



cenusa bioenergy

Quarterly Progress Report

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

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NOTICE

This quarterly report was prepared by Iowa State University and CenUSA Bioenergy research colleagues from Purdue University, United States Department of Agriculture-Agricultural Research Service, University of Illinois, University of Minnesota, University of Nebraska, Lincoln, University of Vermont, and the University of Wisconsin in the course of performing academic research supported by Agriculture and Food Research Initiative Competitive Grant No. 2011-68005-30411 from the United States Department of Agriculture National Institute of Food and Agriculture (“USDA-NIFA”).

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

Quarterly Report: November 1, 2013 – January 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. Val Evans (Financial Manager) has resigned her position to take on a position of permanent employment at Iowa State University. Ms. Evans will provide part-time assistance in preparing the budget portion of CenUSA's Year 4 reapplication. Jill Cornelis, of Iowa State Bioeconomy Institute is providing part-time assistance to the project in handling project day-to-day financial affairs and assisting Kinzel with preparation for the 2014 CenUSA annual meeting.

• Featured Second Quarter Activities

- ✓ **CenUSA Co-Project Director Meeting.** The CenUSA co-project directors met in Ames, Iowa on January 28-29, 2014 to discuss the formation of a new Commercialization Objective (Objective 10). The CenUSA Leadership Team, in consultation with the co-project directors had come to the conclusion following the 2013 annual meeting, that the project is at a stage where a greater emphasis on commercial opportunities is feasible and needed to meet the project's five year goals. During the fall of 2013, the co-project directors were asked to come up with potential commercialization projects that could fit within a new objective tightly focused on commercialization. The following commercial opportunities were discussed in concept.
- ✓ **ADM: Recovery of high value products from ADM's biorefinery co-product streams.** The overall goal of this project is for CenUSA Bioenergy to collaborate with industry partner Archer Daniels Midland to assess the potential of fast pyrolysis and solvolysis as methods for production and capture of high value compounds from the acetate and sugar rich co-product streams from processes used to fractionate biomass into cellulose, hemicellulose and lignin streams. Additionally, conversion of lignin streams into higher value intermediates or end products will be explored. While processes and composition of streams vary between companies, the product recovery techniques developed in this collaboration should be broadly applicable.
- ✓ **Renmatix (Frank Lipiecki):** Renmatix will explore the use of switchgrass as a feedstock in their Plantrose TM Process. The initial work will look into the chemical

composition, physical properties and overall suitability. The next stage allow for first production of cellulosic sugars and lignin from switchgrass. Demonstration runs in the third task enable further optimization, reliability information, economic projections, and larger volumes of outputs for downstream testing and information.

- ✓ **Vermeer.** CenUSA Advisory Board member Jan Van Roekel is working with the Extension and Outreach Objective to establish energy crops on up to 30+ acres on a Vermeer family owned farm located near Pella, Iowa. The site is located across the road from the Vermeer Global Pavilion, where Vermeer is currently building a children's learning center. CenUSA Co-Pd Rob Mitchell will coordinate planting. We anticipate holding field events to educate the public about energy grasses throughout 2014 and beyond.

- ✓ **Additional Projects**

CenUSA Co-Project Director Rob Mitchell (ARS-Lincoln) has proposed the following projects in which he would serve as the Project Leader.

- **Project 1. "Pelleting perennial feedstocks for bioenergy evaluations."** Recent scrutiny of the USDA-NIFA-CAP program calls for evaluating novel approaches to demonstrate that the CenUSA Bioenergy CAP is a critical component of the emerging bioenergy industry. In response to this need for broad, tangible industry collaborations, ARS Lincoln plans to have a commercial pelleting facility make pellets from switchgrass, big bluestem, and low diversity prairie mixtures.
- **Project 2. "Perennial grass biochar commercialization for field and greenhouse evaluations and comparison to hardwood biochar."** Current CenUSA Bioenergy biochar research is using biochar produced from woody plants. This study will produce biochar from switchgrass, big bluestem, and a low-diversity prairie mixture grown in the CenUSA project. The objectives of the study are to produce biochar from switchgrass, big bluestem, and a low-diversity prairie mixture to:
 - Evaluate the feasibility of producing biochar from perennial grasses at the commercial scale;
 - Compare the relative quality of biochar produced from hardwoods and perennial grass; and
 - Compare the impact of biochar from hardwoods and the three perennial grasses on soil quality and plant growth in greenhouse trials; and 4) evaluate the ability of perennial grass biochar to mitigate nutrient transport in

agricultural runoff.

- **Project 3. “Bio-oil production of herbaceous feedstocks processed in the Battelle mobile pyrolyzer.”** ARS Lincoln has contacted Drew Bond with Battelle concerning a research project to evaluate the bio-oil production of perennial grasses using in the Battelle mobile pyrolyzer.

The research objective is to evaluate the bio-oil composition and production potential of Liberty switchgrass, Shawnee switchgrass, big bluestem, and a low-diversity prairie mixture grown in CenUSA replicated field trials.

- **Project 4. “Feasibility of perennial grass feedstocks to supply combined heat and power to an advanced ethanol fermentation plant.”** Abengoa Bioenergy owns two starch-based ethanol plants in Nebraska, one near Ravenna and one near York. Abengoa has publically stated their plans to transition one plant from a corn-based to sorghum-based feedstock. This transition would allow Abengoa to meet the Advanced Biofuel requirements for the D5 Renewable Identification Number (RIN) under the Renewable Fuels Standard (RFS). In addition to converting feedstocks, they are considering feedstock options (i.e., switchgrass, eastern red cedar, etc.) to fuel the plant’s boilers for combined heat and power and have submitted an application to EPA.
- **Project 5. “Grazing mitigates risk potential for perennial warm-season grasses grown for biomass energy.”** Based on 2-years of grazing data, we can demonstrate the potential dual use of these feedstocks by grazing early, then harvesting regrowth and standing residue after frost for bioenergy. Grazing will utilize 50-60% of the total production, leaving 40-50% of the total yield for biomass energy. This grazing information will demonstrate that the livestock industry provides an economically feasible alternative market for herbaceous perennial feedstocks.

- **Year 4 Project Reapplication**

In anticipation of the Year 4 project reapplication we worked with the Iowa State University Bioeconomy Institute to engage Lynn Jelinski (Sunshine Consultants) to assist in a review of the project and to develop the reapplication materials.

- **2014 CenUSA Annual Meeting**

The 2014 CenUSA 2014 annual meeting will be held at the Minnesota Landscape Arboretum in Chaska Minnesota July 30 to August 1, 2014. The focus will be on our Extension and Outreach objective and the new Commercialization Objective.

- **CenUSA Bioenergy Advisory Board**

We are recruiting for a new advisory board member with expertise in the area of water quality and watershed management. We should complete our recruitment before the end of the third quarter.

- **Coordination, Collaboration, and Communication**

- ✓ **Communication Team.** We have completed the organization of the CenUSA Communications team CenUSA Collaborator Pam Porter (University of Wisconsin) is serving as the team leader assisted by CenUSA collaborator Amy Kohmetscher and student interns Charlie O'Brien and Kristin Peterson. The interns have an extensive background in journalism and public relations from their studies in Iowa State University's Greenlee School of Journalism and their past work experiences and have been able to contribute immediately to our communications efforts. Anne Kinzel will oversee the team's efforts serving in the role of "publisher" for CenUSA's external communications.

The team's first objective is to design a CenUSA newsletter for distribution to the interested public and to our extensive research team. By the end of the quarter we have created a plan for a bi-monthly digital newsletter, BLADES to be distributed via the Constant Contact platform. The first edition will be distributed in February 2014.

- ✓ **Executive Team Meetings and CenUSA Research Seminar.** The Co-Project directors representing each of the nine objectives continue to meet monthly with Ken Moore, Anne Kinzel, and Val Evans 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.
- ✓ **Objective and Team Meetings.** All nine CenUSA Objectives continue participate in scheduled and ad hoc meetings using the CenUSA Adobe Connect meeting room or in face-to-face meetings. The five Extension and Outreach Objective teams also meet via Adobe Connect or face-to-face gatherings.¹

- **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 create the new Commercialization Objective budget.

¹ The teams are Broader Public/Master Gardener/Youth Programs, Economics and Decision Tools, Evaluation/Administration, Extension Staff Training/eXtension, Health and Safety, and Producer Research Plots/Perennial Grass. For more information see www.cenusa.iastate.edu/Outreach.

- **Program Matters.** We will continue to focus on project coordination, communication, meetings and data sharing across Objectives, and on reaching the revised timelines milestones and the further development of the Commercialization Objective.

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 2012, the focus is on the establishment of new breeding and evaluation trials.

1. Significant Accomplishments Summary

- The registration article for Liberty switchgrass is in press.
- Our pathology and entomology research collaborators have made significant strides in their work which provides important information on the arthropods associated with bioenergy grasses.
 - ✓ These studies provide valuable information on the host suitability of switchgrass and other bioenergy grasses to four aphids within a system that has been largely overlooked and indicate that there are genetic differences among switchgrass populations for resistance.
 - ✓ The ultimate goal of this part of the 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 (Mike Casler and Rob Mitchell)**
 - ✓ Complete after-frost biomass harvests on switchgrass, big bluestem, and indiangrass yield tests.
 - ✓ Complete after-frost harvests on switchgrass, big bluestem, and indiangrass selection nurseries
 - ✓ Yield and agronomic data entered into databases.
 - ✓ Seed cleaning work on harvested seed initiated and 50% completed.
 - ✓ Biomass grinding work initiated and 50% completed.
 - ✓ New NIRS Unit installed and calibrated.

- ✓ Ash and mineral composition analysis work completed on two experiments.
- **Feedstock Quality Analysis (Bruce Dien – ARS Peoria & Akwasi Boateng – ARS Wyndmoor)**
 - ✓ Complete analysis of 52 and 40 samples, supplied by Drs. Ken Vogel and Michael Casler, respectively, for hexane extractable material.
 - ✓ Begin to analyze above samples for hydroxycinnamic acids.
 - ✓ Continue writing manuscript on relationships between germplasm properties and product yields (Boateng & Sarath).
 - ✓ Perform py-GC/MS experiments on larger set of samples of various switchgrass germplasms. We are using statistical analysis to identify variations in pyrolysis behavior and products among the larger sample set. We will correlate data with compositional data and NIRS spectra of the sample set. Dr. Michelle Serapiglia was scheduled to arrive from Cornell mid-November to continue analysis.
- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
 - ✓ Continue processing samples from sampling Project Year 2 to identify potential pests and beneficial arthropods and characterize their seasonal abundance.
 - ✓ Continue to screen selected switchgrass, big bluestem, and indiangrass cultivars and experimental lines for their susceptibility to sugarcane aphids.

3. Actual Accomplishments

- **Breeding and Genetics – Lincoln, Nebraska (Mike Casler and Rob Mitchell)**
 - ✓ All 2013 plots have been harvested and all data entered into databases.
 - ✓ All seed cleaning, threshing, and weighing has been completed for 12 new experimental populations of switchgrass and big bluestem, plus an additional set of 560 half-sib families.
 - ✓ Biomass grinding is about 75% complete. NIRS scanning of 2013 samples has been initiated.
 - ✓ Network of 13 trial locations has been organized for planting new field trials in 2014. Switchgrass and big bluestem entries have been selected for inclusion in new trials.

- ✓ All DNA sequencing and fragment analysis has been completed on the new lowland switchgrass collections made throughout the southern USA (Atlantic Coast to New Mexico) in 2011-2013.
- **Feedback Quality Analysis (Bruce Dien and Akwasi Boateng)**
 - ✓ Completed analysis of hexane extractable material for all current samples.
 - ✓ Established a method for analyzing samples for hydroxycinnamic acids and have completed analysis of switchgrass calibration set.
 - ✓ The manuscript written with Sarath has been partially written, but not completed.
 - ✓ Dr. Michelle Serapiglia arrived January 2014 and has performed statistical analysis on switchgrass samples from Ken Vogel's group. Total ash content in the biomass was negatively correlated with most pyrolysis products, indicating that ash content may significantly impact pyrolysis yields. Glucose content in the biomass as determined by the NIRs data was negatively correlated with product yield of acetic acid, acetol, phenols, and furans. Unexpectedly, Klason lignin content as determined by the NIRs data was positively correlated with levoglucosan yield. No correlations were identified between pyrolysis product yield and glucose or Klason lignin content determined by wet chemistry from Bruce Dien's group.
- **Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
 - ✓ All pitfall and sticky traps have been sorted and identified. We are in the process of summarizing the data to compare the results from this year with our findings from last year.
 - ✓ We collected similar arthropod families from Nebraska and Wisconsin.
 - ✓ We are also in the process of analyzing the data to compare the influence of stand age and stand diversity on arthropod abundance and seasonal distribution.
 - ✓ We have completed the evaluation of the switchgrass cultivars and experimental strains for their susceptibility to greenbugs and sugarcane aphids. We are now in the process of screening the remaining big bluestem and indiangrass cultivars and experimental lines for their susceptibility to these aphids. To date, 'Kanlow' switchgrass exhibits the highest level of resistance to the both aphids.

4. Explanation of Variances

None to report.

5. Plans for Next Quarter

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**
 - ✓ Finish grinding and scanning 2013 biomass samples.
 - ✓ Complete all seed packeting for 13 locations of new switchgrass and big bluestem trials to be planted in April-June 2014.
 - ✓ Submit SWAG DNA samples to UWBC sequencing facility for exome capture sequencing of 1 million SNP markers for use in genomic selection.
 - ✓ Prepare data sets for arrival of visiting biometrician, Dr. Zulfi Jahufer, who will conduct statistical analyses related to: (1) N-use efficiency in switchgrass breeding, (2) relationship among biomass quality traits, and (3) genomic selection prediction models for biomass quality traits.
 - ✓ Finish flow cytometry on new southern lowland germplasm collections and begin writing manuscript (Rude & Casler).
- **Feedstock Quality Analysis (Bruce Dien and Akwasi Boateng)**
 - ✓ Continue processing biomass samples for ester and ether linked hydroxycinnamic acids.
 - ✓ Begin to process FY2014 samples as received from collaborators.
 - ✓ Continue writing manuscript as described above (Boateng & Sarath).
 - ✓ Switchgrass samples from Mike Casler's group will be analyzed by py-GC/MS. There are also 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. This analysis is in preparation.
- **Pathology and Entomology (Tiffany Heng-Moss and Gary Yuen)**
 - ✓ Collaborate with Rob Mitchell and Mike Casler to develop insect sampling plans.
 - ✓ Begin sampling nurseries for insects and other arthropods in late May 2014.
 - ✓ Complete evaluation of big bluestem and indiangrass cultivars and experimental line for their susceptibility to greenbugs and sugarcane aphids.

6. Publications / Presentations/Proposals Submitted

- Casler, M.D. & Vogel, K.P. (2014). Selection for biomass yield in upland, lowland, and hybrid switchgrass. *Crop Science*, 54: (in press).
- Heng-Moss, T. (2013, September). *Mechanisms of Resistance to Herbivory by Insects*. Presented at the conference Switchgrass II, Madison, WI.
- Koch, K., Heng-Moss, T. & Bradshaw, J. (2013). *Discovery of Aphid Resistance in Perennial Bioenergy Feedstock*. Presented at CenUSA Bioenergy Fridays Web Seminar Series.
- Koch, K., Fithian, R. Bradshaw, J. & Heng-Moss, T. (2012). *Evaluation of switchgrass for resistance to potential aphid pests*. Presented at North Central Branch of Entomological Society of America, Lincoln, NE.
- Koch, K., Fithian, R., Heng-Moss, T., Bradshaw, J., Sarath, G. & Spilker, C. (2014). Evaluation of tetraploid switchgrass populations (*Panicum virgatum* L.) for host suitability and differential resistance to four cereal aphids. *Journal of Economic Entomology*. (In Press).
- Koch, K., Heng-Moss, T., Bradshaw, J. & Sarath G. (2014). Categories of resistance to greenbug and yellow sugarcane aphid (Homoptera: Aphididae) in three tetraploid switchgrass populations. *BioEnergy Research*: (In Press).
- Price, D.L. & Casler, M.D. (2014). Predictive relationships between plant morphological traits and biomass yield of switchgrass. *Crop Science*, 54: (in press).
- Price, D.L. & Casler, M.D. (2014). Inheritance of secondary morphological traits for among-and-within-family selection in upland tetraploid switchgrass. *Crop Science*, 54: (in press).
- Price, D.L. & Casler, M.D. (2014). Divergent selection for secondary traits in upland tetraploid switchgrass and effects on sward biomass yield. *BioEnergy Research*, 7: (in press).
- Vogel, K.P., Mitchell, R.B., Casler, M.D. & Sarath, G. (2014). Registration of 'Liberty' switchgrass. *Journal of Plant Registration*: (in press).

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

• Boyd and Armstrong Farms

- ✓ **Biochar response of corn including biomass and grain harvesting from the long-term plots.**

Preliminary results depict the effects of 2010 biochar application on grain yield of corn and corn biomass production on Boyd farm. No significant differences in yield were observed among the biochar-amended plots.

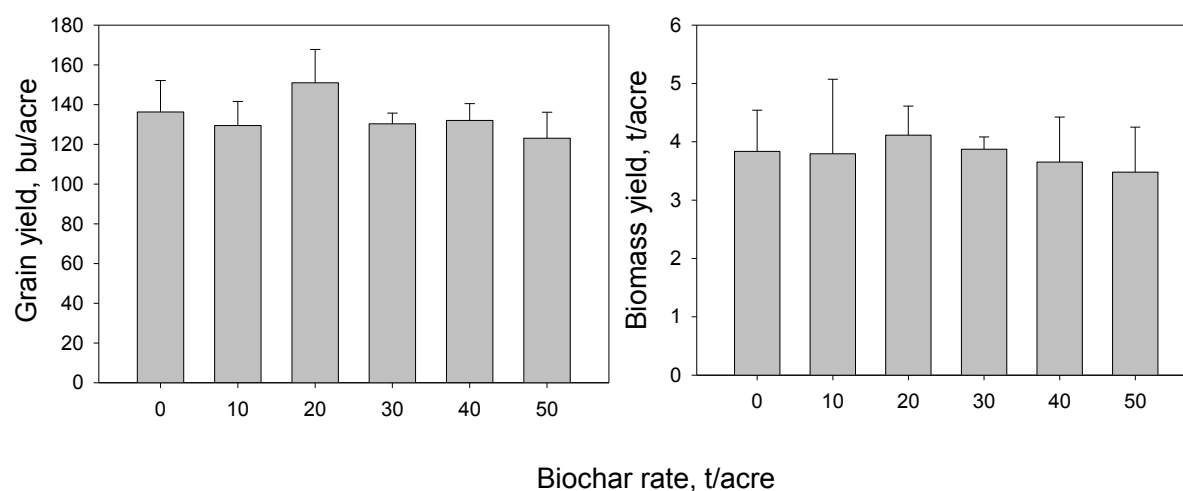


Fig 1. Effects of 2010 biochar application on grain yield of corn and corn biomass production (Boyd Farm)

Analysis continues on the deep soil cores collected in 2011 from the Armstrong plots. Soil extraction for Mehlich III-soluble elements is complete and ready to be analyzed by ICP. Soil cores also are being analyzed for total C and N as well as particulate organic matter C (POM-C).

- **Crop and Soil Response to Biochar Amendments for Sustainable Bioenergy Feedstock Production (Douglas L. Karlen and David A. Laird)**

Applying biochar has been shown to increase crop yields on acidic and low activity soils in the tropics, but grain yield may not be the best metric for assessing biochar effects on Mollisols in the Midwestern United States. We hypothesized that even if biochar did not increase corn (*Zea mays* L.) grain yield *per se*, its application may help offset other potentially negative effects associated with harvesting corn stover as a feedstock for bioenergy or bio-products. Scientists at the USDA-Agricultural Research Service (ARS) *National Laboratory for Agriculture and the Environment* (NLAE) initiated a field study in the autumn of 2007 that has been leveraged with CenUSA Bioenergy funds. Biochar developed from mixed hardwoods was applied at 9 or 18 Mg ha⁻¹ (4 or 8 tons acre⁻¹) to replicated, 0.11 ha (0.275 acre) plots on a Clarion-Nicollet-Webster soil association at the *Iowa State University Agronomy and Agricultural Biosystems Engineering Research Center* (AABER), near Boone, Iowa (42° N, -94° W). Using CenUSA resources, an additional 11 Mg ha⁻¹ (5 tons acre⁻¹) of hardwood-derived biochar was applied in November 2012 to the same plots that received 18 Mg ha⁻¹ of biochar in 2007. Each rate of biochar was applied to plots from which no stover, a moderate amount of stover (referred to as the ‘high-cut’ treatment because all plant biomass from just below the ear shank upward was collected), or the maximum feasible amount of stover (referred to as the ‘low-cut’ treatment because all plant biomass above a 10-cm stubble height was collected) was harvested using a ‘row-crop’ header attached to a John Deere 9750 STS² combine to create a single-pass, dual stream harvest system. The six biochar treatments (2 applications rates * 3 stover harvest treatments) accounted for 27% of a 10 ha (24 acre) area within which four replicates of 22 treatments designed to identify sustainable stover harvest strategies were imposed.

Biochar amendment and stover harvest treatment effects on corn during the past six years (2008 – 2013) were evaluated by collecting early season (V6) and ear leaf samples (growth stage R2) plant samples (Table 1) and by measuring corn grain and stover yields (Table 2). Soil test measurements for the 0 to 5-cm and 5- to 15-cm depth increments were made each year using samples collected after harvest. Weighted averages for the 0 to 15-cm soil depth were calculated for the 0, 4, and 8 tons acre⁻¹ biochar treatments are presented in Table 3 since the stover harvest treatments had no statistically significant effects on any of the parameters (data not presented). In the autumn of 2012, a separate set of surface soil samples was collected from the 0 to 5-cm and 5 to 15-cm depth increments and analyzed for several soil quality indicators. Weighted averages for the 0 to 15-cm depth for those parameters are summarized in Table 4 for the 0, 4, and 8 tons acre⁻¹ biochar treatments since again, the stover harvest treatments resulted in no differences that were of either agronomic importance or detectable (data not presented). Several of the mean values from the two soil-test data sets were then used with the Soil

Management Assessment Framework (SMAF) to compute a soil quality index (SQI) for the 0, 4, and 8 tons acre⁻¹ biochar treatments. Agronomic practices (*i.e.*, autumn chisel plow, spring pre-plant field cultivation, equal planting and fertilization rates) were the same for all nine-biochar rate by stover harvest treatments.

Table 1. Six-year average V6 whole plant and R2 ear leaf nutrient concentrations for treatments receiving 0, 4, or 8 (plus 5 tons acre⁻¹ in 2012) tons acre⁻¹ of biochar in 2007 within Field 70/71 near Boone, IA

Biochar Tons/Acre¹	----- V6 whole plant samples -----											
	N	P	K	Ca	Mg	S	Al	B	Cu	Fe	Mn	Zn
	----- g kg ⁻¹ -----						----- mg kg ⁻¹ -----					
0	35.0	4.2	38.2	5.2	3.2	2.3	539	7.0	17	955	72	30
4	34.9	4.3	39.0	5.2	3.3	2.3	500	7.1	15	1011	72	29
8 + 5	34.7	4.3	40.4	5.2	3.2	2.3	521	7.2	17	987	67	30
Critical Value	35.0	3.0	25.0	3.0	3.0	2.0	---	7.0	7	5	20	20
	----- R2 ear leaf samples -----											
	N	P	K	Ca	Mg	S	Al	B	Cu	Fe	Mn	Zn
0	25.5	3.1	17.5	5.2	3.1	1.7	37	7.0	10	122	53	17
4	25.4	3.1	17.4	5.4	3.2	1.6	36	6.8	9	123	44	16
8+5	25.6	3.1	18.0	5.4	3.1	1.7	36	7.0	9	121	46	16
Critical Value	27.0	2.5	17.0	2.1	2.0	1.0	---	5.0	5	15	15	25

Statistical analysis providing direct comparisons between the control (conventional management) and biochar treatments using SAS “contrast” and “estimate” procedures have not been completed, but the comprehensive datasets for plant tissue analysis, grain and stover yields, as well as the soil test data have been compiled and evaluated “by treatment.” Those analyses indicate that neither the initial (2007) or supplemental (2012) biochar application significantly affected nutrient concentrations in corn plants at the V6 growth stage (data not presented). During the first couple of years S and B concentrations at the V6 growth stage were below critical levels, but there were no apparent differences among the control and two biochar-amended treatments. Similar detailed data were also collected for ear leaf samples collected at the R2 growth stage. For both the control and biochar amended treatments, N and Zn availability were the most nutrient limiting factors during early grain-fill, but there were no significant differences among the stover harvest treatments with or without biochar amendments. For 2013, ear leaf samples from the 0, 4, and 13 (8 + 5) tons acre⁻¹ biochar all had P concentrations that were also below the

critical level (data not presented), but that more likely reflected the relatively high lime application (18 Mg ha^{-1} or 8 tons acre^{-1}) that was also made in the autumn of 2012 to correct surface soil acidity problems that were gradually developing across the entire research site. The 2012 and 2013 ear leaf K concentrations were also below the critical values, but again there was no apparent effect of either the original or supplemental biochar applications. We attribute those differences (data not presented) to severe water stress encountered throughout central Iowa both years. To summarize the plant analysis data, six-year mean values for each of the biochar amendment rates are presented in Table 1 for both growth stages. Please note, the highlighted values are those falling below critical values for corn tissue at either growth stage.

Corn grain and stover yields for the control and two biochar treatments are presented in Table 2. Averaged across years, there was a small but positive grain yield response with the control, 4 ton acre^{-1} biochar, and 13 ton acre^{-1} biochar treatments yielding 168, 170, and 173 bu ac^{-1} (10.5 , 10.7 , and 10.8 Mg ha^{-1}), respectively. Two factors discussed by Rogovska et al. (manuscript in review) may be contributing to this response. First, a comparison of grain yields for the non-stover harvest treatments shows that the high rate of biochar increased the six-year average grain yield by 11 or 12 bu ac^{-1} (0.7 Mg ha^{-1}) compared to the other two treatments. Average corn grain yield for the maximum feasible stover harvest treatment differed by only 3 bu ac^{-1} (0.2 Mg ha^{-1}), but once again, yields were higher for the biochar treatments. This response supports the hypothesis that biochar applications may help offset allelopathic effects of continuous corn production and certainly warrants further microbial community investigations at this site. The potential for biochar to increase soil water holding capacity and reduce soil bulk density because of its porosity are two other factors that may have contributed to the 12 to 13 bu ac^{-1} (0.8 Mg ha^{-1}) yield increase in 2012 for the 8 ton ac^{-1} treatment, especially since growing season precipitation was well below normal that year. In contrast to the grain yields, average stover yield showed no major differences among the three treatments, averaging 1.50 , 1.45 , and $1.52 \text{ tons acre}^{-1}$ (3.36 , 3.25 , and 3.40 Mg ha^{-1}) for the control, low, and high biochar treatments, respectively.

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Table 2. Six-year corn grain and stover yield for the control and two biochar treatments i.e. being evaluated on Field 70/71 in Boone County, IA.

Factor	Grain Yield (bu/acre)	Dry Stover Yield (t/acre)	Factor	Grain Yield (bu/acre)	Dry Stover Yield (t/acre)
Conventional Management System					
Year			Harvest Rate		
2008	171	1.76	None	156	0
2009	174	1.83	High cut	173	1.68
2010	200	1.05	Low cut	176	2.62
2011	177	1.52	LSD _(0.1)	4	0.13
2012	136	1.18			
2013	151	1.63	Tillage		
LSD _(0.1)	5	0.19	Chisel plow	168	1.42
			No-tillage	168	1.58
			LSD _(0.1)	NS	NS
Biochar 1 (4 t/acre in 2007)					
Year			Year		
2008	177	1.80	2008	173	1.86
2009	176	1.72	2009	180	1.82
2010	202	1.28	2010	207	1.23
2011	180	1.53	2011	178	1.52
2012	135	1.10	2012	148	1.35
2013	151	1.24	2013	153	1.31
LSD _(0.1)	9	0.20	LSD _(0.1)	6	0.24
Biochar 2 (8 t/ac in '07 + 5 t/ac in '12)					
Harvest Rate			Harvest Rate		
None	155	0	None	167	0
High cut	178	1.78	High cut	174	1.87
Low cut	177	2.55	Low cut	179	2.67
LSD _(0.1)	5	0.11	LSD _(0.1)	3	0.13

Routine soil-test and soil quality indicator assessment data are presented in Tables 3 and 4. As stated previously both tables are summarized from a very extensive dataset because there are no major differences that can be attributed to the biochar amendments, stover harvest treatments, or their interaction. However, when several of the indicator measurements are put together using the SMAF to compute an overall SQI, the values are 0.80, 0.94, and 0.94 for the 0, 4, and 8 tons acre⁻¹ biochar treatments, respectively. The soil quality indicator responsible for the positive response to biochar was potentially

mineralizable N (Table 4) suggesting additional studies focused on biochar and N cycling is warranted.

The slight advantage for the two biochar amendment treatments appears to be due primarily to differences in potentially mineralizable N and soil pH. Other individual indicator scores for all three treatments were essentially the same (data not presented).

In summary, biochar amendments to Midwestern Mollisols in central Iowa have not shown major differences during the past six years, but subtle differences in yield and overall soil health confirm that continued investigations are warranted, especially using some advanced microbial community assays such as PLFA and DNA profiling. These ideas are being evaluated for possible inclusion in the next ARS National Program plan for this research site.

Table 3. Six-year mean, 0 to 15-cm soil-test values for 0, 4, and 8 (+5 tons ac⁻¹ in 2012) tons ac⁻¹ of biochar applied in 2007 to a Clarion-Nicollet-Webster soil association on Field 70/71 in Boone County, IA.

Biochar tons ac ⁻¹	CEC cmol kg ⁻¹	OM g kg ⁻¹	pH	EC μs cm ⁻¹	P	K	S	Ca	Mg	Cu	Fe	Mn	Zn	B
					----- mg kg ⁻¹ -----									
0	21	33.8	5.7	391	31	140	4	2597	300	1	67	10	0.5	0.24
4	20	33.3	6.1	379	33	137	4	2781	304	1	54	7	0.5	0.25
8+5	20	34.4	6.2	360	30	144	4	2791	299	1	50	6	0.5	0.26

Table 4. Mean soil quality indicator data for the 0 to 15-cm depth increment of a Clarion-Nicollet-Webster soil association within Field 70/71 five years after receiving 0, 4, or 8 tons ac⁻¹ of biochar in 2007.

Biochar tons ac ⁻¹	BD [†] g cm ⁻³	NH4 --- μg g ⁻¹ ---	NO3 ---	MBC mg kg ⁻¹	MA g kg ⁻¹	PMN	TN	OC	POM-N	POM-C
						----- μg g ⁻¹ -----				
0	1.17	4.9	50	235	377	8	2106	24040	356	4273
4	1.15	4.2	53	NM [‡]	365	33	1993	23800	348	5458
8	1.18	3.4	49	NM	358	34	2007	26522	294	6646

[†] BD – bulk density; MBC – microbial biomass carbon; MA – water stable macro-aggregates; PMN – potentially mineralizable nitrogen; TN – total N; OC – organic carbon; POM-N – particulate organic matter nitrogen; POM-C – particulate organic matter carbon

[‡] Not measured

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The slight advantage for the two biochar amendment treatments appears to be due primarily to differences in potentially mineralizable N and soil pH. Other individual indicator scores for all three treatments were essentially the same (data not presented).

In summary, biochar amendments to Midwestern Mollisols in central Iowa have not shown major differences during the past six years, but subtle differences in yield and overall soil health confirm that continued investigations are warranted, especially using some advanced microbial community assays such as PLFA and DNA profiling. These ideas are being evaluated for possible inclusion in the next ARS National Program plan for this research site.

▪ Purdue University

• Biomass yield (kg DM/ha) of perennial grasses at three marginal sites in Indiana in 2012 and 2013 (Table 5)

Establishment continues to be an issue at the Southern Indiana Purdue Ag Center. Liberty switchgrass and the big bluestem/indiangrass mixture were reseeded (for the third time) in 2013. The biomass yield of *Miscanthus* was low at this location where this species was established using transplants. Clearly, the low yields and poor establishment at this site is an indicator of the very poor soil conditions at this location (landfill). Yields at the other locations increased at least three-fold for all biomass systems between 2012 (drought) and 2013. Liberty switchgrass had yields >12,000 kg/ha at both locations. *Miscanthus* yield (>19,000 kg/ha) was highest at the Throckmorton Purdue Ag Center; the least limiting of the three marginal locations.

Table 5. Biomass yield (kg DM/ha) of perennial grasses at three marginal sites in Indiana in 2012 and 2013

Species	S IN Purdue Ag Ctr.		NE IN Purdue Ag Ctr.		Throckmorton Purdue Ag Ctr.	
	2012	2013	2012	2013	2012	2013
Liberty switchgrass	0	0	3793	12739	4344	12611
Big bluestem-indiangrass	0	0	919	4380	1642	4444
<i>Miscanthus x giganteus</i>	0	5190	2267	8657	3921	19486

• Biomass yield (kg DM/ha) of sorghum and maize grown for biomass at three marginal sites in Indiana in fall 2013 (Table 6)

Maize biomass production at SEPAC was poor (1600 kg/ha) and at best about 10% of that observed at TPAC, the least impaired of these three locations. Maize responded to N fertilization at NEPAC and TPAC. Sorghum biomass production at SEPAC was much

higher than maize, and sorghum responded to N fertilizer applications. With low N input (0, 50 kg N/ha) sorghums biomass yield at SEPAC was at least 10-fold more biomass than maize. The photoperiod-sensitive sorghum line had the highest biomass yield at all sites, and responded to N at SEPAC and NEPAC, but not the TPAC site. Sweet sorghum biomass production exceeded that of maize at SEPAC and TPAC, but not NEPAC, and responded to N fertilization at all sites. The dual-purpose sorghum had low biomass production at SEPAC and NEPAC, when compared to the photoperiod-sensitive sorghum. The dual-purpose sorghum had greater biomass than maize at SEPAC and similar yields to maize at NEPAC and TPAC.

Table 6. Biomass yield (kg DM/ha) of sorghum and maize grown for biomass at three marginal sites in Indiana in Fall 2013

Species/Line	N Fertilizer kg/ha	So. IN Purdue Ag Ctr.	NE IN Purdue Ag Ctr.	Throckmorton Purdue Ag Ctr.
Maize	0	700	3361	11479
	50	173	4792	14063
	100	1548	2804	15705
	150	110	9544	14581
	200	195	8053	16896
Sweet Sorghum	0	6867	990	15859
	50	9574	1993	14543
	100	8913	4163	19289
	150	11117	5805	18221
	200	11396	6148	19637
Photoper-Sens. Sorghum	0	9501	2746	23100
	50	8934	6702	22253
	100	10143	7468	23861
	150	12695	8974	23827
	200	14593	13081	23519
Dual-purpose Sorghum	0	5254	2691	14642
	50	5410	5262	16453
	100	8122	7957	16036
	150	7316	9336	17838
	200	7983	7109	16502

- Biomass yield (kg DM/ha) of biomass cropping systems in the Systems Analysis Plots at the Water Quality Field Station at Purdue University in fall 2013 (Table 7)

Biomass yield of unmanaged native prairie was the lowest in 2013 while yields of maize and Miscanthus were greatest at about 23,000 kg DM/ha. Switchgrass produced about 7,200 kg DM/ha biomass, and this yield was about one-half that observed for sorghum in 2013. Biomass production of maize and switchgrass in 2013 doubled over values observed in 2012 (severe drought), while the 2013 yield of the prairie increased nearly 9-fold over the 2012 yields. Surprisingly, biomass production of Miscanthus and sorghum across years was similar despite the severe drought of 2012. Coefficients of variation (CV) are an indication of plot-to-plot variation within a year; low numbers are preferred and indicate uniform biomass production. The CVs in 2013 ($\leq 16\%$) were excellent indicating high level of within-treatment plot uniformity. The CVs were generally higher in 2012, especially for switchgrass, Miscanthus and the prairie, when compared to 2013 indicating that drought can reduce yields and increase within-treatment variation.

Table 7. Biomass yield (kg DM/ha) of biomass cropping systems in the Systems Analysis Plots at the Water Quality Field Station at Purdue University in Fall 2013.

System	Mean Yield/kg/ha		Coefficient of Variation	
	2012	2013	2012	2013
Shawnee switchgrass	3491	7233	29	7
Dual-purpose sorghum	15145	14640	11	16
<i>Miscanthus x giganteus</i>	20788	22787	23	8
Maize	10636	23179	9	6
Native prairie	491	4285	76	11

- **Biomass yield (kg DM/ha) and coefficient of variation for *Miscanthus x giganteus* fertilized with increasing rates of nitrogen fertilizer with and without phosphate and potassium fertilizer additions at the Throckmorton Purdue Agricultural Center in fall 2012 and 2013 (Table 8).**

Biomass yield of Miscanthus in 2013 averaged 24,131 kg DM/ha and was unaffected by N, P, and K fertilization. The 2013 biomass yields were approximately twice those of 2012 when a severe drought affected this region of the corn belt. Within-treatment variation, measured as the coefficient of variation, was lower in most treatments in 2013 than in 2012. Again, this was as a result of the better growing conditions in 2013.

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Table 8. Biomass yield (kg DM/ha) and coefficient of variation for *Miscanthus x giganteus* fertilized with increasing rates of nitrogen fertilizer with and without phosphate and potassium fertilizer additions at the Throckmorton Purdue Agricultural Center in Fall 2012 and 2013

N Fertilizer, kg/ha	P & K Fertilizer*	Biomass Yield, kg/ha		Coefficient of Variation, %	
		2012	2013	2012	2013
0	Minus	14952	25316	23	13
50	Minus	12843	25239	19	18
100	Minus	12888	22004	29	10
150	Minus	13310	26473	19	22
0	Plus	15787	23107	23	11
50	Plus	12307	23553	12	7
100	Plus	14362	23054	14	14
150	Plus	13174	24303	9	22

*300 kg K/ha and 75 kg P/ha applied in spring

- **Biomass yield (kg DM/ha) and coefficient of variation in fall 2012 and 2013 for Shawnee switchgrass fertilized with increasing rates of nitrogen (N) fertilizer applied to plot areas that had previous received high rates of phosphorus (P, 0 or 75 kg P/ha/yr) or potassium (K, 0 or 400 kg K/ha/yr) from 1997 to 2004 at the Throckmorton Purdue Agricultural Center (Table 9).**

Biomass yield of switchgrass was not influenced by N fertilizer application ($P=0.13$), nor was it influenced by variation in soil test P and K that resulted from historic applications of these nutrients that altered soil test P and K levels. Biomass yields were approximately 50% higher in 2013 when compared to 2012 when a severe drought occurred in the corn belt. Within-treatment variation was low and generally similar in both years with coefficients of variation generally less than 15%.

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Table 9. Biomass yield (kg DM/ha) and coefficient of variation in fall 2012 and 2013 for Shawnee switchgrass fertilized with increasing rates of nitrogen (N) fertilizer applied to plot areas that had previous received high rates of phosphorus (P, 0 or 75 kg P/ha/yr) or potassium (K, 0 or 400 kg K/ha/yr) from 1997 to 2004 at the Throckmorton Purdue Agricultural Center

Current Fertilizer N, kg/ha	Historic (1997-2004) Fertilizer Application		Biomass Yield, kg DM/ha		Coefficient of Variation, (%)	
	P, kg/ha	K, kg/ha	2012	2013	2012	2013
0	0	0	7932	11234	9	10
50	0	0	8173	11111	10	13
100	0	0	8846	11987	13	9
150	0	0	8285	11470	14	9
0	0	400	8084	11944	9	11
50	0	400	7641	11587	5	12
100	0	400	7520	12702	6	1
150	0	400	7642	12880	6	17
0	75	0	7628	10998	6	24
50	75	0	7864	11330	8	6
100	75	0	8818	11584	6	10
150	75	0	8249	11937	9	13
0	75	400	8054	11247	5	2
50	75	400	8049	12211	13	11
100	75	400	8018	11786	4	9
150	75	400	7911	12656	4	11

- **Biomass yield (kg DM/ha) and coefficient of variation in fall 2012 and 2013 of Shawnee switchgrass fertilized with increasing rates of nitrogen (N) fertilizer applied to plot areas that had previous received high rates of phosphorus (P, 0, 25, 50, or 75 kg P/ha/yr) or potassium (K, 0, 100, 200, 300, or 400 kg K/ha/yr) from 1997 to 2004 at the Throckmorton Purdue Agricultural Center. All plots received 50 kg N/ha (Table 10).**

Biomass yield of switchgrass in 2013 was approximately 50% greater than 2012 when yields were reduced by a severe drought. Within a year, variation in yield was not influenced by previous P and K fertilizer applications that alter soil test P and K levels. Averaged over years and P treatments, plots in the 0 K treatment tend to have higher yield than plots that historically received higher K rates.

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Table 10. Biomass yield (kg DM/ha) and coefficient of variation in fall 2012 and 2013 of Shawnee switchgrass fertilized with increasing rates of nitrogen (N) fertilizer applied to plot areas that had previously received high rates of phosphorus (P, 0, 25, 50, or 75 kg P/ha/yr) or potassium (K, 0, 100, 200, 300, or 400 kg K/ha/yr) from 1997 to 2004 at the Throckmorton Purdue Agricultural Center. All plots received 50 kg N/ha

Historic (1997-2004) Fertilizer Application		Biomass Yield, kg/ha		Coefficient of Variation, (%)	
P, kg/ha	K, kg/ha	2012	2013	2012	2013
0	0	8970	13173	5	7
0	100	7869	11663	18	21
0	200	8320	12521	10	11
0	300	8821	12368	12	10
0	400	8135	11008	13	6
25	0	8872	13217	8	3
25	100	8339	12062	12	5
25	200	8246	12301	12	2
25	300	8689	12773	5	9
25	400	8526	11702	10	8
50	0	8557	13192	5	8
50	100	8465	12198	9	5
50	200	8224	12235	11	3
50	300	8617	13009	10	9
50	400	8518	12224	4	5
75	0	8469	12301	7	9
75	100	7763	12201	9	8
75	200	8090	12534	8	5
75	300	8857	12733	6	7
75	400	8219	12075	13	9

- **Bulk density of soils by depth at the three marginal sites used for the Factor Analysis studies (SEPAC, NEPAC, and TPAC) and the WQFS used for the Systems Analysis experiments (Fig. 2)**

Bulk densities tend to be lower in the surface layers of the soil profile (0-10 cm), and change little with depth after the 10-20 cm layer. Perennial grass biomass systems generally have lower bulk densities than tilled systems like corn/sorghum. Bulk densities at the WQFS are generally lower than those at SEPAC and NEPAC, with TPAC bulk densities being intermediate. Bulk density data will be used to calculate C sequestration

rates from soil C concentration data for the various biomass cropping systems under study.

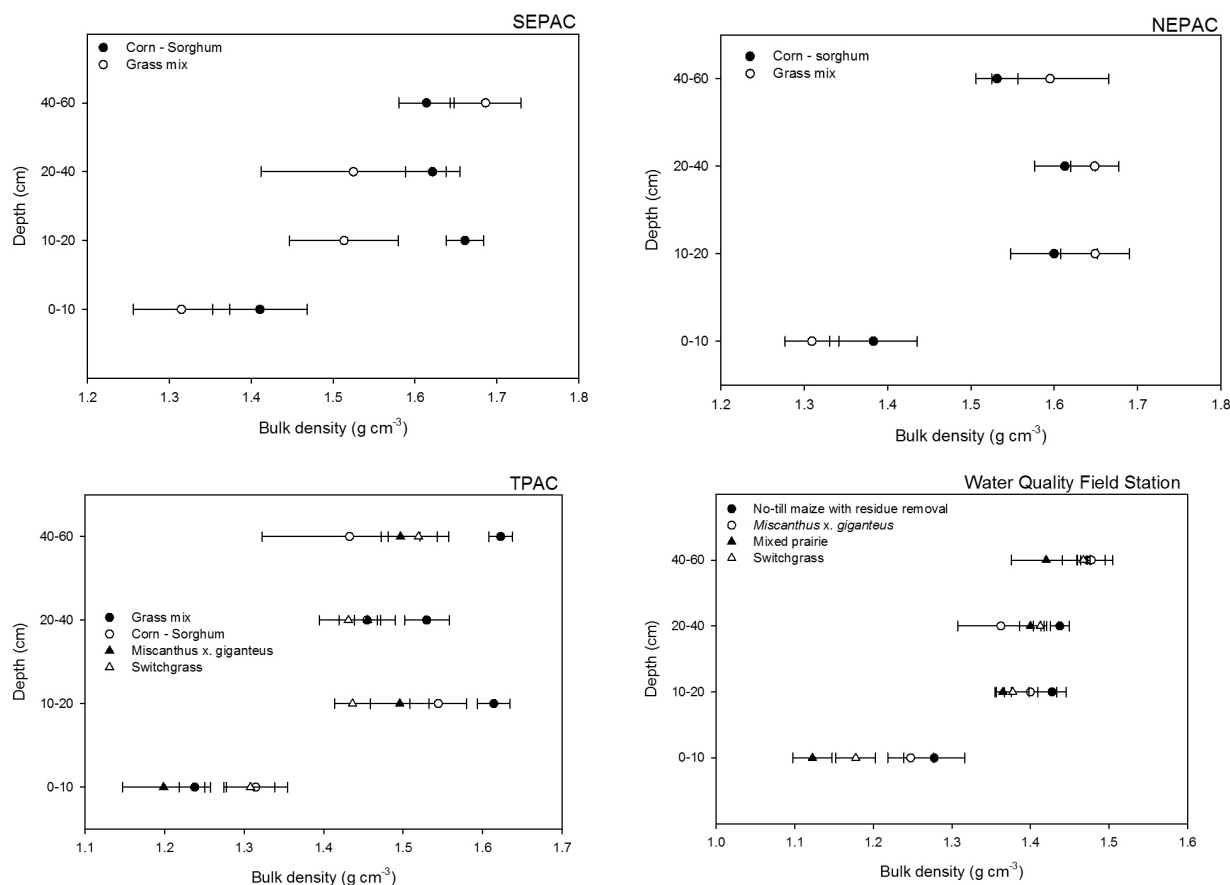


Fig. 2. Bulk density of soils by depth at the three marginal sites used for the Factor Analysis studies (SEPAC, NEPAC, and TPAC) and the WQFS used for the Systems Analysis experiments.

■ University of Illinois Urbana-Champaign

• Factor Analysis Plots

- ✓ Both of the plots seeded in 2012 (reseeded in 2013) and 2013 had adequate plant densities (Fig. 3). However, the plots were not harvested in 2013 because of the low biomass yield associated with drought during summer and late-season weed pressure.
- ✓ Stand count will be evaluated on both of the plots again in the spring of 2014 and necessary weed controls will be applied to ensure good stands.



Fig. 3 Switchgrass plot in Factor Analysis study (picture taken Feb 2014)

- **Comparison Field Trial**

- ✓ A comparison field trial of switchgrass (SW), big bluestem (BB), prairie cordgrass, and *Miscanthus x giganteus* (Mxg) was established by transplanting in 45-cm and 90-cm spacings on wet marginal land in 2010. The plots were harvested on December 2013 and biomass yield data has been analyzed during this quarter (Fig. 4).
- ✓ Overall, biomass yields were high even under drought conditions during the growing season. Precipitation from May to September 2013 was 41 cm below normal and 46 cm below normal from July to September. Biomass yields of two prairie cordgrass populations 17-109 and 20-107 were comparable to those of Mxg and SW and higher than that of BB during 2013. The yield was overall higher in 45 cm spacing as compared to that of 90 cm spacing.

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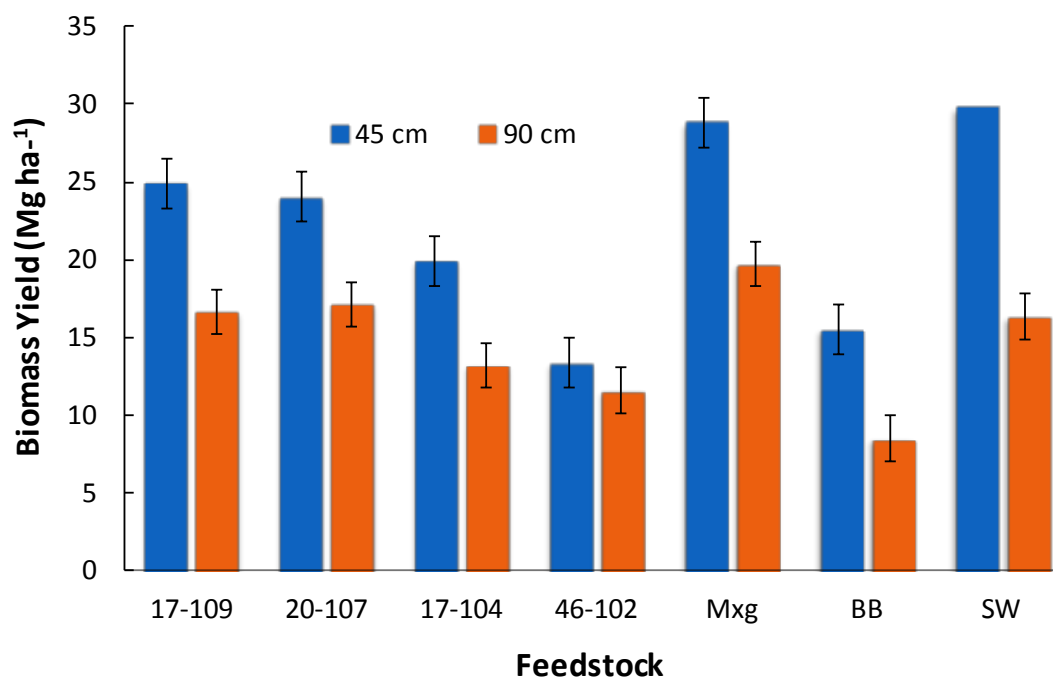


Fig. 4. Biomass yield of 'Kanlow' switchgrass (SW), *Miscanthus x giganteus* (Mxg), big bluestem (BB), and four prairie cordgrass natural populations (17-109, 20-104, 17-104, and 46-102) at 45cm and 90 cm spacing in 2013.

• Abiotic Stress Trial

- ✓ A salt stress trial on salt affected soil ($EC > 20 \text{ dS m}^{-1}$) in Salem, IL was established by transplanting of two populations of prairie cordgrass (PCG-109 and PC 17-109) and two cultivars of switchgrass (Cave-In-Rock and Blackwell) in 2011. During the transplanting year, both switchgrass cultivars did not survive (>90% mortality) and those two plots were replaced with IL-102 prairie cordgrass and Kanlow switchgrass in 2012 (Fig. 5A). All plots were well established in 2012 and biomass was harvested from 2013.

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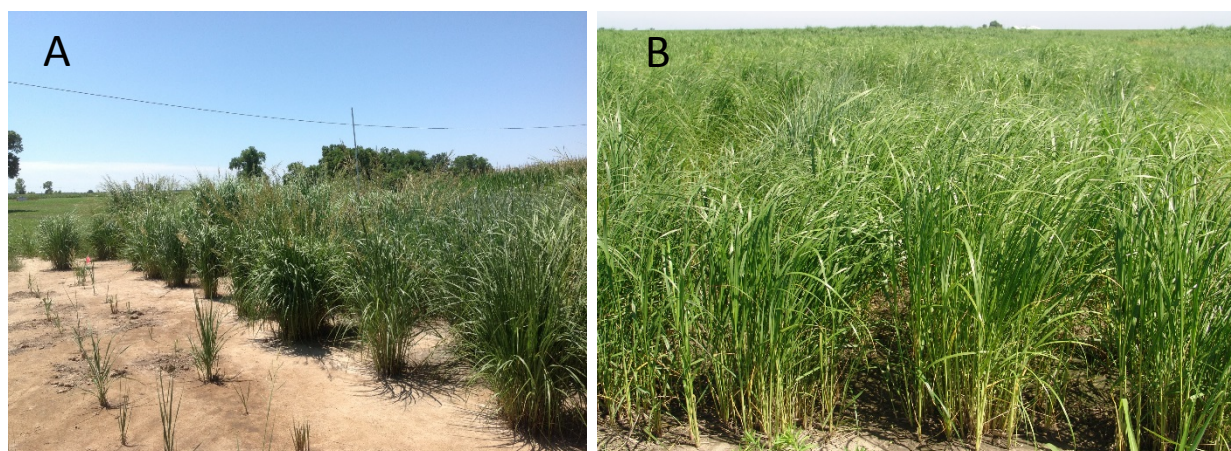


Fig. 5. A) Salt affected site in Salem, IL (picture taken in July, 2013) and B) Poorly drained site in Pana, IL (picture taken in June, 2013)

The mean biomass yield of PC17-109 was higher (10.68 Mg ha^{-1}) in the salt affected soil, however, it was not significant from Kanlow switchgrass (8.99 Mg ha^{-1}) and PCG109 prairie cordgrass (8.80 Mg ha^{-1}) (Fig. 6).

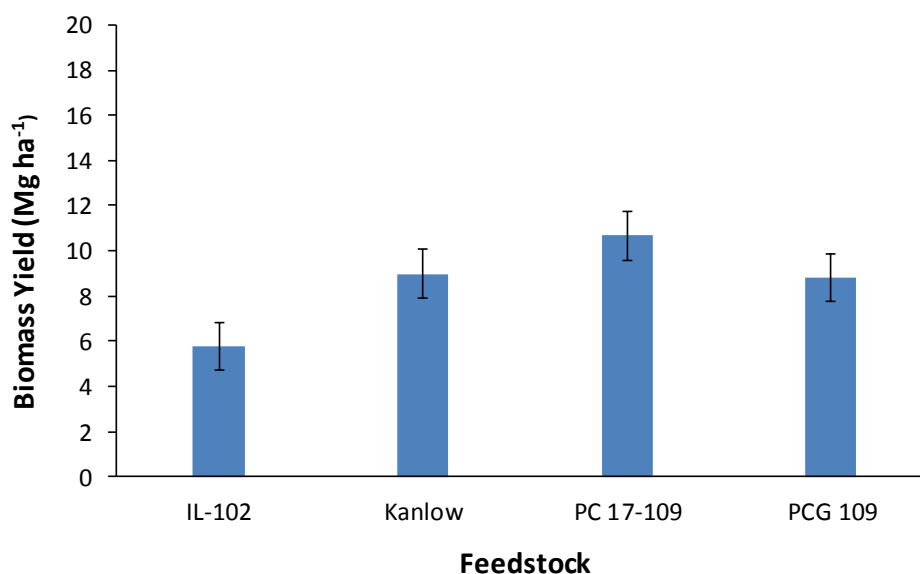


Fig. 6. Biomass yield of prairie cordgrass and switchgrass on salt affected soil in Salem, IL in 2013.

The biomass yield of Kanlow was higher in both poorly drained sites in Urbana (14.82 Mg ha^{-1}) and Pana (9.30 Mg ha^{-1}) as compared to the two prairie cordgrass

populations ($\sim 7 \text{ Mg ha}^{-1}$) (Fig. 7). Precipitation in 2013 was below normal and the sites did not have severe issues related with seasonal flooding in both locations other than during April 2013.

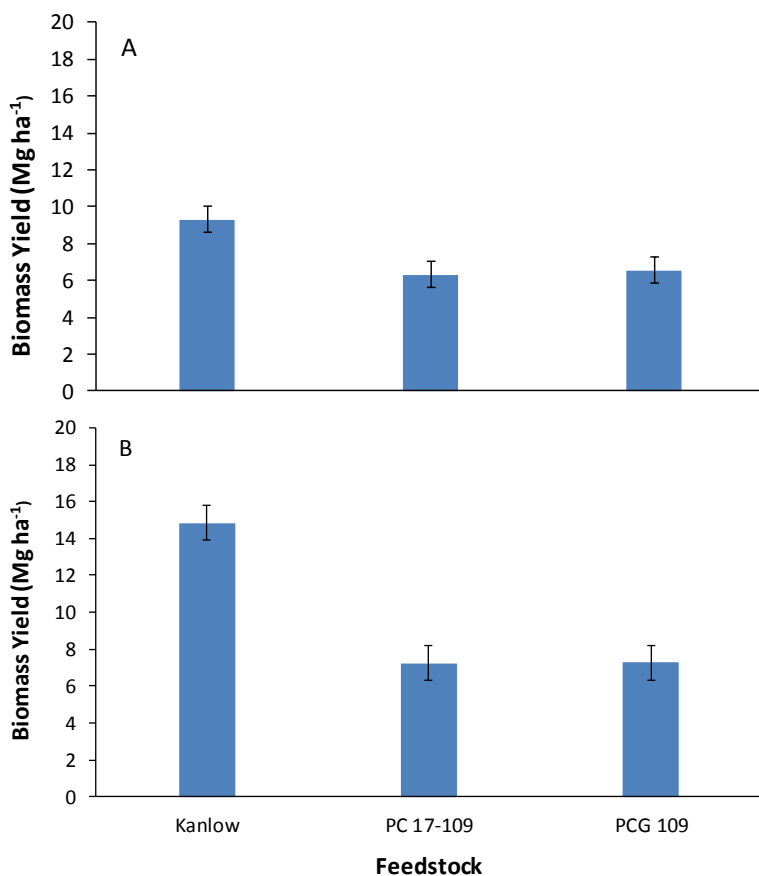


Fig. 7: Biomass yield of prairie cordgrass and switchgrass on poorly drained soils in Pana (A) and Urbana (B), IL in 2013.

▪ University of Minnesota

• Factor plots at Lamberton, Minnesota

- ✓ The Lamberton plots were harvested on November 12, 2013 (Figure 8). The switchgrass monoculture plots had good establishment year production and were minimally affected by weed pressure due to timely pre-emergent atrazine application. The low-diversity mix, CRP mix and low-diversity plus legume plots were less robust as a result of weed pressure, despite spraying LD plots and hand-weeding the polyculture and LD + leg plots.

- ✓ Samples are in the process of being ground and prepared for shipment to UNL.

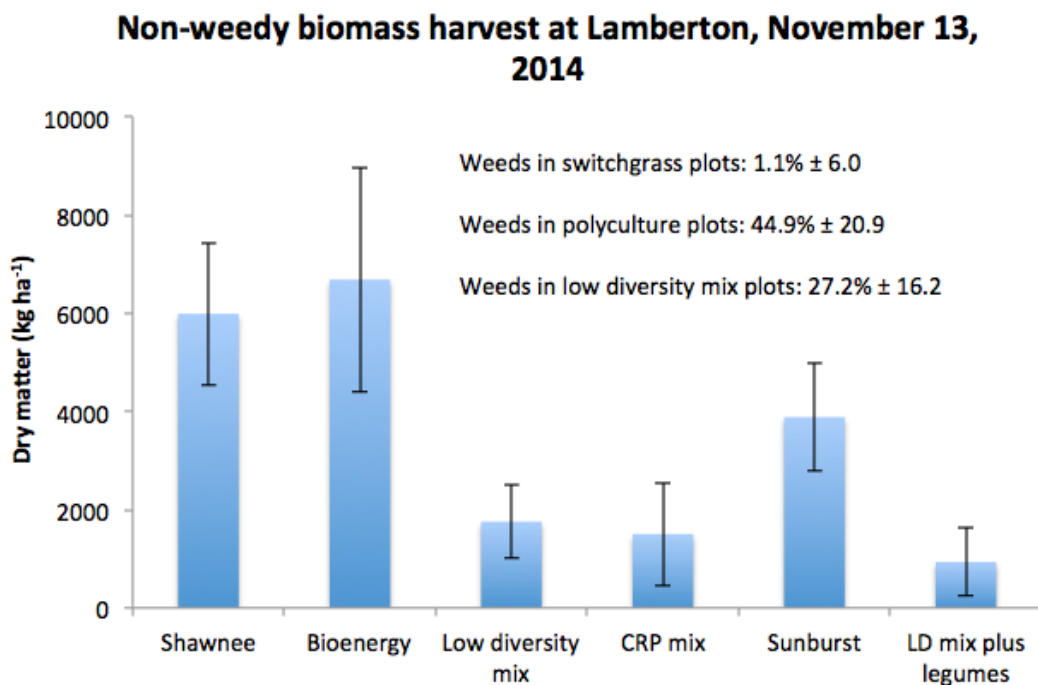


Fig. 8. Nov. 13, 2013 harvest at Lamberton, averaged by feedstock. *Black lines represent standard deviation. After harvest, weeds were separated from grasses, and the wet weight of the weeds is given as an average percentage of total biomass.*

- **Factor plots at Becker Minnesota**

- ✓ The near-anthesis harvest was completed on August 14, 2013 (Figure 9). Grass plots were sprayed with 2,4D on July 22. Standing dead weed biomass was heavy in the plots at harvest time. The polyculture plots (low-diversity mix plus legumes and CRP mix) were hand-weeded on August 8, 2013, which is why the non-weed biomass is much greater in the polyculture plots than the grass plots.

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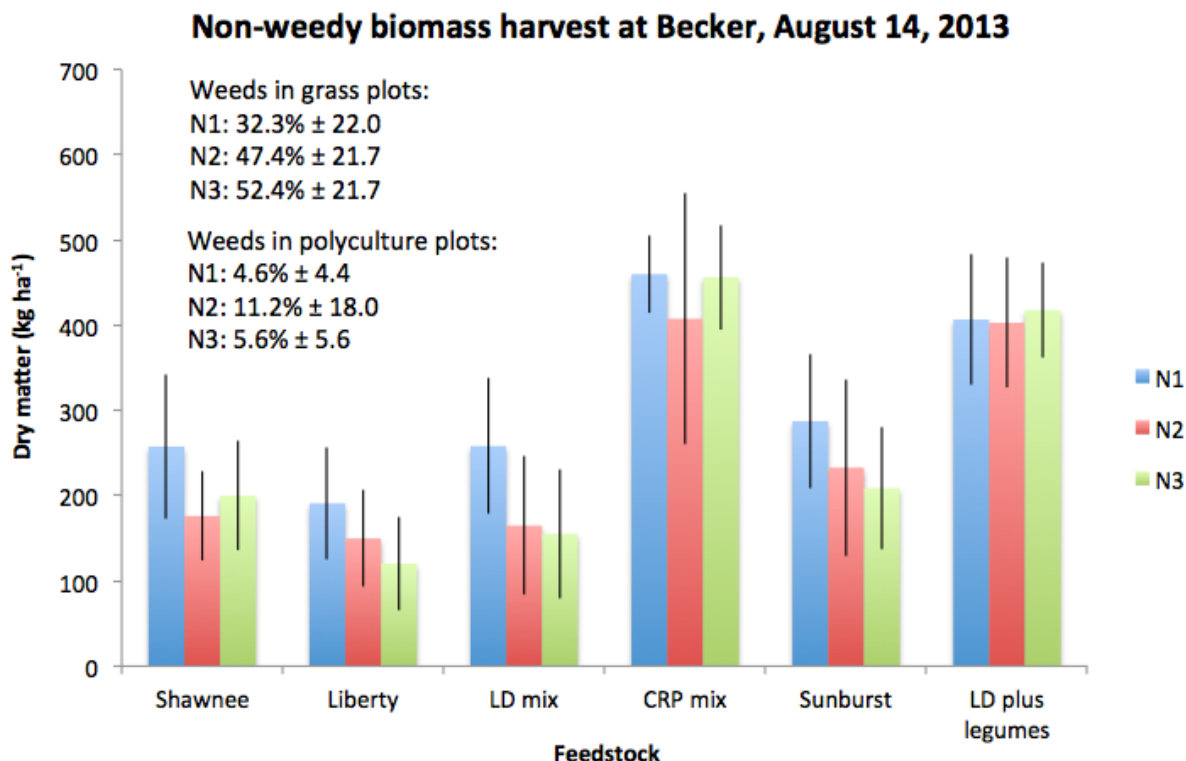


Fig. 9. August 14 harvest at Becker, averaged by feedstock and nitrogen rate. N1 = 0 lb ac⁻¹, N2 = 50 lb ac⁻¹, and N3 = 100 lb ac⁻¹. Solid black lines represent standard deviation. After harvest, weeds were separated from grasses, and the wet weight of the weeds is given as an average percentage of total biomass.

- ✓ The post-frost harvest was completed on October 24, 2013 (Figure 10). August and September were very dry months: between August 7 and September 14, 2013 less than 0.6 inches of rain was observed. The soil at Becker is an excessively drained loamy sand, and the lack of moisture appeared to force much of the grass into premature dormancy. By the time we harvested in late October 2013, the grasses had very low moisture content. By late October, the standing dead weed biomass was still present in the grass plots, but had decreased greatly since August. Overall, the lack of an N response was due to the fact that water was the most limiting factor at the Becker plots in 2013.
- ✓ Samples are in the process of being ground and prepared for shipment to UNL.

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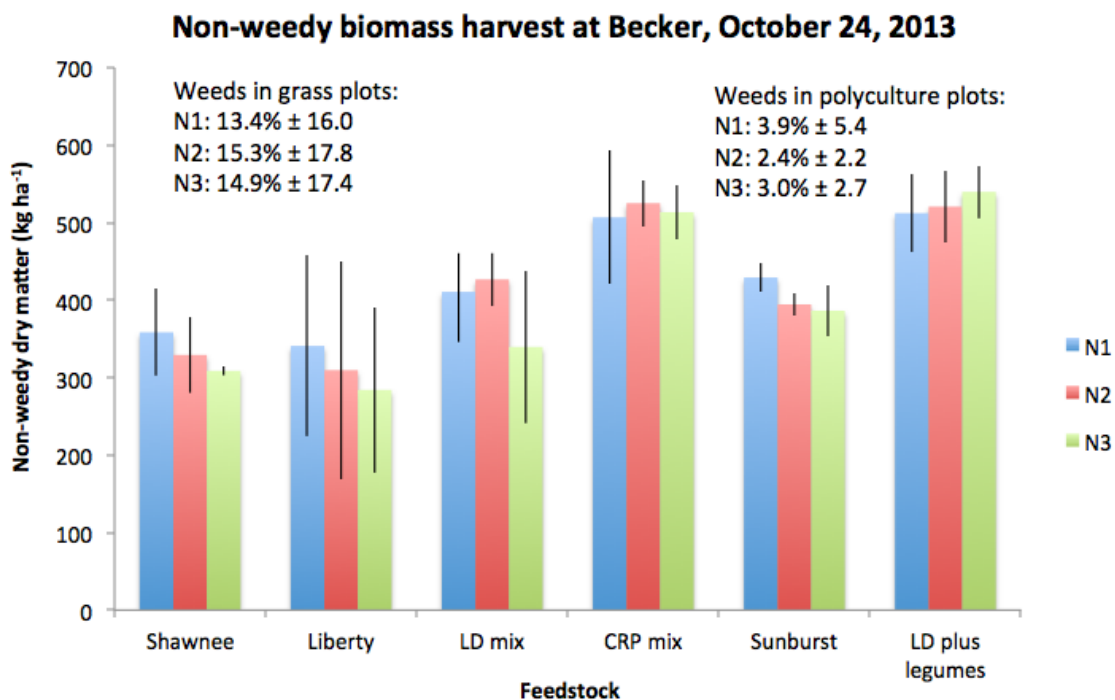


Fig. 10. October 24 harvest at Becker, averaged by feedstock and nitrogen rate. N1 = 0 lb ac⁻¹, N2 = 50 lb ac⁻¹, and N3 = 100 lb ac⁻¹. Solid black lines represent standard deviation. After harvest, weeds were separated from grasses, and the wet weight of the weeds is given as an average percentage of total biomass.



Fig. 11A. Oct. 24, 2013 harvest at Becker, MN

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Fig. 11B. Nov. 13, 2013 harvest at Lamberton, MN

▪ USDA-ARS, Lincoln

- All factor analysis plots seeded in 2012 and 2013 in Nebraska are fully established, with thin stands only in the bioenergy big bluestem plots. The 2013 seeded plots were not harvested. All harvest treatments were completed on the 2012 plots and dry weights have been determined. Feedstock yield was averaged across N rates within a harvest date (Table 11). The feedstock samples collected in 2012 from Nebraska and Minnesota have been scanned by NIRS and are awaiting prediction and the samples collected in 2013 are being processed.

Table 11. Biomass yield in Factor Analysis Plots located in Nebraska (Mg/ha^{-1}).

Harvest Date	Liberty switchgrass	Shawnee switchgrass	LD mixture	Big bluestem blend	Bioenergy Big bluestem
Anthesis	6.5 (0.26)	6.2 (0.32)	3.8 (0.27)	5.0 (0.41)	2.3 (0.16)
Post-frost	4.6 (0.43)	4.8 (0.22)	3.7 (0.35)	3.4 (0.30)	1.8 (0.29)
Alternate Dates	5.7 (0.34)	6.3 (0.28)	5.0 (0.84)	4.9 (0.32)	2.0 (0.22)

• Nebraska System Analysis Plots.

- ✓ The Nebraska system analysis plots were seeded in 2012 and were well established in spite of the severe drought conditions in 2012. Two randomly-selected 25-foot swaths from each of the larger switchgrass, big bluestem, and low diversity mixture field replicates were harvested at 30-day intervals as conditions allowed from October 2012 through February 2013 to quantify establishment-year yield and evaluate

changes in harvestable standing crop during winter (Table 12). Data are means + the standard error of the mean. Samples are being processed for NIRS evaluation.

Table 12. System Analysis Plots (Nebraska)

Feedstock	Yields (tons/acre)				
	Oct	Nov	Dec	Feb	Mean
Liberty Switchgrass	3.6 (0.28)	3.3 (0.14)	3.6 (0.13)	3.0 (0.13)	3.4 (0.17)
Big bluestem	2.1 (0.13)	1.7 (0.12)	1.8 (0.09)	0.9 (0.10)	1.6 (0.11)
LD Mixture	1.4 (0.07)	1.0 (0.08)	1.3 (0.11)	1.2 (0.14)	1.2 (0.10)

- ✓ System analysis plots had excellent growth during the 2013-growing season, even though precipitation was sporadic. The perennial grasses grew well, with some lodging occurring as senescence progresses. Corn was harvested on September 25, 2013. Corn yield on the areas seeded with a triticale cover crop in autumn 2012 was 138 bu/acre, whereas the yield on areas with no cover crop was 160 bu/acre. Weather and the government furlough prevented timely stover removal, but the triticale cover crop was seeded into the standing stover after furlough. Perennial grasses were harvested with field-scale equipment on November 20, 2013. Large round bales were picked up from the field, transported to an enclosed hay storage facility, and weighed. Consequently, reported yields are the field scale dry matter yield for bales transported to a processing plant and represent yield minus harvesting and transport losses (Table 13). Samples are being processed for NIRS evaluation.

Table 13. 2013 Transportable Bale Yield (Nebraska)

Feedstock	2013 Transported Bale Yield (tons/acre)	2013 Transported Bale Yield (tons/acre)
	50# N/acre (Mean ± SE)	100# N/acre (Mean ± SE)
Liberty Switchgrass	5.1 (0.21)	5.0 (0.10)
Big bluestem	4.1 (0.58)	4.1 (0.25)
LD Mixture	5.4 (0.48)	4.6 (0.26)

As recommended by the CenUSA Advisory Board, we initiated a harvest height (2, 4, 6, 8, 10, and 12 inches) by harvest date (at anthesis and after killing frost) study in 2013 to determine switchgrass, big bluestem, and low diversity mixture feedstock response to harvest height and harvest date. Harvest heights were controlled by adjusting the flail head of a Carter Harvester. These data will have implications for areas where maintaining

wildlife habitat for thermal cover during winter and nesting cover for the following spring may be desired. Anthesis and post-frost harvests were completed and dry weights have been determined for both harvests. Harvested biomass was averaged across the 50 and 100 lb N/acre fertilizer treatments (Table 14). Initial evaluations indicate the 2" harvest height after a killing frost has large quantities of soil contamination. Samples are being processed for NIRS evaluation.

Table 14. Anthesis and Post Frost Harvest Height (Nebraska)

Feedstock	Yields (tons/acre)											
	Anthesis						Post Frost					
	Harvest Height (inches)						Harvest Height (inches)					
	2	4	6	8	10	12	2	4	6	8	10	12
Liberty Switchgrass	9.8	8.6	7.1	6.8	5.3	5.7	12.2	7.6	7.6	6.2	6.4	6.2
Big bluestem	8.3	7.1	5.4	5.9	4.8	4.4	13.4	5.9	5.9	4.8	5.1	3.6
LD Mixture	8.0	6.1	5.8	4.8	4.2	3.9	13.5	7.3	7.4	4.7	5.5	5.8

- **Greenhouse Gas Sampling.**

Greenhouse gas (GHG) sampling was conducted throughout the 2013 growing season. Soil water content, biomass, and GHG were sampled at weekly intervals in the System Analysis plots to compare the perennial grass feedstocks and N rate to continuous corn. Cumulative N₂O and CO₂ emissions through the entire growing season are being summarized.

- **Plans for Next Quarter**

- Finish grinding and scanning 2013 biomass samples.
- Process and prepare seed for new trials and Demonstration Plots to be planted in 2014.
- Submit switchgrass and corn stover samples from long-term study for mineral analysis.
- Plant Vermeer Demo Plots near Pella, IA.
- Plant Abengoa Bioenergy Demo Plots near Farwell Nebraska.
- Pellet switchgrass, big bluestem, and low diversity mixture bales.
- Ship switchgrass bales to IA for feedlot feeding trial.
- Ship switchgrass, big bluestem, and low diversity mixture bales to IA for biochar project.

- **USDA-ARS, Madison**

- **Planned Activities**

- ✓ Complete November/December harvest at two locations.
 - ✓ Grind and scan samples harvested in 2013.

- **Actual Accomplishments**

- ✓ Completed November/December harvest at two locations.
 - ✓ Ground and scanned all samples collected in 2013.

- **Explanation of Variance**

- No variance noted.

- **Plans for Next Quarter**

- ✓ Complete the last harvest of 2013 biomass (post-winter harvest) at two locations.
 - ✓ Finish grinding and scanning samples from the last harvest.
 - ✓ Fertilize plots for the 2014-growing season.

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

- Dierking, R.M., J.J. Volenec, J.J. Murphy, P.T. (2013). Forage yield and quality of *Miscanthus giganteus* subjected to simulated haying/grazing conditions. Abstract 245-5. Inter. Meeting of the Amer. Soc. Agron.-Crop Sci. Soc. of Amer.-Soil Sci. Soc. of Amer. Nov. 2-6, Tampa, FL.
<https://scisoc.confex.com/crops/2013am/webprogram/Paper79122.html>
 - Long, M.K., Volenec, J.J. & Brouder, S.M.(2013). Theoretical ethanol yield for potential bioenergy sorghum genotypes of differing compositions. Abstract 373-9. Inter. Meeting of the Amer. Soc. Agron.-Crop Sci. Soc. of Amer.-Soil Sci. Soc. of Amer. Nov. 2-6, Tampa, FL. <https://scisoc.confex.com/crops/2013am/webprogram/Paper80060.html>
 - Mitchell, R.B. (2013). Establishing and managing perennial grasses for bioenergy, Proc. 25th Annual Integrated Crop Management Conference, Iowa State University, pp. 49-51.
 - Mitchell, R.B. & Harlow, S. (2013). Switchgrass stand establishment: key factors for success, Fact Sheet No. 4, CenUSA Bioenergy, Iowa State Univ., Ames, IA.

- Mitchell, R.B., Vogel, K.P. & Schmer, M. R. (2013). Growing switchgrass for biofuels, Fact Sheet No. 3, CenUSA Bioenergy, Iowa State Univ., Ames, IA. 2013.
- Mitchell, R.B., & Schmer, M.R. (2014). Switchgrass for biomass energy, Proc. Nebraska Crop Production Clinic Proceedings, University of Nebraska, pp. 13-16.
- Vogel, K.P., Mitchell, R.B., Casler, M. & Sarath, G. (2014). Registration of ‘liberty’ switchgrass. Journal of Plant Registrations (accepted 25 February, 2014).
- *Establishing and managing perennial grasses for bioenergy*. (December 4, 2013). Presentation at the 25th Annual Integrated Crop Management Conference, Ames, IA.
- *Switchgrass for biomass energy*. (January 9-23, 2014). Nebraska Crop Production Clinics, 5 dates and locations throughout Nebraska. University of Nebraska.

OBJECTIVE 3. FEEDSTOCK LOGISTICS

The Feedstock Logistics objective focuses on developing systems and strategies to enable sustainable and economic harvests, 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:

- Analysis of data collected in 2013 and manuscript preparation;
- Development of machine configurations to size-reduce bales without grinding or shredding; and
- Design activities to increase bale density and package size.

2. Actual Accomplishments

We are statistically analyzing data from our work on bale aggregation; grass drying rate; and biomass size-reduction. The analyzed data is being added to that collected in 2012 and early 2013 and preparation of manuscripts has begun for submission for review for publication. We continued to quantify the energy required to size-reduce perennial grasses post-storage. Our work during the early winter months focused on increasing the size of data set by

processing bales through several different bale processors. Current efforts are focused on designing and fabricating ways to process bales by more efficient means than grinding and shredding. This system will involve decomposing bales by unrolling and using controlled and metered feeding into precision-cut chopping components.

3. Explanation of Variance

There were no variances – we accomplished all that we had planned during this period.

4. Plans for Next Quarter

Our efforts in the next quarter 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 bale densification system for round bales
- Field evaluation of a large-package option for baling grasses; and
- Performing field operations to insure the successful establishment of Liberty switchgrass at our research/demonstration field.

5. Publications, Presentations, and Proposals Submitted

- None during this quarter.

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 scenario using the detailed SWAT model for the Upper Mississippi River Basin and the Ohio Tennessee River Basin with USGS 12-digit subwatersheds. A second manuscript using this modeling system is under review. 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 the water quality and carbon effects at the landscape level.

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Quarter

Continue work on Tasks and 2: 1) to adapt existing biophysical models to best represent field trials and other data and 2) to adapt existing economic land-use models to best represent cropping system production costs and returns. We plan to begin developing a scenario with widespread perennial adoption in the watershed during this quarter. Preliminary results may be completed in the next quarter.

5. Publications, Presentations, and Proposals Submitted

- Kling, C. L. (2013, October). *Agricultural Water Pollution: Some Policy Considerations*. Presented at the *Iowa Environmental Council Annual Meeting*, Available at http://www.card.iastate.edu/presentations/iowa_environmental_council_oct_2013.pptx.

- Kling, C. L. (2013, August). *Optimal placement of Second Generation Biofuels in a Watershed: Is Marginal Land the Answer?* Presented at the annual meetings of the Association of Agricultural and Applied Economics, Washington DC.
- Kling, C. L. (2013, October 11). *Agricultural Water Pollution: Some Policy Considerations*. Presented at the Iowa Environmental Council Annual Meeting. Available at http://www.card.iastate.edu/presentations/iowa_enviornmental_council_oct_2013.pptx
- Kling, C. L., (2013, October 15). *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*. Presented at the Water Resources Conference, Saint Paul, Minnesota. Available at: www.card.iastate.edu/presentations/linking_externalities_from_land_to_sea.pptx
- 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, G., & Rabalais, N. “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,” draft manuscript under review.
- Valcu, A.M. (2013) Agricultural nonpoint source pollution and water quality trading: empirical analysis under imperfect cost information and measurement error. *Graduate Theses and Dissertations*. Paper 13444. Available at: <http://lib.dr.iastate.edu/etd/13444>.
- Schilling, K.E., Gassman, P.W., Kling, C.L., Campbell, T., Jha, M., Wolter, C.F. & Arnold, J.G. (2013). The Potential for Agricultural Land Use Change to Reduce Flood Risk in a Large Watershed. *Hydrological Processes* (2013) Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/hyp.9865.

University of Minnesota

1. Planned Activities

Planned activities for this quarter 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), and Task 4 (Evaluate the life cycle environmental consequences of various bioenergy landscapes).

2. Actual Accomplishments

We spent much of our time this quarter finishing manuscripts on the topics of bioenergy crop yield gaps, implications of the Farm Bill for bioenergy, and regional changes in the biophysical exchange of carbon and water due to increased bioenergy production in the Midwest. We are also delighted to report the successful doctoral defense of CenUSA affiliate Bonnie Keeler, who has now taken a position as lead scientist with the Natural Capital Project. See http://environment.umn.edu/about/ione_bios/bonnie_keeler.html.

3. Explanation of Variance.

No variance has been experienced.

4. Plans for Next Quarter

Next quarter will include continued work on Tasks 1, 2, 3, and 4, and the initiation of Task 5 (Employ the modeling systems to study the design of policies to cost effectively supply ecosystem services from biomass feedstock production).

5. Publications, Presentations, and Proposals Submitted

- Sun J., Twine T., Hill J. (2013, December 20). Historical and projected environmental impacts of land cover change in the Midwest USA. Presentation at the American Geophysical Union Fall Meeting, San Francisco, CA.

Post-Harvest

OBJECTIVE 5. FEEDSTOCK CONVERSION AND REFINING: THERMO-CHEMICAL CONVERSION OF BIOMASS TO BIO-FUELS

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.

Begin technoeconomic analysis looking at a broader portfolio of end products beyond liquid transportation fuels.

2. Actual Accomplishments

We conducted a technoeconomic analysis and a life cycle assessment using previous experimental data on the production of electricity by co-firing pyrolysis liquids and coal. The experimental data for this project was generated using corn stover as the pyrolysis feedstock. However, due to the similar pyrolysis fraction composition and improved yields demonstrated from switchgrass, the results from this study should be applicable to use of perennial grasses. Mark Mba-Wright, Assistant Professor in Mechanical Engineering at ISU led this study.

Study Conclusions

This project studied the economic cost and environmental impact of generating electricity from corn stover and coal by mixing “heavy-ends” of bio-oil derived from the pyrolysis of corn stover and bituminous coal in a combined heat and power (CHP) system. The results of this analysis include an estimate for the minimum electricity-selling price (MESP) required for commercial viability of this technology, and the environmental impact of the electricity generated.

The results of the techno-economic analysis include estimates of the capital and operating costs of Bio-oil Co-firing Fuel (BCF) production and conversion to power. The total project investment is \$216 MM, and the CHP process contributes the most to the capital cost at 35.0%. Corn stover contributes the most (about 60%) to operating costs followed by coal expenses (30.4%). The greenfield BCF system has a total electricity price of 15.2 cents per kWhr for a 10% rate of return. This price is about 5 cents per kWhr higher than the average market electricity price. However, there are a large number of factors affecting the estimated price that need to be optimized.

The net greenhouse gas emissions of the co-firing system are estimated at 119 kg of CO_{2,e} per mmbtu of electricity. This represents a 63.7% reduction in CO₂ emissions compared to the 329 kg CO_{2,e}/mmbtu emissions for a coal-fired power plant. This level of would allow existing coal-fired power plants to meet carbon emission reductions being proposed by the EPA. The other advantage is that BCF has a lower nitrogen and sulfur content, which leads to reductions in NO_x and SO_x emissions.

Considering the reduction of GHG emissions with the minimum electricity-selling price, bio-oil co-firing fuel (BCF) could be competitive with coal for power production. An incentive of \$76.27/Mg of CO_{2,e} could be required to level the cost compared to the industry average. However, future research could help describe strategies to reducing the cost of BCF power production.

Supporting Figures and Tables

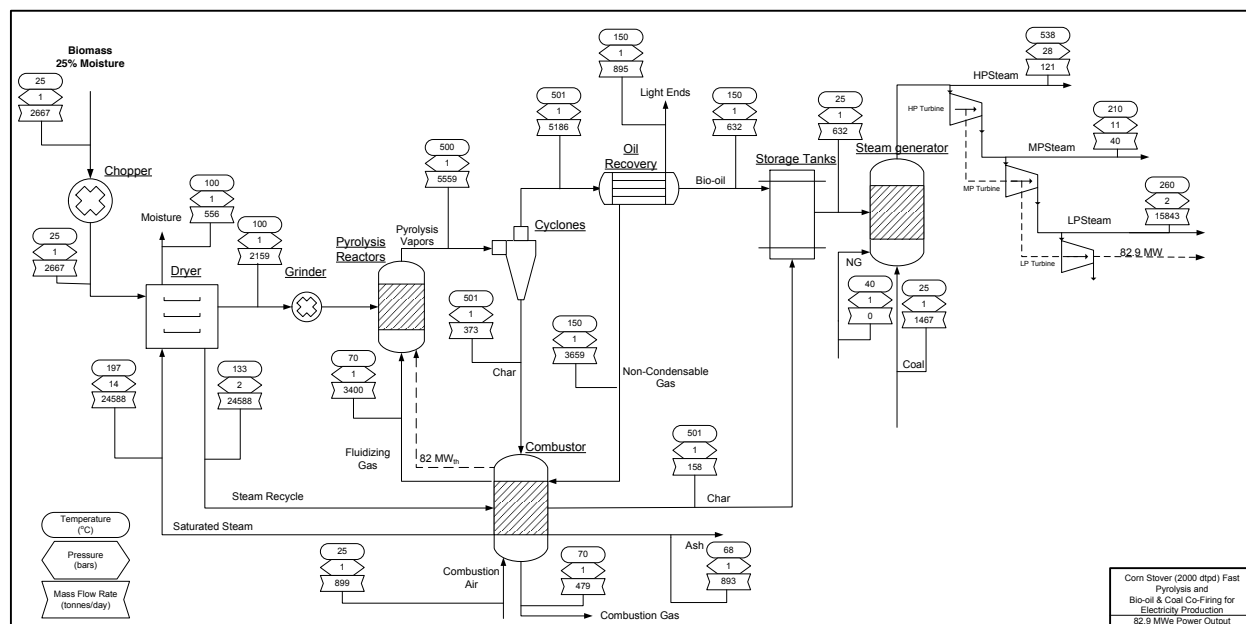


Fig. 12. Simplified process flow diagram of fast pyrolysis bio-oil co-fire fuel & coal combined heat & power system

Table 15. Corn stover fast pyrolysis and bio-oil co-firing fuel power production key material flows

Material	Tons per day	Price (\$/MT)	Energy Content (HHV - MJ/kg)
Corn Stover	2000	83.00	18.00
Coal	1467	57.30	29.50
Biochar	158	-22.10	13.83
Light Ends	895	-21.75	4.28
Steam (2 bar)	15843	-5.29	
Steam (11 bar)	40	-6.62	

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Table 16. Cost factors for estimating total project investment based on total purchased equipment cost

Total Purchased Equipment Cost (TPEC)	100%
Purchased Equipment Installation	39%
Instrumentation and Controls	26%
Piping	31%
Electrical Systems	10%
Buildings (including services)	29%
Yard Improvements	12%
Service Facilities	55%
Total Installed Cost (TIC)	3.02
Indirect Costs	
Engineering	32%
Construction	34%
Legal and Contractors Fees	23%
Total Indirect	3.91
Project Contingency	78.2%

(Working Capital shown in DCFROR)

Total Fixed Capital Investment	4.69
Land	6.00%
Total Investment (with Land)	4.75
Lang Factor	4.75

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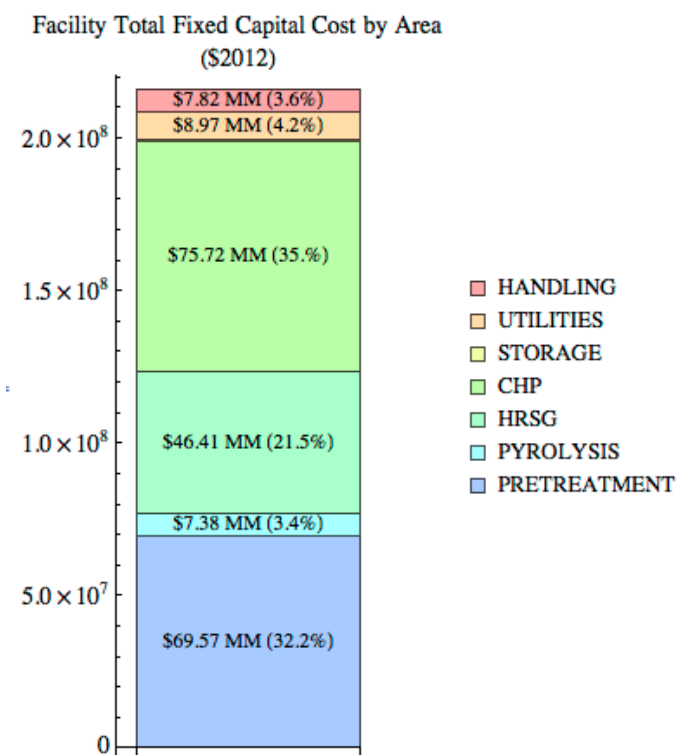


Fig. 13. Corn stover fast pyrolysis and bio-oil co-firing fuel power production fixed capital costs by process area

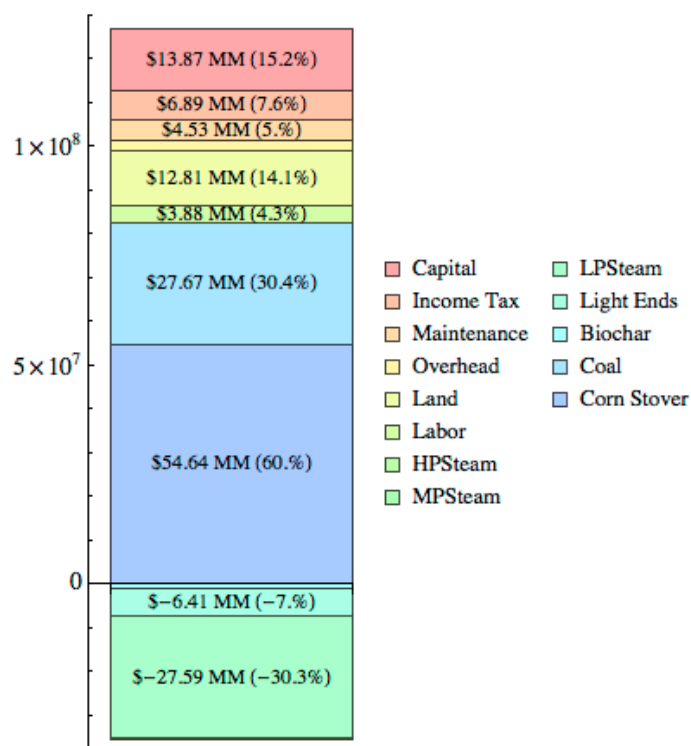


Fig. 14 Corn stover fast pyrolysis and bio-oil co-firing fuel power production operating costs

Table 17. Life cycle well-to-pump greenhouse gas emissions of several utility boiler power production pathways per mmbtuz of electricity generated

	Farmed Trees	Forest Residue	Herbaceous	Coal	Coal + Corn Stover
VOC	34.985 g	48.197 g	46.326 g	27.821 g	36.577 g
CO	424.022 g	1.410 kg	425.720 g	42.255 g	48.736 g
NOx	627.843 g	652.859 g	644.204 g	473.486 g	129.252 g
PM10	71.934 g	782.189 g	71.685 g	585.715 g	623.757 g
PM2.5	37.541 g	706.941 g	36.915 g	171.431 g	158.996 g
Sox	11.071 g	6.883 g	12.603 g	1.256 kg	80.250 g
CH4	43.789 g	188.736 g	84.463 g	463.367 g	568.287 g
N2O	61.646 g	22.601 g	111.327 g	5.236 g	14.206 g
CO2	12.633 kg	683.743 kg	14.764 kg	315.238 kg	33.876 kg
CO2Biogenic	-526.018 kg	-667.712 kg	-492.411 kg	-11.804 g	-31.565 kg
CO2 Land Use Change	0.000 g	0.000 g	0.000 g	0.000 g	0.000 g
CO2 Fertilizer	0.000 g	0.000 g	0.000 g	0.000 g	0.000 g
Greenhouse Gas	-506.553 kg	-656.259 kg	-457.124 kg	13.133 kg	-13.124 kg

3. Explanation of Variance.

No variance has been experienced and accomplishments are on schedule.

4. Plans for Next Quarter.

- Carry out experimental analysis to obtain the optimum method to be used in mild catalytic pyrolysis systems. Develop a plan and carry out catalyst screening experiments.
- Conduct technoeconomic analyses of additional fast pyrolysis scenarios.

5. Publications, Presentations, and Proposals Submitted

None to report this period.

Sub-objective 2. Prepare and characterize biochar

1. Planned Activities.

- Revise the Boehm titration manuscript to address the reviewer comments and return the manuscript to the *Journal of Environmental Quality* for a final decision on publication.

- Data analysis and interpretation for a biochar characterization manuscript. Conduct additional X-ray diffraction and FTIR analyses to complete the data set needed for the characterization manuscript. Prepare a first draft of the biochar characterization manuscript.

2. Actual Accomplishments

- We submitted revisions and responses to the reviewer comments for the Bohem titration paper to the associate editor of the *Journal of Environmental Quality* and the manuscript has been formally accepted for publication. We received, reviewed and returned proofs of the paper to the editor. The manuscript should appear as an on-line publication shortly.
- We prepared a first draft of the biochar characterization paper. The manuscript's focus is on quantifying anion exchange capacity of biochars and identifying the surface functional groups that are responsible for causing AEC of biochars. The following is a synopsis of the data and an analysis which leads us to conclude that the biochars contain oxonium cations which are primarily responsible for AEC.
- As shown in Figure 15, X-ray diffraction patterns of the alfalfa meal and corn stover biochars show evidence of inorganic phases even after treatment with 1 M HCl for 24 hr and 0.1 M HCl + 0.3 M HF for 36 hr. The results suggest that some inorganic phases are occluded within the organic C matrix of these biochars. X-ray diffraction analysis of the cellulose biochar, however, showed no sign of inorganic phases, which is consistent with the chemical analysis, which showed only trace levels of inorganic elements in the cellulose biochar. Because the cellulose biochar contains negligible levels of inorganic material it is appropriate to assume that all of the O in the biochar sample is associated with the organic C phase. The results in Table 18 show significant levels of O in the cellulose and amino acid biochars which is assumed to be structural.

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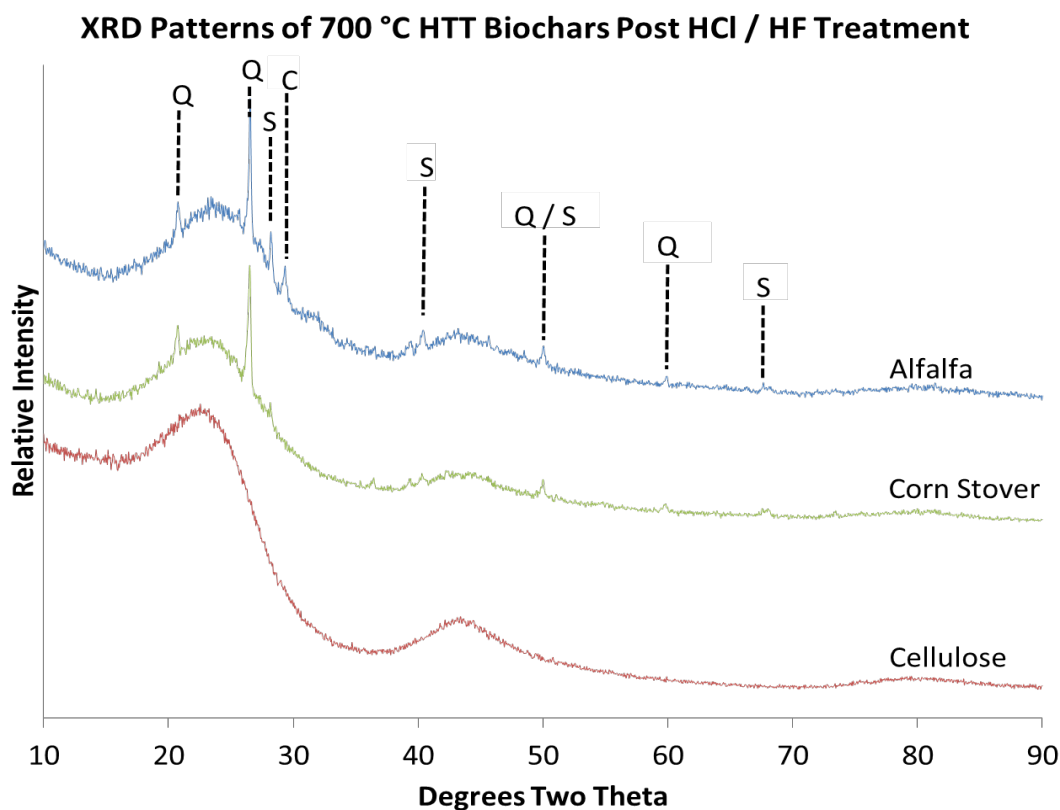
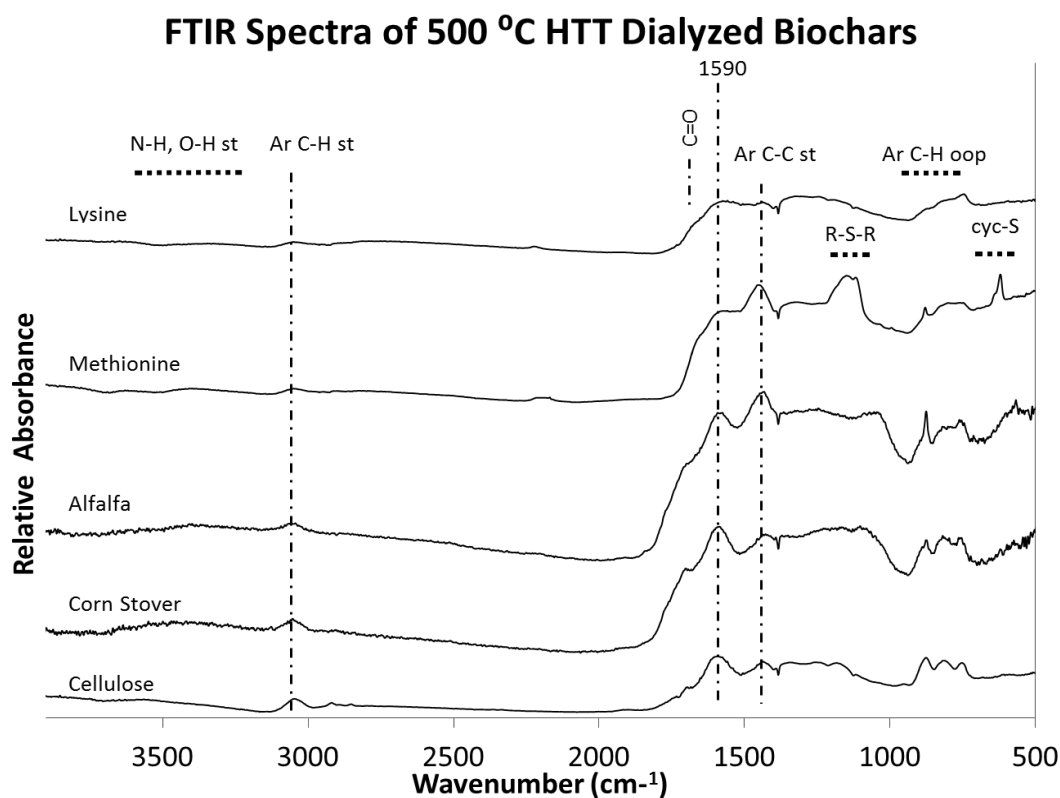


Table 18. Chemical analysis and physical properties of biochars prepared from alfalfa meal, cellulose, corn stover, and reagent grade lysine and methionine at two different temperatures 500 and 700°C

Feedstock	HTT (°C)	Yield (%)	Element Content (%)					pH	Ash (%)	Bet-N ₂ (m ² /g)	Particle Density (g/m ³)
			C	N	H	S	O				
Alfalfa	500	29.8	66.03	3.40	2.43	0.18	**	10.0	28.84	30	30
Alfalfa	700	29.0	68.80	3.23	1.45	0.25	**	10.0	30.89	176	176
Cellulose	500	27.9	84.80	0.00	2.98	0.08	10.82	8.3	0.87	321	321
Cellulose	700	26.0	90.30	0.01	1.72	0.12	6.12	8.6	0.92	229	229
Corn Stover	500	31.5	75.45	1.48	2.67	0.08	**	10.1	20.03	150	150
Corn Stover	700	29.8	77.54	1.23	1.48	0.13	**	10.2	21.93	259	259
Lysine	500	*	80.17	12.63	3.13	0.06	4.01	*	*	*	*
Lysine	700	*	82.32	12.17	1.37	0.18	3.95	*	*	*	*
Methionine	500	*	72.63	12.10	3.01	0.62	11.63	*	*	*	*
Methionine	700	*	61.08	8.56	1.44	4.72	24.20	*	*	*	*

- FTIR analysis of the prepared biochars (Figure 16) showed small adsorption bands for hydroxyl and carbonyl functional group. These peaks are too small to account for the levels of O found in the cellulose, lysine, and methionine biochars (Table 4). Thus we conclude that a significant amount of the O must be present in the form of O-heterocycles. The FTIR analysis shows a strong adsorption band at 1590 cm^{-1} , which we have identified as C-O stretching band for O-heterocycles.
- Anion exchange capacity of the studied biochars (Table 19) varied from 0.602 to $27.76\text{ cmol kg}^{-1}$. The AEC generally increased with decreasing pH and increased with pyrolysis temperature.



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Table 19. Life cycle well-to-pump greenhouse gas emissions of several utility boiler power production pathways per mmbtu of electricity generated

Feedstock	HTT (°C)	pH 4 (cmol kg ⁻¹)	pH 6 (cmol kg ⁻¹)	pH 8 (cmol kg ⁻¹)
Alfalfa	500	10.88 (2.461)	3.095 (0.279)	0.938 (0.338)
Alfalfa	700	25.85 (4.083)	9.64 (1.075)	2.15 (0.871)
Cellulose	500	7.84 (1.938)	2.63 (0.211)	0.602 (0.372)
Cellulose	700	24.23 (5.944)	18.07 (8.656)	4.11 (0.182)
Corn Stover	500	17.51 (5.808)	3.77 (0.658)	1.05 (0.206)
Corn Stover	700	27.76 (9.098)	13.82 (4.225)	7.19 (1.39)

- Based on the above evidence we conclude that AEC in biochars is primarily due to oxonium functional groups which are formed during pyrolysis and that the surface density of oxonium functional groups increases with the peak pyrolysis temperature.
- This research adds to basic understanding of biochar surface chemistry and how feedstock type and pyrolysis temperature influence biochar surface chemistry. The research also suggests that it may be possible to optimize pyrolysis conditions to generate high AEC biochars which would add value to biochar due to the increased ability to retain anionic nutrients such as nitrate and phosphate.

3. Explanation of Variance.

No variance has been experienced and accomplishments are on schedule.

4. Plans for Next Quarter.

We will begin work on preparing a manuscript documenting the stability of biochar AEC with a harsh oxidizing environment. Additional chemical and spectroscopic analysis will be conducted as needed to complete this paper.

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 anticipated a total of four activities for the second quarter of the project's third year.

- **Planned Activity A.** Administer the *Adoption of Switchgrass Production Survey* at the 2013 ICM Conference at ISU (Jacobs).
- **Planned Activity B.** Continue to interact with industry on an ISU *Bioeconomy Institute* (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).
- **Planned 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.
- **Planned Activity D.** Construct the budgeting analysis of threshold returns necessary to make biomass production feasible under various yield regimes and land use alternatives (Perrin).

2. Actual Accomplishments

- **Planned Activity A.** CenUSA project information was presented at this year's Integrated Crop Management Conference at Iowa State University by Drs. Keri Jacobs and Chad Hart. The presentation was an update on the project and associated economics and we followed by administering the survey.
- **Planned Activity B.** ongoing
- **Planned Activity C.** ongoing
- **Planned Activity D.** Ongoing

- **Added Activity.** Dermot Hayes has initiated a project to study the transportation economics of CRP when the filter strips and grassy plantings are harvested for biomass.

3. Explanation of Variance

Hayes undertook a related research project. This was not part of the planned work of the objective, but the outcome will be relevant and useful to our project

4. Plans for Next Quarter

During quarter 3 of year 3 (Q3 Y3), our team will work toward the following:

- Prepare and finalize report of the survey results.
- All other planned activities will continue.

5. Publications, Presentations, and Proposals Submitted

- Jacobs, K. (2014, February 28). *Competition for land use: Why would the rational producer grow switchgrass for biofuel?* Presentation for the CenUSA Graduate Seminar.
- Jacobs, K. (2013, December 4 – 5). Perennial grasses for bioenergy in the central United States: Updates on economics and research progress.” Presented at the Integrated Crop Management Conference, Ames, Iowa.
- Kauffman, N. & Hayes, D.J. (2013) The Trade-off Between Bioenergy and Emissions With Land Constraints. *Energy Policy* 54, 300-310.
- Kauffman, N., Dumortier, J., Hayes, D.J., Brown, R.C. & Laird, D.A. Producing energy while sequestering carbon? The relationship between biochar and agricultural productivity. Forthcoming in Biomass and Bioenergy.
- Perrin, R. (2014, February 19). *Switchgrass Economics in the North Central Region of the USA*. Presentation for the CenUSA Webinar.
- Elobeid, A., Carriquiry, M., Dumortier, J., Rosas, F., Mulik, K., Fabiosa, J.F., Hayes, D.J. & Babcock, B.A. (2013). Biofuel Expansion, Fertilizer Use, and GHG Emissions: Unintended Consequences of Mitigation Policies. *Economics Research International*.

OBJECTIVE 7. 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.

1. Task 1 – Managing Risks in Producing Feedstocks

a. Planned Activities

The hierarchy of various subheadings will be reexamined for major tasks associated with the establishment of biofeedstocks. The major headings main tasks are:

- Establishment (with seed bed preparation, weed control and planting);
- Maintaining (weed control);
- Harvest;
- On-site processing and storage (stacking);
- Transportation, which will be expanded with additional action details necessary for evaluation; and
- Begin the assessment of the three risk assessment tools applied to establishment of biofeedstocks would begin.

b. Actual Accomplishments

Refining the listing of tasks/responsibilities for biofeedstock production was ongoing. Actions, the lowest level where potential risks are discernible, were connected with important details like equipment type, horsepower, etc. that are critical elements needed for assessing risk. Both the details associated with actions and the actions were expanded.

The risk assessments tools of *Frequency/Severity Analysis*, *Deviation Analysis*, and *Fault Tree Analysis* have been evaluated for the ease of application to the various actions for the biofeedstock production. The criteria rubric to assess the success of the different risk assessment tools has started.

The team continued to reinforce the cooperative arrangement with the investigator at Penn State University by collaborating on a paper for the *Biomass Journal*.

c. Explanation of Variance

None to report.

d. Plans for Next Quarter

The three-risk assessment tools evaluation will continue and the criteria rubric will be tested and reevaluated. Additional detail necessary for analysis in the other major categories of: Maintaining (weed control); Harvest; On-site processing and storage (stacking); and Transportation will take place.

e. Publications, Presentations, and Proposals Submitted

Schaefer, D. H., Yoder, A.M., Murphy, D.J., Schwab, C. V. & A. F. Dehart, A.F. (2014). Safety and Health Hazards in On-Farm Biomass Production & Processing. Manuscript developed for submission to the Biomass Journal. (Pending submission).

Presentation to the Biomass and Biofuels session of the 2013 North American Agricultural Safety Summit. (2013, September 25-27). Agricultural safety & Health Council of America. Minneapolis MN on.

2. Task 2 – Assessing Primary Dust Exposure

a. Planned Activities

Data for priority or first few sample sites will be narrowed down from the potential field operations. Those locations for dust exposures will be compiled and reviewed.

Appropriate monitoring equipment will be investigated for the pilot study. Approvals for human subjects and procedures will have begun.

b. Actual Accomplishments

Primary locations for dust exposure measurement have been identified in the seedbed preparation, harvesting operations, and transporting materials. Literature review indicates very little published research on respirable dust in agricultural operations, however it clearly indicates that seedbed preparation and harvesting operations are the most likely to have respirable dust exposures. The *2013 North American Agricultural Safety Summit* provided new data that would also suggest that transportation of biofeedstock was also a location of interest.

The identification of the monitoring equipment, a 10-mm nylon cyclone and 5 um PVC filter to an air-sampling pump running at 1.7 L/min, was being prepared for purchase. Actual purchase of equipment was delayed, but will begin shortly.

The exact details of the potential subjects and plot locations were not finalized at the time of this report and the human subject detailed final study needs a new approval for changes in the new area being evaluated.

c. Explanation of Variance

No variance has been experienced and accomplishments are on schedule.

d. Plans for Next Quarter

Seek new approval for modifications to the human subjects study to include the transportation location and potential subjects. Purchase the air sampling equipment and begin data collection for first few sample sites during field operations seedbed preparation.

e. Publications, Presentations, and Proposals Submitted

A poster on identification of potential sources for dust exposures of farmers engaged in biomass production was presented at the CENUSA meeting of principle investigators at West Lafayette, Indiana.

OUTREACH AND EXTENSION

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**

Rerecord portions of the Camtasia lectures that need to be revised (Nicole Widmar).

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

Submit for internal review (Nicole Widmar).

- **Module 9. Enterprise budget**

Identify a lead author to evaluate current content and begin module development activities with Amy Kohmetscher.

- **Module 10.** Title to be determined – initial feedstock development module (Authors Na, Vavala and Guretzky).

Complete outline of module content and begin module development activities with Amy Kohmetscher.

- **Evaluation tasks**

- ✓ Analyses of evaluation data sets from UNL and Purdue have been completed (Gwen Nugent).
- ✓ Complete evaluation of content delivered to students at UNL and UIUC (Gwen Nugent).

2. Actual Accomplishments

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

Revisions are being made to content and lectures edited based on internal reviewer comments (Nicole Widmar).

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

Submitted for internal review of draft module (Nicole Widmar).

- **Module 9. Enterprise Budget**

Authors at Iowa State University have been identified to assist with reviewing existing content and developing new content for the module.

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

Completed module rough draft.

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

Completed module rough draft (authors Kohmetscher, Na and Guretzky).

- **Module 12. Perennial Grass Seed: Protection, Certification and Production** (authors Na and Guretzky)

Completed module rough draft (authors Kohmetscher, Na and Guretzky).

- **Evaluation tasks**

Completed initial data analysis of evaluation data sets from Purdue, University of Nebraska, Lincoln and University of Illinois, Champaign.

3. Explanation of Variance

None to report.

4. Plans for Next Quarter

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

Complete all revisions and make module publicly available.

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

Complete internal review and, if needed, begin making revisions.

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

Complete all revisions and make module publicly available.

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

Complete preliminary internal review, make necessary revisions and submit for internal project review.

- **Module 9. Enterprise Budget**

Complete preliminary draft of module content and begin module development activities with Amy Kohmetscher.

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

Complete preliminary draft of module content and begin module development activities with Amy Kohmetscher.

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

Complete module development activities and submit for internal review.

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

Complete module development activities and submit for internal review.

- **Evaluation Tasks**

Complete analysis of existing data sets

5. Publications, Presentations, and Proposals Submitted

None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. Planned Activities

- Finish solicitation of projects from faculty.
- Determine distribution of students to sites (number of slots for each participating lab).
- Review program assessment provided by Iowa State University's *Research Institute for Studies in Education* (RISE).
- Promote the undergraduate internship program and encourage application submissions, working with lists of underrepresented minority students generated by ISU graduate college, through job-posting boards at regional institutions, and by communication with Agronomy and Engineering department chairs at partner institutions.
- Migrate program website to primary CenUSA Bioenergy host, rather than independent site (Iowa State University's Agricultural and Biosystems Engineering Department's website) used for the program years of 2012 and 2013.

2. Actual Accomplishments

- Obtained research project descriptions from faculty members. In addition to promotion of research project opportunities from Objectives 1-7 as we have in 2012 and 2013, this year we added new projects from the Outreach and Extension Objective (Objective 9). These new extension and outreach projects focus on the development of a bioenergy/agricultural production instructional game for students.

- Promoted the undergraduate internship program to encourage application submissions as detailed above.
- Created a detailed schedule for the 2014 undergraduate internship program.
- Website content for the undergraduate internship program was successfully migrated to the CenUSA host website from the Agricultural and Biosystems Engineering site (this site location was used for the 2012 and 2013 programs).
- Applications are being accepted and inquiries regarding the program and application process are being answered.
- Secured on-campus housing for students who will be hosted by Iowa State faculty.

3. Explanation of Variance

None to report.

4. Plans for Next Quarter

- Continue to promote the undergraduate internship program and encourage application submissions through the March 9, 2014 application deadline.
- Centrally vet and rank applications based on the letters of interest, academic achievement, previous research experience, and letters of recommendation.
- Pool of likely candidates will be given to faculty hosts for review during the week of March 17, 2014 with selections and rankings of students requested from faculty by March 24, 2014.
- Highly ranked students, as indicated by faculty hosts, will be interviewed by telephone the week of March 24 and March 31, 2014.
- First offers to students beginning March 31, second offers to students beginning April 7 with cohort (14 students) finalized on April 15, 2014.
- Arrange travel for accepted students.
- Secure housing for students who will be placed with faculty mentors at partner institutions.

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 Quarter

N/A

5. Publications, Presentations, and Proposals Submitted

None to report this period

Subtask 2C –Subtask 2C – Training Graduate Students via Monthly Research Webinar**1. Planned Activities**

Organize and deliver research webinar for the Markets and Distribution Objective (Objective 6).

2. Actual Accomplishments

We did not host any graduate research webinars during this time quarter.

3. Explanation of Variance

We did not host a research seminar during December because of the semester and holiday break academic schedule. Also, due to the CenUSA Co-Project center-wide meeting held January 28-29, 2014 the graduate research webinar for the Markets and Distribution Objective was postponed until February 28, 2014.

4. Plans for Next Quarter

- Organize and deliver research webinars
 - ✓ February 28, 2014 – Objective 6: Markets and Distribution
 - ✓ March 29, 2014 – Objective 7: Health and Safety

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 will focus 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

a. Planned Activities

- ✓ Finish the entomology video.
- ✓ Produce first cut of the plant pathology video.
- ✓ Organize webinars for February and March of 2014.
- ✓ Prepare Fact Sheet: *Reducing Hypoxia in the Gulf: An Alternative Approach* (short version of longer paper for extension and outreach audience).
- ✓ Continue assistance with planning for *National Extension, Energy and Environment Conference (E3 Conference)*, which will be held September 23-25, 2014.
- ✓ Prepare plan for expanded outreach and communication using social media channels.
- ✓ Launch monthly e-newsletter.
- ✓ Publish noted articles that are nearing completion.
- ✓ Continue maintenance of index: *Resources from CenUSA – Sustainable Production and Distribution of Bioenergy for Central USA*.
- ✓ Setup eXtension Ask an Expert system to answer questions on CenUSA topics.
- ✓ Begin development of an *Economics of Bioenergy Grasses* Fact Sheet.

b. Actual Accomplishments

- ✓ The number of people reached this quarter was 3629 (Vimeo – 109, YouTube = 865, Facebook = 597). 2903 of the contacts were men; 726 of the contacts were women.
- ✓ **Continuing Impact of the CenUSA Vimeo Channel.** During this quarter, the 30 CenUSA videos archived on CenUSA's Vimeo site (<https://vimeo.com/cenusabioenergy>) have had 109 plays, or users who viewed a video on our Vimeo site, or on a web site that embedded a CenUSA video. The 30 videos also had 1,042 loads, 777 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 39 times. Vimeo videos were downloaded 6 times. This means that video was saved to the user's hard drive (users typically 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 the home computer to watch at their convenience.
- ✓ **Continuing Impact of YouTube Channel.** CenUSA videos are also posted on CenUSA's YouTube channel (<https://www.youtube.com/user/CenusaBioenergy>), and those videos have been viewed 865 times between November 1, 2013 and January 31, 2014. 503 views were from the United States. Demographic analytics indicate an 80% male and 20% female audience. 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: 35-44 years (20%), 45-54 years (36%), and 55-64 years (44%). The remaining 362 views do not have demographic associated with them.
 - YouTube also provides data related to how users access the videos. 94.6% of the videos were viewed on their associated YouTube watch page (each video has a unique "watch page"). Views from mobile apps or from direct traffic (links in an e-mail or copying/pasting the direct URL) account for 28% of video views. Finally, referrals from outside YouTube (Google search or access through external web sites) account for 9.3% of video views.
- ✓ **CenUSA web site, Facebook and Twitter.** In January, with the help of Anne Kinzel, the Communications Team was created to manage an e-newsletter (BLADES), the CenUSA web site, Facebook, Twitter, Vimeo, YouTube and other communications and press outlets. The team consists of Anne Kinzel, Pam Porter, Amy Kohmetscher, Charles O'Brien and Kristin Peterson. Charles and Kristin are undergraduate interns from the Iowa State University Greenlee School of Journalism will focus on social media (Facebook and Twitter), newsletter stories, and other communications tasks as assigned. The goal of the communications team is to expand CenUSA outreach using social media and other communications outlets.

- The CenUSA web site had 1,123 visitors this quarter; 573 of those were in January after the Communications Team launched. This demonstrates that the formation of a Communications team is having a positive effect.
- CenUSA Twitter traffic consists of followers who subscribe to our account (@CenUSABionergy) and “follow” our tweets (announcements). Followers can “favorite” a tweet, or “retweet” it to share with their own followers. They can also “mention” CenUSA by tagging CenUSA’s twitter account in their own tweets. CenUSA currently has 244 followers, up from 225 prior to the creation of the Communications Team.

Table 20. CenUSA Social Media – Twitter Interactions

Twitter	Retweets	Favorites	Mentions	Followers
	67	12	18	244

- The CenUSA Bioenergy Facebook page had only 7 likes and little to no reach prior to the creation of the Communications Team in January 2014. By the end of January, CenUSA’s Facebook page had 93 likes. After current posts were made in the beginning of January, our total reach spiked to a high of 681 individuals. On January 26, 2014 our Facebook page had a record 100 visits. Our highest engagement this quarter resulted in 184 engagements for a single posted sharing of Flickr photos via Facebook. It is also important to note that Facebook user traffic was so low on our page that the Facebook analytics program did not track our page statistics until the Communications Team began to work to improve the page outreach in January 2014.
- ✓ Google Analytics for CenUSA articles/fact sheets on the eXtension Farm Energy Site:
 - CenUSA articles/fact sheets received 896 page views by 597 unique visitors, 78% of them new visits, averaging 1.4 pages per visit. The bounce rate is 81% and average time on page is 3:37 minutes.
 - Traffic sources are 69% search engines, 20% direct traffic and 11% referring sites.
 - The top 10 states accessing CenUSA articles were Michigan, Minnesota, Wisconsin, New York, Illinois, Texas, Iowa, California, North Carolina, and Nebraska; with use from throughout the US and world.

- ✓ Facilitated meetings with extension representatives from all Bioenergy CAPs. The plan is to meet monthly on topics of mutual interest:
 - "Communicating effective and realistic bioenergy messages through extension"- December 17, 2013.
 - "Providing feedback on each other's publications" - January 21, 2014.
- ✓ Posted CenUSA videos posted on the eXtension Farm Energy Media Archive (farmenergymedia.extension.org).
- ✓ Posted CenUSA events on eXtension Farm Energy Facebook, CenUSA Twitter account and eXtension Learning Community.
- ✓ Began development of an Economics of Bioenergy fact sheet with Richard Perrin, based on material he presented in February 19, 2014 webinar.
- ✓ The entomology video editing was finished and we are waiting for a final copy with grant information and acknowledgements added to the video. The plant pathology video is still in the editing and production process.
- ✓ We scheduled and marketed a CenUSA webinar for February 19, 2014 featuring CenUSA collaborator Richard Perrin's research on the costs of producing switchgrass.
- ✓ We published two fact sheets this quarter:
 - *Growing Switchgrass for Biofuels* (retitled) by Rob Mitchell, Ken Vogel and Marty Schmer.
 - *Switchgrass Stand Establishment Key factors for Success* by Rob Mitchell and Susan Harlow.
- ✓ The paper: "Reducing Hypoxia in the Gulf, An Alternative Approach" is still in final review.
- ✓ We completed and published to Vimeo and YouTube the video: *Enhancing the Mississippi Watershed with Perennial Bioenergy Crops* (Note: the name changed from "Reducing Hypoxia in the Gulf: An Alternative Approach") see: http://www.youtube.com/watch?v=87UHZn73Yj4&list=UU3vEk1qHeHfk27D06H2L_QA and <http://vimeo.com/84352256>
- ✓ We completed the plan for expanded outreach and communication using social media channels (Facebook, Twitter, Vimeo, You Tube, Flickr and the BLADES newsletter).

Two Iowa State University undergraduate interns were hired to assist in communication and outreach efforts. We began production of new CenUSA newsletter “BLADES” that will be sent bimonthly to a dedicated contacts list using the Constant Contact platform. The initial list is 471, but is anticipated to grow significantly beyond this number.

- ✓ We continued providing assistance with planning for *National Extension, Energy and Environment Conference* to be held September 23-25, 2014.
- ✓ We maintained a published index: *Resources from CenUSA - Sustainable Production and Distribution of Bioenergy for the Central USA* (<http://www.extension.org/pages/68136>) which includes recently published CenUSA resources hosted on eXtension.org, and the CenUSA site, and others. Social media and newsletter links are now available on this page as well.
- ✓ We setup an eXtension “Ask an Expert” system to answer the publics’ questions on CenUSA topics including bioenergy from perennial grasses, thermochemical process, pyrolysis, biochar, and switchgrass, etc. Our ask form can be shared with the public: <https://ask.extension.org/groups/1848/ask>. CenUSA’s webmaster will post the “Ask Widget” on the CenUSA site in March 2014.
- ✓ Google Analytics for CenUSA articles/fact sheets on eXtension Farm Energy Site:
 - We received 896 page views by 597 unique visitors, 78% of the views were new visits, averaging 1.4 pages per visit. The bounce rate is 81% and average time on page is 3:37 minutes.
 - Traffic sources are 69% search engines, 20% direct traffic and 11% referring sites.
 - The top 10 states accessing CenUSA articles were Michigan, Minnesota, Wisconsin, New York, Illinois, Texas, Iowa, California, North Carolina, and Nebraska. There are also visitors from throughout the US and world.
- ✓ We facilitated meetings with extension representatives from all of the Bioenergy CAPs. The plan is to meet monthly on topics of mutual interest:
 - "Communicating effective/realistic bioenergy messages through extension" (December 17, 2013).
 - “Providing feedback on each other's publications” (January 21, 2014).

- ✓ CenUSA videos were posted on the eXtension Farm Energy Media Archive – farmenergymedia.extension.org.
- ✓ We posted CenUSA events on eXtension Farm Energy Facebook, Twitter and eXtension Learn.
- ✓ We began development of an *Economics of Bioenergy* fact sheet with Richard Perrin, based on material he presented in February 19, 2014 webinar.

c. Explanation of Variance

- ✓ The entomology video was delayed because the video expert picked up more contracts, delaying the finishing touches to our video. The video editing process is complete, and we are waiting for appropriate acknowledgements and grant information to be added to the webinar. The additional contracts added by our video expert have also delayed the plant pathology related video.
- ✓ We decided to postpone the production of *Reducing Hypoxia in the Gulf: An Alternative Approach* until April. – Publication development is still in process for *Storage of Two Perennial Grasses as Biomass Feedstocks*.

d. Plans for Next Quarter.

- ✓ Finish entomology video and the plant pathology video.
- ✓ Host two webinars related to economics topics.
- ✓ Finish paper “Reducing Hypoxia in the Gulf: An Alternative Approach.”
- ✓ Prepare Fact Sheet: Commercialization Opportunities of Biochar.
- ✓ Continue assistance with planning for National Extension, Energy and Environment Conference, September 23-25, 2014.
- ✓ Prepare February e-newsletter, begin production of April e-newsletter and continue expansion of social media channels.
- ✓ Develop eXtension BIO pages for CenUSA collaborators. These pages will rotate with others’ bios on the <http://www.extension.org/>, and the eXtension Farm Energy Home Page: http://www.extension.org/ag_energy.
- ✓ Develop publications(s) on:
 - *Economics of Switchgrass*, authored by Richard Perrin, University of Nebraska, Lincoln.

- Biochar research.
- ✓ Publish fact sheet: *Storage of two Perennial Grasses as Biomass Feedstocks* by Kevin Shinnars, University of Wisconsin, Madison.
- ✓ Continue maintenance of index: **Resources from CenUSA – Sustainable Production and Distribution of Bioenergy for the Central USA**, to include All CenUSA resources.
- ✓ Facilitate monthly Bioenergy CAPS extension calls, and represent CenUSA.
- ✓ Use eXtension Farm Energy Social Media sites to broadcast information from CenUSA.

e. Publications, Presentations, Proposals Submitted

- ✓ Peer reviewed publications on eXtension. The publications are linked to the “Resources from CenUSA” page at <http://www.extension.org/pages/68136/>.
 - “Plant Breeders Create New and Better Switchgrass Varieties for Biofuels” (Casler and Harlow).
 - “Research Summary: Research Finds Strong Genetic Diversity Switchgrass Gene Pools” (Casler and Harlow).
 - “Control Weeds in Switchgrass (*Panicum Virgatum* L.) Grown for Biomass” (Rob Mitchell).
 - “How to Successfully Harvest Switchgrass Grown for Biofuel” (Shinnars and Porter).

2. Producer Research Plots/Perennial Grass Team

a. Planned Activities

- ✓ Indiana: Collect samples, dry and grind samples, determine fate of plot at FFA Leadership Center, plan for IN FFA Center Exhibit, host round-table conference call with High School Ag Science Teachers and Extension Educators to build awareness of the IN FFA Center plot.
- ✓ Iowa: Harvest demonstration plots for yield samples and host education seminars for producers and industry leaders.
- ✓ Minnesota: Harvest demonstration plots, hand-sample biomass and do visual observations.

- ✓ Nebraska: harvest Humboldt site (large round bales).

b. Actual Accomplishments

- ✓ Indiana

- We did sampling at the Sweeten Farm in November 2013, and the samples were dried and ground.
- We made determination to keep the Indiana FFA Leadership Center plot and reseed the Pflug farm plot.
- We continued development of IN FFA Center Exhibit.
- We held a round-table conference call with 40 High School Ag Science Teachers and Extension Educators to build awareness of the Indiana FFA Center plot.

- ✓ Iowa.

- We harvested the demonstration plots on November 8, 2013 and collected yield samples.
- We hosted five seminars for a total of 753 agricultural industry leaders and producers. Participants were asked to complete pre/post knowledge self-rankings about the topics taught by Mitchell, Birrell, Heaton, Euken/Muth to assess learning that took place in the sessions. Participants in the session led by Jacobs participated in a survey to evaluate their attitudes about switching land to production of perennial grass production. Responses to all of the evaluations/surveys is underway and will be available for reporting in the next quarterly report. Sessions are listed below:
 - *Establishing and managing perennial grasses for bioenergy* (Rob Mitchell, 89 attendees).
 - *Biomass feedstock supply logistics for corn stover, perennial grasses* (Stuart Birrell, 135 attendees).
 - *Producing food, feed and energy: How can agriculture do it all* (Emily Heaton, 181 attendees).
 - *Perennial grasses for bioenergy in central US: economics, research and progress* (Kerri Jacobs, 143 attendees).
 - *Integrated agricultural landscapes for profit and risk management* (Jill Euken and David Muth, 205 attendees).

✓ **Minnesota**

- We harvested the Elko plot on November 1, 2013. We took hand-samples taken and *completed* visual observations. The team was not able to complete full harvest/baling of the plot because their contract harvester was too busy. Therefore, the team will burn the dead standing biomass early in the spring.
- Brian Prchal, a high school student being mentored by the Minnesota Extension team participated in the Elko evaluation in the fall. Brian did a study of polyculture biomass as a function of N fertilization with biosolids and presented his results at the science fair in January. Brian's parents own a farm and are also interested in the project.
- We harvested and sampled the Lamberton plot on November 12, 2013. The team was able to cut the field so no burning will be needed in the spring.

✓ **Nebraska.**

- We baled biomass at the Humboldt site.
- We took visual observations and samples at the Humboldt site, the Ben and Paula Sue Steffen site, and the Blane Steckly site.

c. Explanation of Variance

Minnesota: We were unable to cut/bale Elko plot, but able to do sampling and visual observations. No other sites experienced any variance from planned activities.

d. Plans for Next Quarter

✓ **Indiana**

We will:

- Host a CenUSA exhibit at the Indiana Small Farm Conference;
- Participate in the Indiana Biomass Energy Working Group session;
- Remove 2013 residual growth at Sweeten and FFA Center;
- Reseed Pflug demonstration site, apply fertilizer and herbicides at demonstration sites, finalize; and
- Submit plans for the exhibit at the FFA Center, plan 2014 growing season tours at the demonstration sites.

✓ Iowa

We will:

- Hold teleconferences with other states on demo plot management for 2014;
- Apply N rate treatments to the demo plots; apply fertilizer; and
- Apply herbicides to control weeds as needed.

✓ Minnesota

We will:

- Burn the Elko plot;
- Apply fertilizer to both plots and apply herbicides if needed,
- Start planning for a July 19, 2014 field day.

✓ Nebraska

We will:

- Make land rental payment to cooperating farm operators;
- Assess stand establishment at the Milford site and general condition coming out of winter at both sites;
- Burn first year biomass growth at Milford site;
- Apply fertilizer treatments per protocol at both CenUSA sites and apply herbicides to control weeds as needed.

e. Publications, Presentations, Proposals Submitted

None.

3. Economics and Decision Tools**a. Minnesota**✓ **Planned Activities**

- Hold a workshop on Watershed Nitrogen Reduction Planning spreadsheet (NBMP.slxm).

- Hold five seminars for agricultural producers and ag industry leaders.

✓ **Actual Accomplishments**

Gave a seminar on the Watershed Nitrogen Reduction Planning spreadsheet (NBMP.slxm) to the U of MN Water Resource Center. The spreadsheet was downloaded 27 times over the quarter. Lazarus reorganized the N loading calculations in the spreadsheet and made other improvements. Work is continuing on a web-based crop budget calculator for biomass crops that will have links to a production record database and environmental models.

✓ **Explanation of Variance**

We did not experience any variance from our expected plans.

✓ **Plans for Next Quarter**

Continue work on the web budget calculator. Begin work on a phosphorus component or companion spreadsheet to the NBMP.xlsm spreadsheet.

✓ **Publications, Presentations, Proposals Submitted**

See spreadsheet model above.

4. Health and Safety

See Health and Safety Objective report, above.

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

a. Youth Development

✓ **Planned Activities**

- Indiana
 - Plan 4-H science workshops.
 - Complete career component for display; utilize display at 4-H/FFA event in December.
 - Host meetings with Ag Education teachers and Extension Educators to review curriculum and programming.
- Iowa

- Develop position descriptions for two CenUSA interns to work on computer app led by character “C6.” The learning game will focus on the carbon economy, as it would be viewed in an agriculture production setting. The game will include information on the science, economy, agricultural production, and social impacts relating to the biorenewables industry.
- Participate in the Cedar Valley STEM Festival in Waterloo on November 21st.

✓ **Actual Accomplishments**

○ Indiana

- 4-H Bioenergy Workshop planning is underway.
- Career component for display is in planning stages; quotes have been obtained to construct a portable display.
- Focus group meeting with ag teachers and extension staff has been scheduled.
- We are continuing development of online 4-H modules and curricula.
- We are continuing collaborative work on planning, creating and establishing demonstration plots on state FFA center grounds.
- Supplies and materials for spring, summer activities have been purchased.
- Quotes for displays and demo plot signs we have been re solicited.

○ Iowa

- CenUSA 4-H K-12 Outreach presented the biorenewable posters and C6 game at Cedar Valley STEM Festival held in Waterloo, Iowa on November 21st. More than 3400 people participated and the community was extremely positive about the new C6 and Biorenewables programming. We have mailed a post-event survey to all attendees that provided an email address. The results of the survey are pending.

✓ **Explanation of Variance**

○ Indiana

- A focus group meeting was “snowed out” in January 2014.

- Career development event where display was to be used was snowed out twice.
- One undergrad student assisting with work on online modules and curriculum graduated and the second is student teaching away from campus.
- Iowa: No variance has been experienced and accomplishments are on schedule.
- ✓ **Plans for Next Quarter**
 - Indiana
 - Continue work on display for careers, as well as demo plot educational materials and displays; target date for materials to be installed is May or June 2014.
 - Hire a new student to continue assisting with work on online modules.
 - Demo-test activities in classrooms in April and May 2014.
 - Planning for summer 4-H science workshops continues (to be held in June 2014).
 - Iowa
 - Continue development of C6 game and materials.
- ✓ **Publications, Presentations, Proposals Submitted**
 - Indiana
 - Abstract for presentation submitted to National Science Teachers (NSTA) meetings.

6. Broader Public Education/Master Gardener Program

a. Iowa

- ✓ **Planned Activities**
 - Meet with the Minnesota and Iowa CenUSA biochar Test Garden teams to:
 - Discuss communication team goals and updates
 - Give presentation at Iowa State University Department of Horticulture in-service on the CenUSA biochar project.

- Investigate establishment of an additional biochar test garden site in Iowa.
- Determine if there would be enough Master Gardener support to do the planting and data collection at the Northeastern Research site.

✓ **Actual Accomplishments**

- Held a meeting on December 13, 2013 at University of Minnesota with the Minnesota and Iowa CenUSA biochar Test Garden teams. Discussion focused on ways to improve communication. Data collection and updates were shared.
- Gave a presentation on January 6, 2014 on “Iowa Master Gardeners and the CenUSA Biochar Project.” 30 ISU staff (15 male and 15 female) from around the State of Iowa attended.
- Put out call to gage interest level of Buchanan County Master Gardeners to volunteer if a new test garden were to be established. There is not enough interest in this county for on-going data collection at this time.

✓ **Explanation of Variance**

None.

✓ **Plans for Next Quarter**

- Recruit Master Gardener volunteers for 2014 data collection at the three Iowa test plot sites.
- Continue to investigate interest in the possible establishment of an additional test site for Iowa.
- Obtain seeds for test plots and start them in the green house on campus.
- Speak on biochar project to the General Federation of Women’s Clubs state convention on April 25, 2014.

b. Minnesota

✓ **Planned Activities**

- Conduct soil tests from the three metro area demonstration garden sites.
- Develop the 2013 Biochar Demonstration Garden Report based on the data that was submitted by Extension Master Gardener volunteers.

- Complete the final design for more interpretive signage that will be used at the demonstration garden sites.

✓ **Actual Accomplishments**

- Soil tests were conducted at the three metro area demonstration garden sites (report attached as addendum).
- Design for interpretive signage is complete.
- Seeds were ordered for biochar garden sites.
- U of MN extension educator, Julie Weisenhorn, attended the Gichi Manidoo Giizis Pow Wow, January 11, 2014, at Black Bear Casino Resort, Carlton, Minnesota. The pow wow theme was “Taking care of the land and the community” and included info booths and displays of Tribal, State and Federal programs involved in taking care of the land and community. Weisenhorn exhibited banners and provided an information booth about the Fond du Lac Master Gardener program and their involvement in the CenUSA biochar study. Weisenhorn spoke with 55 people over the four hours. Many had not heard of biochar but were interested in hearing how it can benefit poor soils and that Fond du Lac Master Gardeners were involved in this national study.

✓ **Plans for Next Quarter**

- Give presentation to Hennepin County Extension Master Gardeners to include:
 - The CenUSA Research team overview,
 - Introduction to biochar
 - Information regarding the demonstration gardens in Minnesota; recruit EMG volunteers for demonstration gardens via avenues that reach all Twin Cities Metro Extension Master Gardener groups.
- Contract with grower to start demonstration garden seeds.
- Update applications, position descriptions and procedures for volunteers.
- Update garden design.
- Schedule demonstration garden leader team meeting in March 2014.
- Anoka County Extension Master Gardeners Home Landscaping and Garden Fair event on April 12. A non-staffed biochar exhibit to be put on display and a

presentation for the public about the project will be one of the concurrent sessions.

- Get results from Kurt Spokas regarding tissue tests made on select 2013 garden plants to determine effects from the biochar.
- Extension Master Gardener volunteers ran into difficulty establishing the demonstration garden at the Fond du Lac Tribal Community Center. In 2014, the garden will be moved due to logistical issues.
- Order more biochar from Royal Oak for new site at Fond du Lac Tribal Community Center.

✓ **Publications, Presentations, Proposals Submitted**

- Minnesota
 - 2013 Extension Master Gardener Biochar Demonstration Gardens Annual Report
 - Soil test results: Fall 2013
 - Signage graphics
 - Images from Pow Wow

7. Evaluation and Administration

• **Planned Activities**

- ✓ Participate in planning for the new CenUSA Commercialization objective.
- ✓ Conduct interviews of CenUSA Extension team members to determine how much carryover there will be in Extension accounts that could be redirected to the new objective.
- ✓ Assist CenUSA Extension staff with developing and analyzing survey instruments for CenUSA Extension programs.
- ✓ Participate in planning for the Year 4 reapplication.
- ✓ Work with Extension teams to conduct activities promised in CenUSA Extension plan of work
- ✓ Develop plans for new tasks recommended by CenUSA Advisory Board for Extension/Outreach for CenUSA:

- **Recommendation:** Expand/better utilize Extension Network;
 - **Recommendation:** Establish and share “values” for alternative uses of perennial grasses, starting with evaluating use of switchgrass as an animal feed;
Recommendation: Promote “quilt-like pattern” of grass/corn/soy on the landscape;
 - **Recommendation:** Summarize and share biochar results;
 - **Recommendation:** Summarize/share competing technologies/economics for biomass;
 - Form planning team to plan Extension Energy and Environment conference for September 23-25, 2014; formulate agenda, identify and recruit plenary speakers, tours and tour presenters; develop process for soliciting abstracts from Extension Educators working in the areas of energy and the environment.
- **Actual Accomplishments**
 - ✓ Developed plans to address recommendations for Extension/Outreach for CenUSA.
 - **Recommendation:** Expand/better utilize Extension Network; Activity to address: Conference for Extension Educators planned for September 23-25, 2014 (see: <http://www.2014e3.org/>).
 - **Recommendation:** Establish and share “values” for alternative uses of perennial grasses, starting with evaluating use of switchgrass as an animal feed; Activity to address: Beef feedlot feeding trial using CenUSA bioenergy switchgrass as roughage in the rations.
 - **Recommendation:** Promote “quilt-like pattern” of grass/corn/soy on the landscape; Activities to address: 1) continuation of program as planned; 2) add bioenergy grass demonstration at Vermeer Headquarters in Pella, IA to increase visibility of project.
 - **Recommendation:** Summarize and share biochar results; Activity to address: publications and videos summarizing what we know and what we don’t know about impact of biochar as a soil amendment.
 - **Recommendation:** Summarize/share competing technologies/economics for biomass; Activity to address: publication to provide short summary of different processes for advanced biofuels

- Recruited faculty and staff to support the new activities, developed plans of work and budgets for each new activity.
- Revised the evaluation factsheet “Asking the Right Demographic Questions” which was posted on the CenUSA site.
- Three survey analyses were done on the following educational and outreach events:
 - Biochar survey during the 2013 Minnesota State Fair.
 - Integrated Crop Management Conference survey on the adoption of switchgrass.
 - Integrated Crop Management Conference survey of establishing and managing perennial grasses for bioenergy.
- A small group met to discuss methods of surveying webinar participants. This venue of education has been especially difficult to measure as participants do not elect to readily complete online surveys thereby making it hard to show the level of increased knowledge for the webinar topic.
- A communications and marketing worksheet was developed by CenUSA members from Minnesota and Iowa to gather information from various social media so that we can develop a communication protocol that taps into social media to expand outreach for biochar education.
 - We worked on defining a “common language” and terminology around our blog postings for consistency and clarity, and how we want to promote the potential benefits of biochar, including cautionary statements; e.g. how should we refer to biochar sites ... as Demo gardens? Research plots? Trial gardens?
- Outline more clearly what CenUSA wants to say and how to say it, and develop a calendar/post frequency schedule, and a process for reviewing content.
- Three survey analyses were done on the following educational and outreach events:
 - Biochar survey during the 2013 Minnesota State Fair;
 - Integrated Crop Management Conference survey on the adoption of switchgrass; and

- Integrated Crop Management Conference survey of establishing and managing perennial grasses for bioenergy.
- We worked on defining a “common language” and terminology around our blog postings for consistency and clarity, and how we want to promote the potential benefits of biochar, including cautionary statements; e.g. how should we refer to biochar sites ... as Demo gardens? Research plots? Trial gardens?
- ✓ We outlined more clearly what CenUSA wants to say and how to say it, and started developing a calendar/post frequency schedule, and a process for reviewing content.
- **Explanation of Variance**

None
- **Plans for Next Quarter**
 - ✓ Continue planning for new tasks and deliverables.
 - ✓ Continue planning for E3 Conference.
 - ✓ Develop Extension section of CenUSA reapplication.
 - ✓ Develop budget for Extension components of Year 4 reapplication.
- **Publications, Presentations, Proposals Submitted**

None this quarter

Commercialization Summaries

Here are the summaries of the potential activities for our new Commercialization Objective (Obj. 10). These activities will be described to you in depth at our dinner meeting on January 28th. I have provided these summaries to you that you will be able to prepare for your charge during the “2014 and Beyond” sessions on Jan. 29th.

- **ADM**

Robert Brown Comment: The overall goal of this project is to evaluate the suitability of switchgrass for conversion to value-added products using the ADM acetic acid pulping process. Iowa State University will provide switchgrass to ADM for processing into cellulose pulp, lignin, and mixed streams of hemicellulose, lignin, acetate and salts. ISU will explore the fractionation/conversion of the mixed streams into additional value-added products such as furfural and acetic acid. ISU will also evaluate the pyrolytic conversion of lignin derived from the ADM process.

- **ADM - Tom Binder**

Project Title: Objective 10a - Recovery of high value products from ADM's biorefinery co-product streams

Lead Institution: Iowa State University

Partner Organizations: Archer Daniels Midland Company

Objective Leader: 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.

Objective Co-Leader: Xianglan Bai, Assistant Professor of Mechanical Engineering, Iowa State University, 515-294-7669, bxl9801@iastate.edu;

Start Date: April 1, 2014

Project Duration: 2.5 years

Executive Summary. The overall goal of this project is for ISU to collaborate with industry partner Archer Daniels Midland to assess the potential of fast pyrolysis and solvolysis as methods for production and capture of high value compounds from the acetate and sugar rich co-product streams from processes used to fractionate biomass into cellulose, hemicellulose and lignin streams. Additionally, conversion of lignin streams into higher value intermediates or end products will be explored. While

processes and composition of streams vary between companies, the product recovery techniques developed in this collaboration should be broadly applicable.

Figure 1 shows a flow diagram of a general biomass fractionation process. Archer Daniels Midland and several groups in Europe are developing similar variations of this process (Tom Binder, ADM). Conversion of ADM's lignin and acetate and sugar-rich streams into higher value intermediates or end products will be explored.

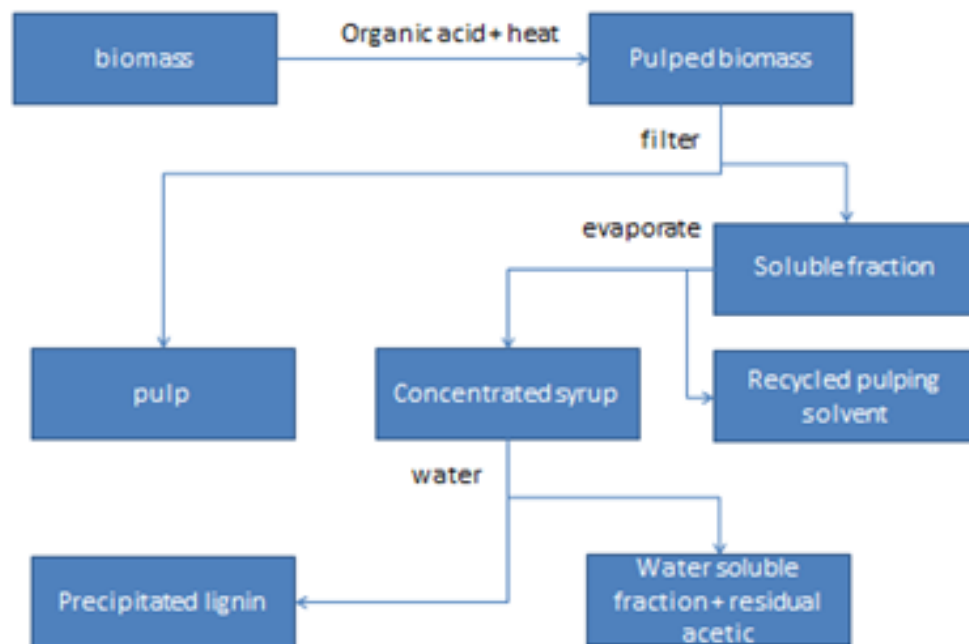


Figure 1. Biomass fractionation process

- **Renmatix - Frank Lipiecki**

Renmatix will explore the use of switchgrass as a feedstock in their Plantrose™ Process. The initial work will look into the chemical composition, physical properties and overall suitability. The next stage allow for first production of cellulosic sugars and lignin from switchgrass. Demonstration runs in the third task enable further optimization, reliability information, economic projections, and larger volumes of outputs for downstream testing and information.

- **Vermeer**

Advisory Board member Jan Van Roekel is working with the Extension and Outreach

Objective to establish energy crops on up to 30+ acres on a Vermeer family owned farm. The site is located on Gary Vermeer's home place, across the road from the Vermeer Global Pavilion, which Vermeer is currently building a children's learning center.

- **Rob Mitchell**

- **Project 1. Pelleting perennial feedstocks for bioenergy evaluations**

Recent scrutiny of the USDA-NIFA-CAP program requires us to evaluate novel approaches to demonstrate that the CenUSA Bioenergy CAP is a critical component of the emerging bioenergy industry. In response to this need for broad, tangible industry collaborations, ARS Lincoln plans to have a commercial pelleting facility make pellets from switchgrass, big bluestem, and low diversity prairie mixtures.

We plan to process twelve (12) big round bales each of three feedstocks (switchgrass, big bluestem, and a low diversity prairie mixture = 36 bales), evaluate the compositional characteristics of the pellets, compare the composition of baled and pelleted material, and bag the pellets in 50 lb bags. This will result in the production of 1.5-2 tons of pellets for each feedstock.

The bags of pellets of known composition can be distributed to people requesting feedstock in lieu of shipping bales or ground material. Additionally, we'll evaluate the feasibility of using biomass pellets to heat one of the buildings at the University of Nebraska Agricultural Research and Development Center and to meet with local pellet distributors (i.e., Tractor Supply, Orscheln Farm Stores, etc.) to determine their interest in doing a "locally grown pellet day" at a retail outlet. The commercial pellet company is very interested in working with us. This will provide at least four quantifiable interactions that demonstrate CenUSA is impacting commercial aspects of the emerging bioenergy industry plus two science/technology transfer items. I can get the pelleting, bagging, and transporting done for about \$10,000.

1. Quantifiable interactions with the emerging bioenergy industry
2. Custom hay harvester
3. Pelleting facility
4. Commercial pellet distributors
5. University demonstration for biomass pellet heating
6. Publishable Research (Compositional characteristics of baled and pelleted bioenergy feedstocks)
7. Fact sheet (Biomass pellets for home heating) – include caloric value and ash content

➤ **Project 2. Perennial grass biochar commercialization for field and greenhouse evaluations and comparison to hardwood biochar**

Current CenUSA Bioenergy biochar research is using biochar produced from woody plants. This study will produce biochar from switchgrass, big bluestem, and a low-diversity prairie mixture grown in the CenUSA project. The objectives of the study are to produce biochar from switchgrass, big bluestem, and a low-diversity prairie mixture to:

- Evaluate the feasibility of producing biochar from perennial grasses at the commercial scale;
- Compare the relative quality of biochar produced from hardwoods and perennial grass;
- Compare the impact of biochar from hardwoods and the three perennial grasses on soil quality and plant growth in greenhouse trials; and 4) evaluate the ability of perennial grass biochar to mitigate nutrient transport in agricultural runoff.

To produce the needed biochar for these projects, the perennial grasses first need to be processed by briquetting. *Renew Energy Systems* in St. Ansgar, IA will produce the briquettes. Six big round bales each for switchgrass, big bluestem, and a low diversity prairie will be shipped to Ames, IA, ground to 1" particle size, and shipped in supersacks to *Renew Energy Systems* for briquetting. Briquettes will be shipped to *Biochar Now* in Berthoud, CO for conversion to biochar. The biochar will be shipped to Ames, IA. The estimated cost for partnering with *Renew Energy Systems* and *Biochar Now* is \$35,000.

➤ **Project 3. Bio-oil production of herbaceous feedstocks processed in the Battelle mobile pyrolyzer**

ARS Lincoln has contacted Drew Bond with *Battelle* concerning a research project to evaluate the bio-oil production of perennial grasses using in the Battelle mobile pyrolyzer. The research objective is to evaluate the bio-oil composition and production potential of Liberty switchgrass, Shawnee switchgrass, big bluestem, and a low-diversity prairie mixture grown in CenUSA replicated field trials.

I have requested a cost estimate for running up to 9 big round bales (~2 tons of processed material) for each feedstock through the Battelle mobile pyrolyzer. ARS Lincoln would provide 3 bales from each of the 3 field replicates (9 bales for each feedstock) plus nine randomly selected Shawnee switchgrass bales, process those bales to Battelle's specifications, and ship the processed feedstock to Battelle for evaluation in their mobile pyrolyzer. I have been invited to travel to Battelle to meet with the production staff, evaluate the mobile unit, and discuss this collaboration. Cost estimates

are forthcoming.

➤ **Project 4. Feasibility of perennial grass feedstocks to supply combined heat and power to an advanced ethanol fermentation plant**

Abengoa Bioenergy owns two starch-based ethanol plants in Nebraska, one near Ravenna and one near York. *Abengoa* has publically stated their plans to transition one plant from a corn-based to sorghum-based feedstock. This transition would allow *Abengoa* to meet the Advanced Biofuel requirements for the D5 Renewable Identification Number (RIN) under the Renewable Fuels Standard (RFS). In addition to converting feedstocks, they are considering feedstock options (i.e., switchgrass, eastern red cedar, etc.) to fuel the plant's boilers for combined heat and power and have submitted an application to EPA.

Abengoa has estimated each plant would require 180,000 tons of woody or perennial grass biomass per year to meet their biomass fuel needs. Additionally, *Abengoa* will be promoting sustainable production of the feedstock including no-till farming, crop rotations, and cover crops. Their plans dovetail with the research being conducted in the CenUSA Project. On January 22, 2014, ARS Lincoln presented CenUSA research information to *Abengoa* Bioenergy, state and federal agencies, NGO's, and wildlife and conservation organizations demonstrating the establishment and yield potential of herbaceous perennial feedstocks. Eric Zach, a member of our Advisory Board, has been involved with *Abengoa* as well. *Abingdon's* plans are linked to the RFS, so they are delaying decisions until the Farm Bill and other political decisions have been made. We plan to establish a demonstration site in 2014 containing perennial grass feedstocks and sorghum to provide CenUSA research information directly to *Abengoa* as they finalize their transition plans for these ethanol facilities.

➤ **Project 5. Grazing mitigates risk potential for perennial warm-season grasses grown for biomass energy**

Based on 2-years of grazing data, we can demonstrate the potential dual use of these feedstocks by grazing early, then harvesting regrowth and standing residue after frost for bioenergy. Grazing will utilize 50-60% of the total production, leaving 40-50% of the total yield for biomass energy. This grazing information will demonstrate that the livestock industry provides an economically feasible alternative market for herbaceous perennial feedstocks.



Obj. 9 / Extension & Outreach Master Gardener Meeting

Dec. 13, 2013

University of Minnesota - Dept. of Horticultural Science 1970 Folwell Av., Rm 152 Alderman Hall, St. Paul, MN 55108

10:00 - 10:15am (Rm 152 Alderman Hall will be open at 9:00am)

Welcome & Housekeeping (Julie)

Continental breakfast provided (fruit, bagels+, pastries, coffee, tea, oj)

10:15 - 11:15am

Debrief, review & report

- Update on sites & volunteer work
- What came out of the CenUSA Annual Meeting at Purdue?
 - Review: CenUSA Advisory Board Comments (Aug. '12 - July '13)
 - Objective 9. Outreach and Extension.

"I liked the programs being developed. This group really needs to think about how to inform and remain objective in providing this information. Biomass advocates have had a long history of promotion without production of results. Information on options for biomass production and options for using that biomass needs to be developed and sent out. I would like all the trials with biochar by the various groups to report back about what worked and what did not work. Finding out what information the various stakeholders need and then providing this unbiased information back is critical."

 - Education, education, education. Provide this to the media and politicians.
 - Provide concise information on what can be done now.
- Progress:
 - How are we doing meeting USDA & CenUSA expectations?
 - Where have we made the most progress?
 - Where do we see the need to improve?

11:15 - 12:00 pm

Review of Project Goals: refer to Cenusa deliverables grid (see page 5)

- Where should we be going now?
- What are our priorities for 2013?
- What do we want to do this year that aligns with our objective/tasks?
 - Sorrel mentioned any additional instructional research training materials (e.g. a YouTube video on how to take measurements) for MGs should apply even though this is Yr 3).

12:00 - 12:45pm - Lunch / Break

Lunch provided from *Panera Bread* - Spinach Power salad, Fuji Apple Salad, assorted sandwiches, chips, cookies, lemonade, iced green tea.

12:45 - 1:45pm

Communication plans/worksheets

- Discuss communication needs for both a) external / public audience, and b) our own team
- Two worksheets: You don't have to fill them out completely, but please spend about 5-10 minutes thinking about the questions, so we can discuss.
 - eXtension CoP / Learning Network Communications Plan
 - Communications & Marketing Worksheet
- Social media
 - Create goals and a process for social media, and some goals that can help us communicate clearly together.
 - Define “common language” & terminology around our blog postings for consistency and clarity, and how we want to promote the potential benefits including cautionary statements.
 - ex: Do we call the biochar sites demo gardens? Research plots? Trial gardens?
 - Review site signage for 2014 (Julie)
 - Set an editorial calendar including photo ideas and links, post frequency, and a process for reviewing.
 - What we want to say and how we want to say it?
 - Citizen science / volunteer management aspect (winter topic)
 - What’s happening with the research.
 - Report on “big picture” - annual data, annual meeting, etc.
 - Capture small things / events with photos and contribute to “Wordless Wednesday”.

1:45 - 2:30pm

2014 Annual Meeting - July 30 - Aug 1 @ the Minnesota Landscape Arboretum - Chaska, MN

- What message(s) do we want attendees to leave with after this annual meeting?
- How do we involve volunteers / others to emphasize the importance of Extension & Outreach in this grant, and show deliverables?
- How do we connect the attendees with the far away Iowa site & Fond du Lac site, tell their stories, and demonstrate the synergy between the sites in Extension / MGs in MN and IA?
 - Virtual tours?
 - Interviews?
 - Social Media - should we promo the meeting via social media, create a build-up to the meeting?
 - Provide food samples of biochar-grown food?
- Other ideas?

2:30 - 3:00pm

Wrap up

- “Who-Do?” Exercise
 - Who is responsible for carrying out our goals
 - How will they do this?

- When will goals be met?
- Schedule next group call / meeting

3:00pm - Adjourn & Safe Travels!



"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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... and justice for all

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