulose) and C6 sugars (cellulose) using their Plantrose™ process[2], a multi-stage supercritical hydrolysis process. Projected advantages of the Plantrose™ process are its use of water as a solvent, and its fast reactions with minimal consumable usages. To date the Plantrose™ process has been used primarily for woody biomass. This project will evaluate the use of perennial grasses and corn stover as feedstocks in Renmatix's Plantrose™ process.

[2] See http://renmatix.com/technology/plantrose-process/ for an animated diagram of the Renmatix process.

Hypotheses to be evaluated include:

- The Plantrose™ process will convert cellulose and hemicellulose from perennial grasses to C5 and C6 sugars at yields similar to those from woody biomass;
- Conversion of perennial grasses to C5 and C6 sugars is economically feasible.

Tasks:

a) 10c-1: Determine chemical and physical characterization of 2 samples each of 4 biomass materials (corn stover for baseline; switchgrass, big bluestem, low diversity mix), including sugar, lignin, ash and metals. [See task 10d-1, below. CenUSA will provide 1 kg x 8 samples of the biomass screened to <200 microns for initial characterization and for task 10c-2, 10 kg x 2 samples of biomass (one cornstover, one perennial grass; size to be determined) for task 10c-2; and 75 kg x 2 samples (one cornstover, one perennial grass; screened to < 100 microns) for task 10c-3.]

b) 10c-2: Bench scale: determine suitability for processing herbaceous biomass with Plantrose™ process;

c) 10c-3: Pilot scale: determine potential economic feasibility of 1 switchgrass and 1 cornstover conversion into sugars and lignin via the Plantrose process; and

d) 10c-4: Samples of lignin residue produced from each of 2 biomasses in the Plantrose pilot plant provided to ISU for conversion to value-added products (Objective 10d).

Schedule and Milestones: Objective 10c

	Federal Fiscal Year 2014		Federal Fiscal Year 2015				Federal Fiscal Year 2016			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 10c-1			a							
Task 10c-2				b						
Task 10c-3						c				
Task 10c-4							d			

a) Initial physical and chemical characterization of feedstocks provided to CenUSA

b) Initial assessment of feedstock suitability from bench scale tests provided to CenUSA

c) C5 sugar, C6 sugar and lignin yield compositional data from pilot scale tests provided to CenUSA.

d) Lignin streams (<10 kg each) from the two pilot scale tests delivered to ISU for further conversion testing

Key outcomes from task 10c:

- This research and development will allow Renmatix to compare product yield and composition to that from other feedstocks currently being used.
- This project will establish the difference in product yield and composition between conversion of woody biomass, agricultural residues and perennial grasses using the Plantrose™ process.

10d. Recovery of high value products from Renmatix's biorefinery co-product streams

Lead Institution: Iowa State University, *Robert C. Brown*, Distinguished Professor of Mechanical Engineering, Director, Bioeconomy Institute (BEI) and Center for Sustainable Environmental Technologies (CSET), Iowa State University, 515-294-7934, rcbrown3@iastate.edu; *Xianglan Bai*, Assistant Professor of Mechanical Engineering, Iowa State University, 515-294-7669, bxl9801@iastate.edu;

Partner Organization: Renmatix, Inc., *Frank Lipiecki*, Research and Development Director, 484-751-4013

This project will explore the conversion Renmatix's lignin streams into higher value intermediates or end products. Renmatix converts biomass into C5 and C6 sugars using their Plantrose™ process, a multi-stage supercritical hydrolysis process. To date the Plantrose™ process has been used only for woody biomass. A solid lignin co-product remains after recovery of the sugar streams, which we will evaluate via fast pyrolysis and solvolysis (as described in the LTLP process for Objective 10b) to capture high value compounds. While ADM's Acetosolv and Renmatix's Plantrose™ processes both generate lignin-rich co-product streams, the physical and chemical characteristics of these streams can differ significantly.

Hypotheses to be evaluated include:

- Thermochemical conversion of lignin streams allows for recovery of high value compounds, specifically phenolic monomers.
- Utilization of ISU's LTLP stabilization technique is effective in conversion of lignin streams into high value products, such as phenolic monomers, refinery blendstocks, and intermediates for polymer and carbon fiber production

Tasks:

a) 10d-1: Prepare and ship perennial grasses and cornstover feedstocks to Renmatix;
b) 10d-2:Test the effectiveness of pyrolysis and catalytic pyrolysis of lignin streams for recovery of high value products such as phenolic monomers using the Frontier Tandem micropyrolysis unit;
c) 10d-3: Test the effectiveness of solvolysis of lignin streams for recovery of high value products such as phenolic monomers using solvolysis microreactors;

d) 10d-4: Assess potential of ISU's LTLP stabilization technology to convert lignin streams into high value intermediates or end products;

e) 10d-5: Conduct exploratory upgrading tests of stabilized lignin streams from Task 4. These tests will be carried out using laboratory slurry or fixed bed reactors;

f) 10d-6: Conduct continuous flow pyrolysis tests using down-selected conditions from micropyrolysis trials. These tests will be carried out using a laboratory scale pyrolysis reactors with capacities ranging from 100 g/h to 2 kg/h; and

g) 10d-7: Conduct larger scale semi-batch or continuous trials using down-selected conditions from solvolysis microreactor trials. These tests will be carried out using laboratory slurry or fixed bed reactors.

Schedule and Milestones: Objective 10d

	Federal Fiscal Year 2014		Federal Fiscal Year 2015				Federal Fiscal Year 2016			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 10d-1	a									
Task 10d-2				b						
Task 10d-3				c						
Task 10d-4				d						
Task 10d-5										e
Task 10d-6										f
Task 10d-7										g

a. Quantities of switchgrass needed for proof of concept testing delivered to Renmatix.

b. Completion of Tandem micropyrolysis tests of lignin streams. Conditions for production and recovery of high value products in a pyrolysis or catalytic pyrolysis scenario down-selected. Test plan for lab scale proof of concept determined.

c. Completion of solvolysis microreactor tests of lignin streams. Conditions for production and recovery of high value products in a solvolysis scenario down-selected. Test plan for lab scale proof of concept determined.

d. Completion of lab scale stabilization tests. Mass balance, physical and chemical characterization, and thermal stability differences determined.

e. Completion of lab scale upgrading tests. Mass balance, physical and chemical characterization determined.

f. Completion of lab scale proof of concept tests for selected pyrolysis and catalytic pyrolysis conditions. Complete mass balance and product analysis

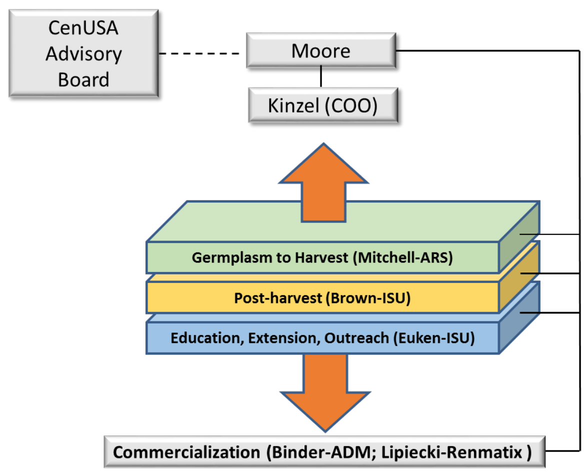
g. Completion of lab scale proof of concept tests for selected solvolysis conditions. Complete mass balance and product analysis

Key outcomes from task 10d:

- This project and may lead to the production of value-added products from lignin.
- This project will establish the possible combinations and yields of end products and additional value thermochemical processing of biorefinery co-products.

Administration

Project administration oversees all aspects of CenUSA's project coordination, communications, budgeting and data sharing among institutions. Project Director Ken Moore leads the overall research effort; Chief Operating Officer Anne Kinzel is responsible for the day-to-day project management, and is assisted by Financial Manager, Jill Cornelis.



Beginning in Year 4 we will operate under our revised organization chart that reflects the addition of Objective 10 (Commercialization). Our team plan-of-work includes continuing our regularly scheduled co-PD meetings, holding our annual all-hands meeting, and scheduling and holding the Advisory Board meeting. We will also continue our multi-modal/media communication plan that we strengthened in Year 3. This includes a mixture of social media, an enhanced web site, and the quarterly publication of *BLADES*.

Year 4 outputs include regularly scheduled quarterly reports, four issues of the *BLADES newsletter*, publication of our team-written article in *Biofuels*, and well-attended team meetings and annual meeting.

Anticipated outcomes for Year 4 include the continuation of what has proven to be a successful and effective administrative plan that encourages and values team contributions, an enhanced public profile, and actions taken on the advice of the Advisory Board.

Team Outcomes/Impacts for the Period August 1, 2013 –July 31, 2014

2014 CenUSA Annual Meeting
Participants

Exhibit 6

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2014 CenUSA Annual Meeting
Trade Show Exhibits

Exhibit 7

Location	Presentation	Exhibitor(s) / Mentors
Table 1	C6 BioFarm and the C6 BioFarm Game Guide iBook	Arne Jacobson, Caitlyn Carlson, Breanna Branderhorst • Staker, Jill Euken, Sorrel Brown (ISU)
Poster 1	Agricultural Game Development for Students: C^6 BioFarm	Aaron Jacobson, Breanna Branderhorst, & Caitlyn Carlson • Euken & Staker (ISU)
Poster 2	Analysis and Development of Biomass Densification Systems	Robert Preston • Birrell (ISU)
Poster 3	Analysis of Nutrient Use Efficiency in Switchgrass	Haley Chatelaine • Jin & Mitchell (ARS-NE)
Poster 4	Biochar: Extension and Outreach	Lynne Hagen & Julie Weisenhorn
Poster 5	CenUSA Communications	Kristin Peterson • Porter, Kohmetscher & Kinzel (ISU)
Poster 6	Comparing Nitrous Oxide Emissions Among Bunch Grasses and Corn	Joel Bauer • Jin & Mitchell (ARS-NE)
Poster 7	Corn Fiber Conversion: Laboratory to Pilot Scale-up	Helen Gerlach • Tom Binder (ADM)
Poster 8 Table 2	Creating and Evaluating Online Education Modules	John Guretzky, Pat Murphy, Deana Namuth-Covert, Gwen Nugent & Amy Kohmetscher

Location	Presentation	Exhibitor(s) / Mentors
Poster 9	Effects of Irrigation on Switchgrass Yield and Stability	Claire Haselhorst • UNM – Hill
Poster 10	Evaluation of Perennial Forage Grown as Bioenergy Crops as a Feedstuff for Beef Cattle	Stephanie Clark • Hansen & Loy (ISU)
Poster 11	Extension and Outreach	Sorrel Brown
Poster 12	GIS-based Suitability Model for Siting Bioethanol Plants in the U.S.	Bhavna Sharma & Fernando Miguez
Poster 13	Hydrogenation of Bio-Oil Heavy Ends	Zach Spangler • R. Brown (ISU)
Poster 14	Impacts of Biochar on Soil Greenhouse Gas Emissions and Soil Moisture: A Three-Year Study	Rena Weis (UMN)
Poster 15	Impacts of Corn Stover Removal on Soil Water Availability in Corn and Switchgrass Plots	Julie Juarez • Jin & Mitchell (ARS–NE)
Poster 16	Influence of Biochar Age and Cropping Systems on Soil Physical Properties	Ross Mazur Laird (ISU)
Poster 17	Influence of Rainfall Level and Crop Density on Dry Matter Loss from Corn Stover and Switchgrass	Amit Khanchi
Poster 18	Nitrogen and Cultivar Effects on Community Structure of Switchgrass Rhizosphere Microflora	Anne Sawyer, Carl Rosen, John Lamb, Craig Sheaffer, Michael Sadowsky & Jessica Gutknecht

Location	Presentation	Exhibitor(s) / Mentors
Poster 19	Screening Alfalfa, Reed Canarygrass and Switchgrass Cultivars for Ethanol Yield by Treating with Dilute-acid Followed by Simultaneous Saccharification and Fermentation	Bruce Dien
Poster 20	Sustainability of Fertilizer Use in the Production of Switchgrass for Ethanol	Jackson Hambrick • Jin & Mitchell (ARS-NE)
Table 3	Takin' it to the Streets: Online Extension and Outreach	Pam Porter, Sue Hawkins, Amy Kohmetscher, Susan Harlow &Gillian McGarvey
Poster 22	Techno-Economic Analysis for Pyrolysis-Based Biofuels	Mark Wright, Robert Brown, & Rajeeva Thilakaratne
Poster 23	Understanding Lignin Char Formation During Pyrolysis	Andrew Troxell • Brown & Xianglan Bai (ISU)
Poster 24	Understanding Nitrogen Use, Annual and Perennial Bioenergy Crops	Diego Trejo–Soria • Chaubey (Purdue)
Poster 25	Water Quality Analysis from Growing Switchgrass and Miscanthus for Biofuels on Marginal Land	Christopher Tito • Chaubey (Purdue)

cenusa bioenergy www.cenusa.iastate.edu

Exhibit 8

2014 CenUSA Year 4 Annual Meeting

Evaluation Report

Prepared by Sorrel Brown, CenUSA Project Evaluation

CenUSA Bioenergy is supported by Agriculture & Food Research Initiative
Competitive Grant No. 2011-68005-30411 from the National Institute of Food & Agriculture

Table 1. 2014 Annual Meeting Objectives

#	Question	Strongly Agree (1)	Agree (2)	Disagree (3)	Strongly Disagree (4)	Total Responses	Mean
1	The meeting covered all the project objectives clearly.	23	20	2	1	46	1.59
2	The meeting format was conducive to learning what other teams were doing	22	21	2	0	45	1.56
3	There was enough time to network with project colleagues.	18	20	7	0	45	1.76
4	The tours was valuable in helping me better understand Objective 9 and the role of project master gardeners.	23	18	2	0	43	1.51

Table 1a. 2014 Meeting Objectives - Statistics

#	Min. Value	Max Value	Mean	Variance	Standard Deviation	Total Responses
The meeting covered all the project objectives clearly.	1	4	1.59	0.47	0.69	46
The meeting format was conducive to learning what other teams were doing	1	3	1.56	0.34	0.59	45
There was enough time to network with project colleagues.	1	3	1.76	0.51	0.71	45
The tours was valuable in helping me better understand Objective 9 and the role of project master gardeners.	1	3	1.51	0.35	0.59	43

Table 2. Trade Show

#	Question	Strongly Agree (1)	Agree (2)	Disagree (3)	Strongly Disagree (4)	NA (5)	Total Responses	Mean
1	The Trade Show increased the depth of my knowledge regarding what other objectives have accomplished.	10	25	3	0	4	42	2.12
2	The Trade Show was a beneficial addition to the CenUSA annual meeting.	14	22	1	0	5	42	2.05

Table 2a. 2014 Meeting Objectives - Statistics

#	Min. Value	Max Value	Mean	Variance	Standard Deviation	Total Responses
The Trade Show increased the depth of my knowledge regarding what other objectives have accomplished.	1	5	2.12	1.18	1.09	42
The Trade Show was a beneficial addition to the CenUSA annual meeting.	1	5	2.05	1.46	1.21	42

Table 3. 2013 Annual Meeting Value
If you participated in last year's annual meeting in West Lafayette (July-Aug 2013), how was last year's meeting beneficial in helping your team accomplish its objectives for the 3rd year? (n=15)
n/a
Communication is important and face to face communication tends to improve a teams ability throughout the year.
Nope, didn't participate last year
Helped to coordinate activities with team members from other states.
I thought the teams did a good job of following up on the suggestions made at last year's meeting
Didn't participate last year
Identifying some of the needs of the other collaborators in the same objective feedback from collaborators on what had been completed
Always hear new ideas and acquire energy
Did not participate last year
Very
Great place to network with the other collaborators
It improved our networking, especially with Nebraska efforts.
Networking to create more extension materials
Some
By touring the garden plot test site - I learned of many things that I was unaware of that the MN group were doing in the gardens regarding, tilling, mulching, soil testing and fertilizer application...things we are not doing at the Iowa test plots.

Table 4. Barriers in 2013
What barriers have you encountered in reaching your team's objectives for the 3rd year? (n=11)
N/A
In-state communication across objective areas
Time
Biggest problem is communication between partners @ other universities and agreeing on ways to achieve goals. Travel meeting is critical to help bridge gap.
Intern - n/a
Communication
Time & people
University transition and politics, lack of communication between objective 9 teams at different institutions
The evaluation component has been difficult to fulfill but we are reaching out to others for more ideas
None this program is very well organized and funded
Weather issues and rabbits!

Table 5. Administrative Support

#	Question	Strongly Agree (1)	Agree (2)	Disagree (3)	Strongly Disagree (4)	NA (5)	Total Responses	Mean
1	Administrative support during the past year has been helpful.	18	8	0	0	11	37	2.41
2	Administrative responses to my questions/concerns were handled quickly.	20	7	0	0	10	37	2.27
3	Budget requests were handled in a timely manner.	10	7	0	0	20	37	3.35
4	Budget issues were resolved to my satisfaction.	12	4	0	0	20	36	3.33
5	Online meetings have been useful in settling issues related to my responsibilities.	8	8	1	0	18	35	3.34

Table 5a. 2014 Administrative Support - Statistics

#	Min. Value	Max Value	Mean	Variance	Standard Deviation	Total Responses
Administrative support during the past year has been helpful.	1	5	2.41	3.08	1.76	37
Administrative responses to my questions/concerns were handled quickly.	1	5	2.27	2.98	1.73	37
Budget requests were handled in a timely manner.	1	5	3.35	3.40	1.84	37
Budget issues were resolved to my satisfaction.	1	5	3.33	3.66	1.91	36
Online meetings have been useful in settling issues related to my responsibilities.	1	5	3.34	3.17	1.78	35

Table 6. Project Administration
What might have project administration done during the past year that would have helped you meet your team's objectives for the 3rd year? (n=8)
n/a
A little more direction on how things connect across the project.
Management team did a great job on reapplication. Thanks!
Admin has been both proactive in anticipating issues and solutions as well as helping solve problems best admin team I have ever worked with.
Can't recall anything
It's all good!
You all have been doing a great job!
Administration is supportive of new ideas for creative and efficient education/extension materials which is very helpful

Table 7. Year 4 Anticipated Needs
What do you anticipate needing from administration for the coming year? (n=10)
Push inter-objective collaboration (yes, I know this is a tough one!)
n/a
Continued guidance and support
Ongoing budget support and helping solve problems with partners @ other institutions
Continue to enhance communications
Support
Facilitation of cross-university communication as far as content and marketing opportunities
May need help "herding cats" for reviews or content development, may need help for ideas to market events or materials
Public outreach (not just producers) and national media outreach
Additional free gift items for Master Gardener volunteers....

Table 8. Additional Comments
What might have project administration done during the past year that would have helped you meet your team's objectives for the 3rd year? (n=8)
I feel we need to carve out more time for the Extension objective to meet. This is a large group and we never seem to have enough time at the annual meetings.
I suggest encouraging students and postdocs to attend the CenUSA annual meeting and present posters. It is important for students to see how their work fits into a bigger picture. Also schedule more time for the poster sessions.
Wonderful meeting. I appreciated the breadth of participants.
Very good organization of the Minnesota meeting. Great location.
Thanks for the awesome education experience through the internship. Also, the baklava was fantastic.
Food at conferences should be something that 90% of people would enjoy...Wednesday's meal was not that! Optional garden tour should have been 1) during supper 2) after poster session As an intern, I was not able to eat much of a "walking supper" since I was presenting and got back late due to the placement of the optional garden tour.
I thought that the commercialization comments by Binder and the Renmatix one were interesting, but I don't understand enough about the context of how that work relates to their ordinary commercial activities and the IP issues involved.
Could have used longer breaks and used to network. On dinners schedule hour before dinner to network/socialize and then have dinner. Poster session was good but more room to view/discuss would have been helpful. Enjoyed having college students present & added much to meeting. Overall very happy w/ meeting.
First year here, learned a lot and very impressed with everyone
There are a lot of opportunities for Extension to step up now that the project is "maturing"
Objective 7 needs to change focus to looking at helping industry make improvements to machinery used for productivity biomass. Company corn production to biomass production isn't overly helpful
I really liked the tradeshow and I hope we can continue that next year
Very well-organized, great job Anne! Excellent food!!! The trade show was not very successful for extension team - attention seemed to be on food and posters. Seems like good venue for that - but next year, I think ext team could benefit by having table throughout entire conference w/ our materials and videos. At end of a long day, people want to relax, eat, chat...not "study" extension materials or have to think about publications, etc. I've been to conferences where there are trade-show type tables set up throughout with a person there. Extension people could take turns manning table during breaks. Industry reps could also have tables - or at least a display, if that made sense. Communication objective - Ideas to have policy makers here is good - also what about inviting the press? Maybe its too early for that... The last day/advisory board comments were excellent - very nice format.
Great job to all objectives Well planned event Food options were questionable
I think we need more explicit discussion as to how diverse platforms and agroecosystems can fit together to boost biorenewable fuel & energy production in the region alongside environmental sustainability

Teacher's guide and lesson plans available.

- Web App and more information can be found at C6BioFarm.Weebly.com.
- C6BioFarm.Weebly.com, Web App, and iBook are available August 15.
- Download the iBook from the Apple iTunes store.
- Provide feedback on C6 website about what you learned.

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Project is supported by grant no. 2011-68005-30411 (USDA National Institute of Food and Agriculture).

IOWA EPSCoR

This material is based on work supported by the National Science Foundation under Grant Number EPS-1101284.

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Exhibit 9

Check out C6 BioFarm!

C6 BioFarm

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Designed for middle and high school students in agriculture and science classrooms!

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Check it out at

C6BioFarm.Weebly.com

(Website available August 15)

Web App

- Teach your students about many different topics, including…
    - Bioenergy
    - Agricultural Production
    - Carbon
    - The Environment
    - Agricultural and Bioenergy Careers
- Motivate your students to learn in a fun, interactive "Farmville" experience.
- Load it on any web browser!

iBook

- Provides additional teaching and learning information useful for both students and teachers
- Watch career videos from a variety of professions
    - Science teacher
    - Engineers
    - Research scientist
    - And more
- Download it from the Apple iTunes store!

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- Designed for
    - Middle and high school students
    - Agriculture and STEM classrooms
- Lesson plans, videos, and additional teaching materials available on the C6 website
- Partner with C6 to teach students about renewable fuels and biobased products

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"Our vision is to create a regional system for producing advanced transportation fuels derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels, the proposed system will improve the sustainability of existing cropping systems by reducing agricultural runoff of nutrients and soil and increasing carbon sequestration."

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This project is supported by Agriculture and Food Research Initiative Competitive Grant No. 2011-68005-30411 from the National Institute of Food and Agriculture.