cenusa bioenergy

Quarterly Progress Report

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

January 2016

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

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

Second Quarter Report: November 1, 2015 – January 31, 2016

Project Administration, Project Organization and Governance

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

- **CenUSA Bioenergy Advisory Board**

  We continue to integrate our Advisory Board into our project activities. This quarter our primary communication has been through informal project updates and sharing of information. We have invited the to participate in our March 2016 Co-project director monthly meeting (virtual) where Objective 4 Co-project director Cathy Kling will be presenting the work her research group has completed to date for CenUSA. We will be inviting the Board to further presentations throughout the remainder of the project.

- **Executive Team Meetings**

  The Co-Project directors representing each of the ten project objectives continue to meet monthly with Ken Moore and Anne Kinzel via online meetings held in CenUSA's dedicated Adobe Connect meeting room. The virtual meeting room allows documents to be viewed by all participants, enhancing communications and dialogue among participants. Tom Binder, the Advisory Board chair also attends these meetings on behalf of the Advisory Board.

- **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 request a No-cost Extension as provided for by the project sponsor USDA-NIFA and are exploring the availability of supplemental funding to continue the pursuit of the CenUSA vision.

  We will submit our No-cost Extension year package in March 2016.

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.

1. Significant Accomplishments Summary

- **Plant Pathology and Entomology.** This research provides important information on the arthropods associated with bioenergy grasses and valuable information on the host suitability of switchgrass and other bioenergy grasses to four aphids within a system that has been largely overlooked, indicating that there are genetic differences among switchgrass populations for resistance. The ultimate goal of this project is to develop effective and sustainable management strategies for the key arthropod pests affecting switchgrass.
- **Feedstock Quality Analysis.** Collaborator Bruce Dien gave a keynote address at an industrial meeting on biopolymers and extensively described progress being made by CenUSA in commercializing perennial grasses as a renewable source of carbohydrates.
- We are also very close to completing the analysis of the samples for this fiscal year.

2. Planned Activities

- **Breeding and Genetics – ARS-Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**
  - ✓ Begin grinding and scanning 2015 biomass samples.
  - ✓ Oversee data organization and sample processing from 24 field trials planted at remote locations.
  - ✓ Thresh and clean seed of all new switchgrass and big bluestem populations.
- **Feedstock Quality Analysis (Bruce Dien – ARS Peoria and Akwasi Boateng – ARS Wyndmoor)**
  - ✓ Process 88 samples for enzymatic sugar release following hot-water pretreatment.
  - ✓ Repeat any outliers for the cinnamic acid ester/ether linkages.
  - ✓ Optimize NIR models for composition and pyrolysis products. Create NIR models for enzymatic hydrolysis.
- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Finalize the analysis and compile the data for 2015 from the arthropod survey (Nebraska and Wisconsin).

- ✓ Complete analysis of the electronic feeding monitoring for greenbugs.
- ✓ Compile and analyze switchgrass rust severity data from five CenUSA varietal trial locations.

3. Actual Accomplishments

- **Breeding and Genetics – Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**
  - ✓ Completed all grinding and scanning of 2015 samples.
  - ✓ Completed data proofing from 2014 (13 locations).
  - ✓ Half of 2015 data and samples from 13 locations have been collected.
  - ✓ Completed all seed threshing and cleaning.
  - ✓ Finished data analysis for one manuscript on the impact of cell-wall traits on ethanol yield from switchgrass biomass. The manuscript is 70 percent complete.
- **Feedstock Quality Analysis (Bruce Dien and Akwasi Boateng)**
  - ✓ NIR models for biomass composition, pyrolysis products, and sugar release from enzymatic hydrolysis have been developed and optimized.
  - ✓ Data are being incorporated into manuscripts.
  - ✓ We have completed 50 percent of the processing of the 88 samples for enzymatic sugar release following hot-water pretreatment. The delay is a result of processing 53 samples (including 3 repeats) to support an upcoming publication. The remaining samples will be completed in the next quarter.
  - ✓ We completed repeating analysis of outliers for the cinnamic acid ester/ether linkages.
  - ✓ We completed the necessary paperwork and received 6 hydrolysate samples from Renmatix (Objective 10, Commercialization).
- **Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ The processing of the arthropod survey samples for the 2015 season is 100 percent complete and the data analysis is 50 percent complete.

- ✓ All recordings have been performed for the electronic feeding monitoring studies of greenbug and characterization of the feeding behaviors is 50 percent complete.

- ✓ Switchgrass rust severity data collected from five CenUSA varietal trial locations in 2014 and 2015 was analyzed. The analysis revealed significant differences in rust susceptibility among switchgrass varieties particularly when comparing those of upland backgrounds (more susceptible) to those of lowland backgrounds (more resistant). Resistance in most lowland varieties was consistent across locations and years.

4. Explanation of Variances

See "Feedstock Quality Analysis" above.

5. Plans for Next Quarter

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**

  - ✓ Prepare for the 2016 field season.

  - ✓ Fertilize and apply herbicides, as needed, to all field plots.

- **Feedstock Quality Analysis (Bruce Dien and Akwasi Boateng)**

  - ✓ Continue analyzing data generated from NIR models and write manuscript(s).

  - ✓ Add mineral content, biomass composition, and pyrolysis product yield from the 88 grass samples (indiangrass and big bluestem) to the NIR models. These samples need to be analyzed by the NIR.

  - ✓ Complete processing the 2015 sample set for enzymatic sugar release following hot-water pretreatment.

  - ✓ Begin to evaluate hydrolysates received from Renmatix for lipid production.

- **Pathology and Entomology (Tiffany Heng-Moss and Gary Yuen)**

  - ✓ Finalize feeding monitoring for yellow sugarcane aphid.

  - ✓ Begin writing the arthropod survey publication.

  - ✓ Prepare a publication on results from CenUSA varietal trials focusing on resistance to rust.

6. Publications / Presentations/Proposals Submitted

- Ramstein, G.P., Evans, J., Kaeppler, S.M., Mitchell, R.B., Vogel, K.P., Buell, C.R. & M.D. Casler. (2015). Accuracy of genomic prediction in switchgrass improved by accounting for linkage disequilibrium. *Genes, Genomes, Genetics* (Accepted, in press).
- Dien, B. (2016). National Programs on BioMass: Development, Production & Refining. Conference of Biomass for Sustainable Future: The re-invention of polymeric materials. InnoPlast Solutions, Inc. Feb. 10, 2016, Las Vegas, NV.
- Slininger, P.J., Dien, B.S., Kurtzman, C.P., Moser, B.R., Bakota, E.L., Thompson, S.R., O'Bryan, P.J., Cotta, M.A., Balan, V., Jin, M., & L.D. Sousa. (2016). Comparative lipid production by oleaginous yeasts in hydrolyzates of lignocellulosic biomass and process strategy for high titers. *Biotechnology and bioengineering*. DOI: 10.1002/bit.25928.

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**

  1. Planned Activities

  - **Report on Activities - Armstrong Farm System Plots**
    - ✓ We collected post-frost plant biomass samples from all native plant plots on December 7, 2015, and plots were mechanically harvested and weighed on December 11. Hand harvests tended to overestimate total plant biomass by 1.7 Mg ha^{-1} (Fig. 1). Switchgrass plots consistently yielded the most biomass (12.0 Mg ha^{-1}), followed by low diversity plots (7.9 Mg ha^{-1}), then high diversity plots (2.0 Mg ha^{-1}, $P = 0.0211$). Biochar had no effect on post-frost yields. Hand-harvested samples will be ground and shipped to collaborators for analysis. A manuscript is in preparation that discusses stand establishment and yields during the first four years of establishment.

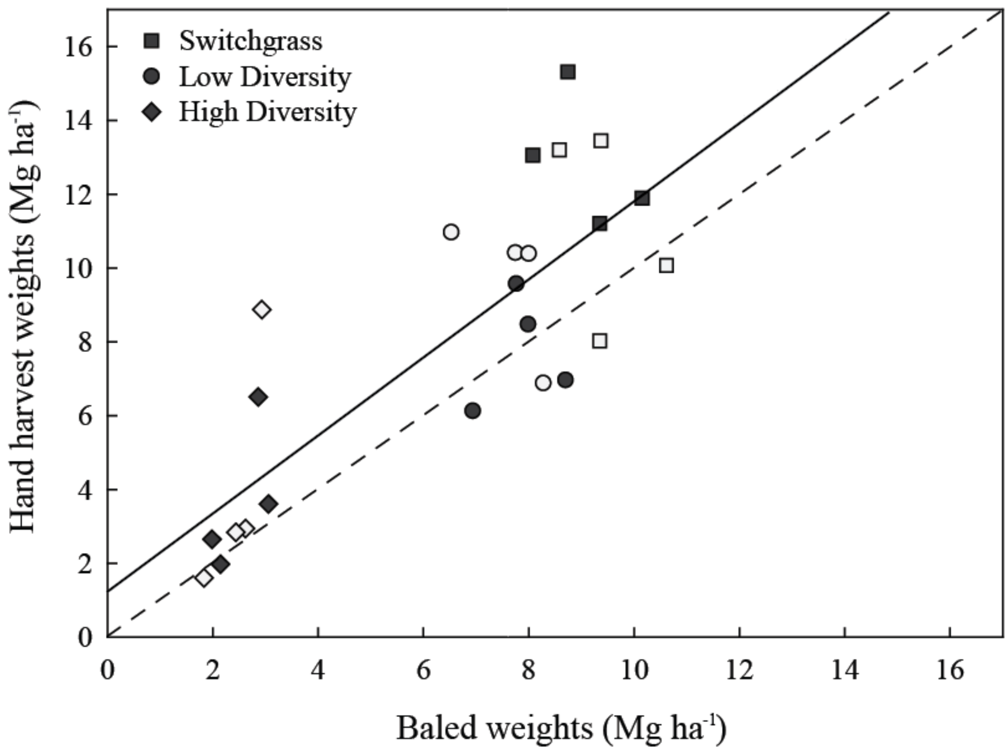

Fig 1. Correlations between mechanically baled weights and hand-harvested estimates for each subplot. The solid line represents the actual correlation, while the dashed line represents a 1:1 ratio. Empty symbols represent subplots that received a biochar application, while filled symbols represent subplots with no biochar application.

- ✓ Soil samples were collected in Fall 2015 from fields (Armstrong and Boyd) by depth 0-5 and 5-15 cm (from Boyd one extra depth 15-30 cm was considered for all plots). All these samples were air dried, sieved through 2mm sieve and analyzed for the Mehlich III extractable elements.
- ✓ A significant (<0.05) effect of biochar application, cropping system and depth was found for Mehlich III extractable P (Fig. 2) and K (Fig. 3) for the Armstrong plots.

The cropping system symbols means:

HD = High diversity plants

LD = Low diversity plants

SG = Switch grass

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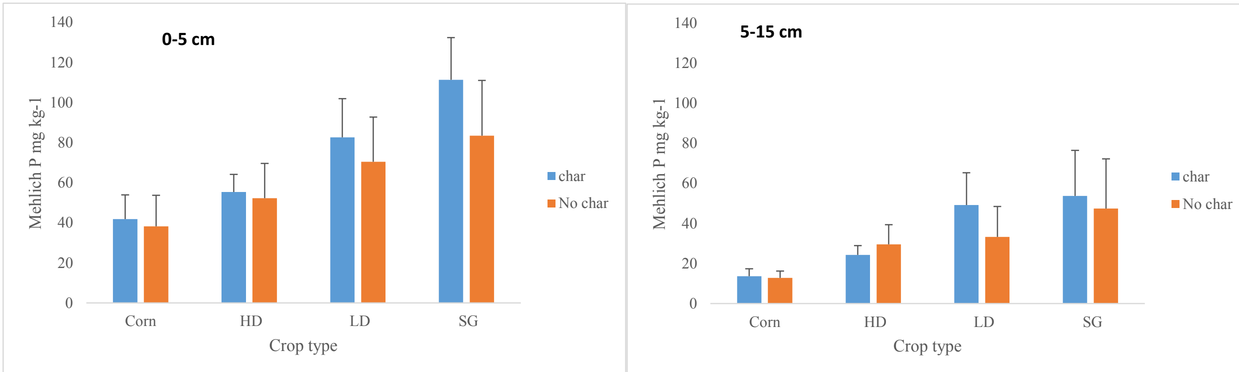

Fig 2. Mehlich III extractable soil P levels for the system plots on the Armstrong farm showing the effects of soil depth, biochar applications, and cropping systems.

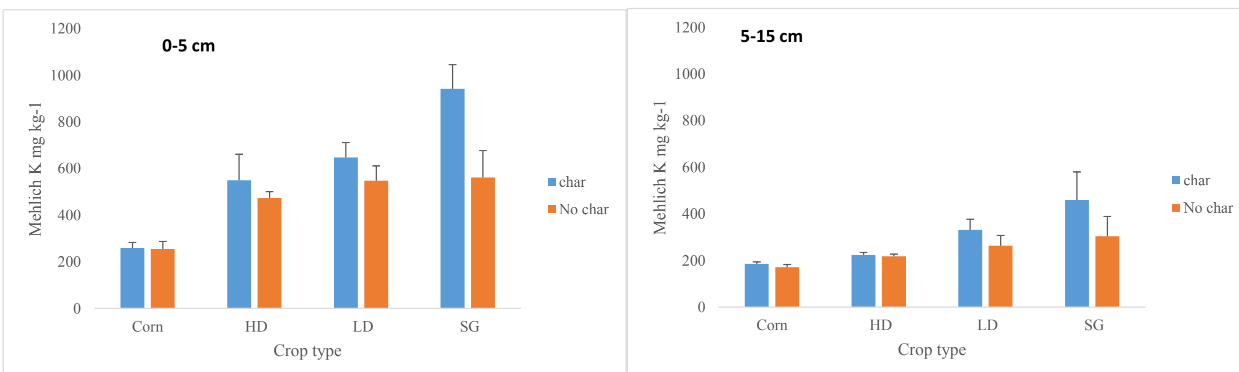

Fig 3. Mehlich III extractable soil K levels for system plots on the Armstrong farm showing the effects of soil depth, biochar applications, and cropping systems.

- ✓ **Boyd Field.** A significant depth effect was found for Mehlich III extractable P (Fig. 4) and K (Fig. 5) for biochar rate trial plots on the Boyd field.

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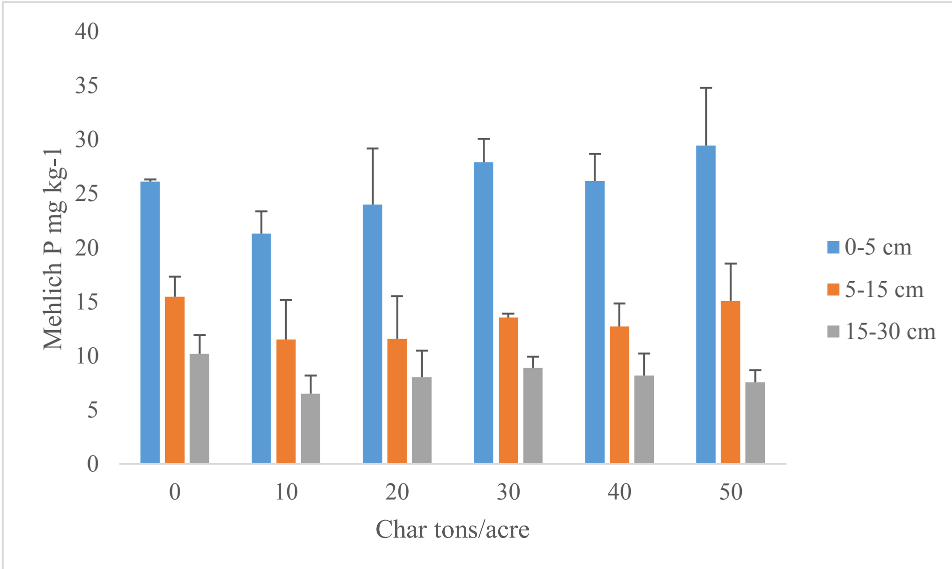

Fig 4. Mehlich III extractable soil P levels for plots on the Boyd Farm showing the effects of soil depth and biochar application rate.

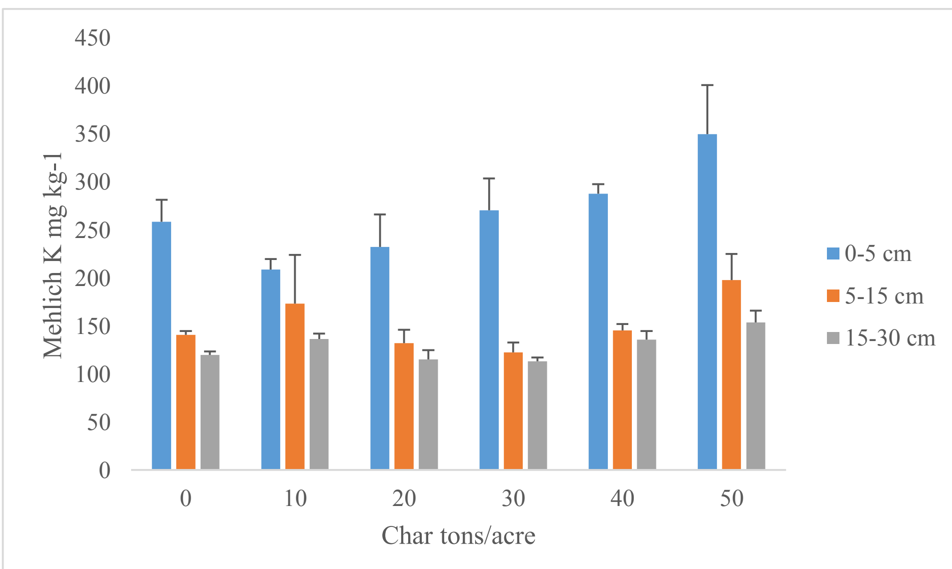

Fig 5. Mehlich III extractable soil K levels for plots on the Boyd Farm showing the effects of soil depth and biochar application rate.

- **Update of Activities on the Long Term Rotation Plots (Sorenson Farm)**
  - ✓ A new study, initiated spring 2015, investigated the effect of biochar and biochar age on soil nitrogen dynamics. Soil samples were collected from the continuous corn rotation plots only and analyzed using the KCl extraction method to determine nitrate

and ammonium concentrations. Samples were collected monthly from April (prior to planting and fertilization) through October (after harvest). Ammonium and nitrate concentration data over time for plots with and without biochar at two different depths (0-5 and 5-15cm) are presented in Figures 6 and 7, respectively

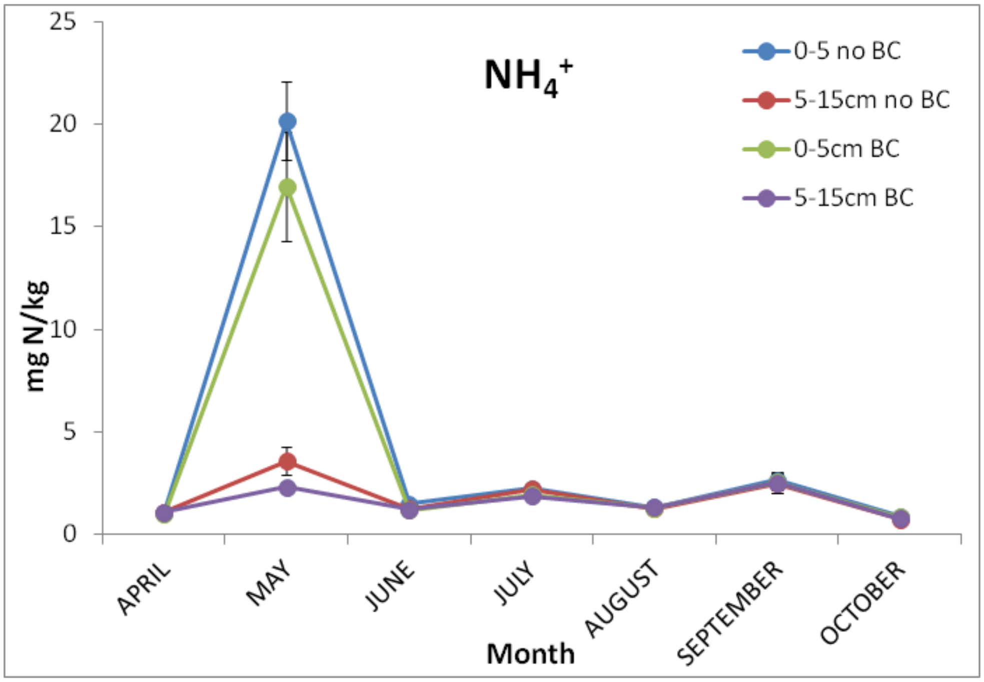

Fig 6. Ammonium concentrations (mg N/kg) showed no differences across the growing season for biochar/no biochar plots and by depth with the exception of May. Soil measurements taken in May were two weeks after fertilizer was applied. Ammonium concentrations were slightly lower when biochar was present for both depths. Values are the average of 64 plots for no biochar and 32 plots for biochar with standard error bars. Statistical analysis is pending.

- ✓ Additionally, leaf chlorophyll measurements were collected using a SPAD 502 plus chlorophyll meter to assess plant N status. Meter readings were collected from the newest fully expanded leaf with a visible leaf collar. Readings were taken 1-2 cm from the leaf edge and as close to mid-leaf as possible, with any disease and damaged spots avoided. Readings were collected from 6 plants per split plot which were located near where soil sampling occurred- about 1 m inside the edges of the plots on rows 2 and 5 and a center plant in rows 3 and 4. Readings were taken every 2 weeks from V6 to R5. Results will be presented in the next report.

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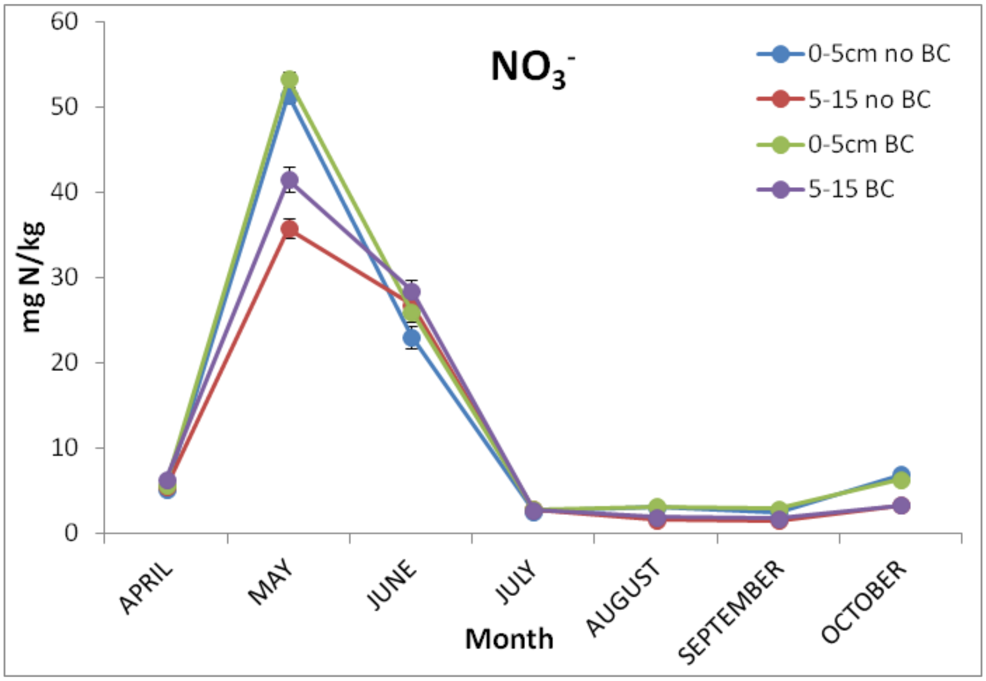

Fig 7. Nitrate concentrations (mg N/kg) varied little with only slight differences in May, June, and October. Statistical analysis is pending. Values are the average of 64 plots for no biochar and 32 plots for biochar with standard error bars.

2. Plans for Next Quarter

- **Future Activity**

  The CenUSA team met with the farm manager from the Armstrong Farm on 2-22-2016 to plan field management and sampling strategy for the 2016 growing season. Soil test P and K levels are all low or very low. To bring up fertility, switchgrass and low diversity plots will receive 90 lb/acre P_2O_5, 170 lb/acre K_2O and 90 lb/Acre N (as coated urea). Corn controls will receive 90 lb/Acre P_2O_5, 170 lb/ acre K_2O and 200 lb/ acre N as 32 percent UAN. Broadleaf herbicide will be used to control weeds (if needed) in the switchgrass and low diversity plots. High diversity plots will receive the same K and P fertilizer applications but will not receive N fertilizer. Weeds on the high diversity plots will be controlled by mowing as needed. Plant community composition and biomass production and yield will be measured the same as previous years.

- A number of the soil moisture sensors have failed on the Armstrong plots. The failed moisture sensors will be replaced as soon as the ground is trafficable. Graduate student Hamze Dokoohaki is working on modeling soil moisture for this site using this data with the APSIM cropping systems model. This will be a test of the new biochar module and the new switchgrass model that have recently been built by the ISU team for the APSIM model.

- Plans are still being developed for more intensive in-season soil sampling to quantify nutrient dynamics in the Boyd and Armstrong plots. Incubations to quantify potentially mineralizable N for the 2015 samples are planned. To do so 2M KCl extractable nitrate and ammonium before and after incubation of all the soil samples will be done. The incubation will be aerobic for 28 days at 300 C under 60 percent WFPS.

- **Purdue University**

We have been actively processing biomass and soil samples from the 2015 harvest season and analyzing them for various constituents. In addition, we have been updating the CenUSA datasets on the Purdue University Research Repository (PURR). Some data has been compiled and summarized for this report and for publication.

Figure 8 shows the biomass yield of *Miscanthus* × *giganteus* genotypes in Years 1 and 2 of establishment, and cumulative two-year total biomass yields at the Kentucky (top) and Indiana (bottom) locations**.** Genotypes included the Illinois (IL), Mississippi (MS), and Nagara clones and the open-pollinated Nagara sib population (OP Nagara). Data are averaged over nitrogen management (see Fig. 9) for presentation. At each location columns within group (year, cumulative) with letters in-common are not significantly different (P>0.05). The Nagara clone exhibited higher cumulative yield at both locations when compared to the commonly grown Illinois clone.

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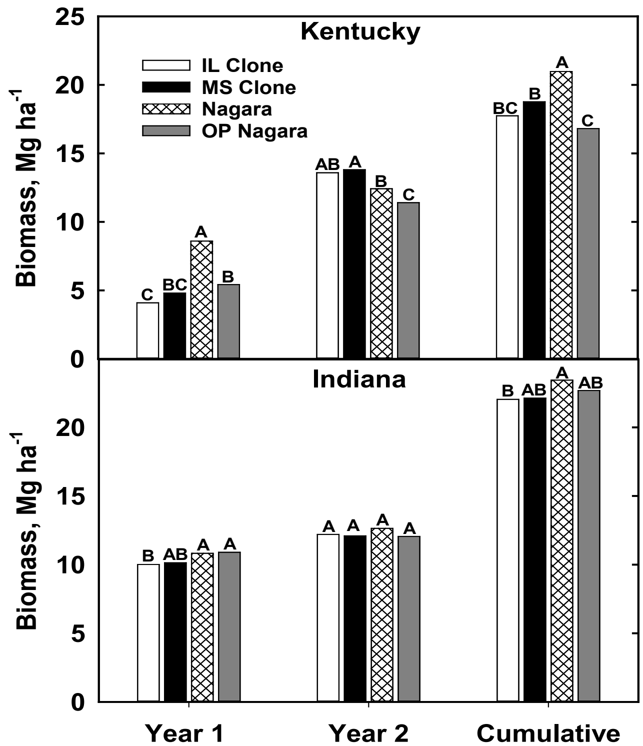

Fig 8. Biomass yield of *Miscanthus × giganteus* genotypes in Years 1 and 2 of establishment, and cumulative two-year total biomass yields at the Kentucky (top) and Indiana (bottom) locations.

Figure 9 shows the influence of nitrogen management on biomass yield of *Miscanthus* × *giganteus* during establishment. Data are dry matter yields in Years 1 and 2 of establishment, and cumulative two-year total biomass yields at the Kentucky (top) and Indiana (bottom) locations. Data were averaged over four genotypes (see Fig. 8) for presentation. A two-year total N application of 150 kg ha^{-1} N was applied using various combinations (e.g., 50-100; 75-75;…) of 50, 75, and 100 kg ha^{-1} year^{-1} of N. Control N rates included 0 (0-0) and 150 (150-150) kg ha^{-1} N each year. At each location columns within group (year, cumulative) with letters in-common are not significantly different (P>0.05). Nitrogen management had no impact on biomass yield at the Kentucky location where a silt loam soil was present. In sandy loam soils at the IN location addition of 50 kg ha^{-1} N increased biomass yield during establishment. Biomass yield in Year 2 for IN plots provided high N in Year 1 (150-0 treatment) were lower than those of plots provided 75 kg ha^{-1} N every year. This suggests that N carryover from Year 1 to 2, either in the soil or in plant storage organs, was not adequate to replace annual applications of modest N rates.

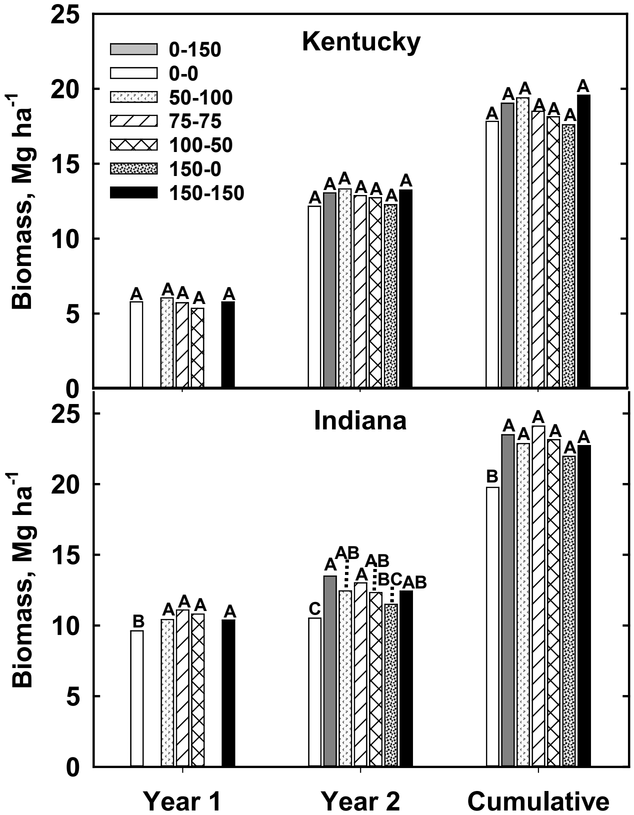

Fig 9. Influence of nitrogen management on biomass yield of *Miscanthus × giganteus* during establishment.

Agronomic N use efficiency (ANUE) was calculated as the change in biomass dry matter divided by increment of N fertilizer applied over the 0 N control rate (Table 1). Physiological N use efficiency (PNUE) was calculated as the ratio of dry matter yield (kg DM ha^{-1}) and biomass N accumulation (kg N ha^{-1}). Data within a site-year column without letters indicate that the N rate F-test was not significant for that trait. Means followed by the same letter within a site-year are not significantly different ($P>0.05$). The ANUE means for Kentucky in Year 2 differ at $P<0.10$. Tissue N concentrations increased with N fertilization. ANUE tended to be greater where less fertilizer N was applied. PNUE was consistently higher in the 0 N control plots and declined as N fertilizer application increased. Biomass C concentrations were not influenced bu N management.

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Table 1. Carbon and nitrogen concentrations of biomass and nitrogen use efficiencies (NUE) as influenced by N management averaged over four *Miscanthus × giganteus* genotypes during establishment over two years in Kentucky and Indiana.

	Carbon	Nitrogen	ANUE	PNUE	Carbon	Nitrogen	ANUE	PNUE
	--------g kg^{-1}--------		kg kg^{-1} N fertilizer	kg kg^{-1} biomass N	--------g kg^{-1}--------		kg kg^{-1} N fertilizer	kg kg^{-1} biomass N
N rate (Yr 1)	-------------- Kentucky Year 1 --------------				-------------- Indiana Year 1 --------------			
0	465	6.5 C	ND†	157 A	478	3.3 C	ND	303 A
50	465	6.9 BC	16.2	147 AB	478	3.9 B	23.5 A	262 B
75	464	7.3 AB	2.9	138 BC	478	4.0 B	24.6 A	257 B
100	465	7.4 AB	0.6	139 BC	480	4.2 B	15.6 AB	245 B
150	465	7.7 A	-0.6	132 C	479	4.8 A	7.6 B	216 C
N rate (Yr 1-2)	-------------- Kentucky Year 2 --------------				-------------- Indiana Year 2 --------------			
0-0	475	3.6 C	ND	282 A	473	4.5 D	ND	226 A
0-150	477	4.4 AB	8.9 B	237 BC	474	6.3 AB	19.8 ABC	162 CD
50-100	476	4.2 B	18.5 AB	250 B	475	5.9 BC	19.2 BC	177 BC
75-75	477	4.3 AB	11.9 B	244 BC	475	5.6 BC	33.2 AB	183 BC
100-50	476	4.3 AB	27.8 A	243 BC	474	5.5 BC	36.2 A	182 BC
150-0	477	4.2 AB	ND	248 BC	474	5.3 C	ND	191 B
150-150	476	4.7 A	11.9 B	224 C	475	7.0 A	12.8 C	146 D

†ND, not determined because N fertilizer not applied

Relative leaf retention was estimated as a visual rating ranging from 1 to 5 where 1= no leaves retained; 5= all leaves retained (Table 2). Means followed by the same letter within a site-year are not significantly different (P>0.05). Composition of the MS clone was similar to that of the Il clone. Higher leaf retention of the Nagara lines increased their hemicellulose concentrations, but reduced cellulose and lignin concentrations.

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Table 2. Concentrations of hemicellulose, cellulose, acid detergent lignin (ADL) and ash of biomass from four *Miscanthus × giganteus* genotypes averaged over nitrogen managements during establishment over two years in Kentucky and Indiana.

Genotype	Hemicellulose	Cellulose	ADL	Total Ash	Leaf Retention
	------------------------------ g kg^{-1} ----------------------------				
	Kentucky Year 1 (2010)				
IL Clone	328.6	387.8 AB	72.8 AB	26.5	
MS Clone	326.3	392.6 A	75.0 A	25.8	
Nagara	321.5	381.0 B	64.8 C	24.9	
OP Nagara	325.9	364.0 C	69.8 B	26.5	
	Kentucky Year 2 (2011)				
IL Clone	259.4 B	452.5 A	113.3 A	15.3 C	1.3 C
MS Clone	256.1 B	451.5 A	111.1 A	15.9 C	1.3 C
Nagara	292.5 A	415.9 B	89.2 C	21.0 B	3.2 B
OP Nagara	284.1 A	422.6 B	94.3 B	22.9 A	4.2 A
IL Clone	256.1 B	451.5 A	111.1 A	15.9 C	1.3 C
	Indiana Year 1 (2011)				
IL Clone	276.4	423.8 A	98.6 A	20.4 B	
MS Clone	287.0	413.1 A	95.6 A	21.2 B	
Nagara	285.8	415.4 A	76.6 B	21.7 B	
OP Nagara	285.2	389.0 B	72.0 C	25.6 A	
	Indiana Year 2 (2012)				
IL Clone	300.3 C	413.0 A	84.5 A	36.2	2.0 B
MS Clone	294.8 C	412.6 A	85.7 A	34.3	2.1 B
Nagara	316.5 B	400.6 B	66.5 B	35.2	5.0 A
OP Nagara	329.6 A	355.2 C	63.3 C	40.0	4.9 A

Agronomic N use efficiency (ANUE) was calculated as the change in biomass dry matter divided by increment of N fertilizer applied over the 0 N control rate (Table 3). Physiological N use efficiency (PNUE) was calculated as the ratio of dry matter yield (kg DM ha^{-1}) and biomass N accumulation (kg N ha^{-1}). Data within a site-year column without letters indicate that the genotype F-test was not significant for that trait. Means followed by the same letter within a site-year are not significantly different (P>0.05). The ANUE means for Indiana in Year 2 differ at P<0.10. Concentrations of C and N, and N use efficiencies of the IL and MS clones were similar at both locations each year. The OP Nagara population had higher biomass N concentrations resulting in lower PNUE than the other genotypes; however, this line had high ANUE in Indiana.

Table 3. Carbon and nitrogen concentrations of biomass and nitrogen use efficiencies (NUE) of four *Miscanthus × giganteus* genotypes averaged over N managements during establishment over two years in Kentucky and Indiana.

	Carbon	Nitrogen	ANUE	PNUE	Carbon	Nitrogen	ANUE	PNUE
	--------g kg^{-1}--------		kg kg^{-1} N fertilizer	kg kg^{-1} biomass N	--------g kg^{-1}--------		kg kg^{-1} N fertilizer	kg kg^{-1} biomass N
Genotype	------------- Kentucky Year 1 -------------				------------- Indiana Year 1 -------------			
IL Clone	465	7.1 B	4.7	144 A	482 A	3.6 C	14.2 B	280 A
MS Clone	465	6.7 B	10.4	152 A	481 A	3.7 BC	13.9 B	272 AB
Nagara	464	7.0 B	6.0	147 A	477 B	4.0 B	7.1 B	258 B
OP Nagara	465	8.0 A	-3.2	126 B	476 B	4.8 A	27.9 A	216 C
	------------- Kentucky Year 2 -------------				------------- Indiana Year 2 -------------			
IL Clone	479 A	3.4 B	8.4 B	297 A	476 A	5.6 B	24.2 AB	182 A
MS Clone	479 A	3.6 B	8.9 B	286 A	477 A	5.4 B	23.8 AB	190 A
Nagara	473 B	4.9 A	31.2 A	204 B	473 AB	5.4 B	15.1 B	192 A
OP Nagara	474 B	5.1 A	9.0 B	200 B	470 B	6.4 A	34.0 A	161 B

Switchgrass and Miscanthus models were created using APSIM Lucerne and APSIM Sugarcane modules as starting points, respectively (Fig. 10). Observed vs. modelled dry matter yield for (a) switchgrass and (b) Miscanthus using data from different field sites in IN including: WQFS, Water Quality Field Station; TPAC, Throckmorton Purdue Agricultural Center; NEPAC, Northeast Purdue Agricultural Center and SEPAC, Southeast Purdue Agricultural Center. Solid black line, dotted line and solid grey line represent 1:1 fit (i.e. y = x), +/- 20% of curve 1:1 value and linear equation fit to the data, respectively. Vertical bars represent the standard deviation in observed values where such data were available. CCC is the concordance correlation coefficient. Calibration of APSIM was successful for both biomass species with slopes near 1 and CCC values over 0.9.

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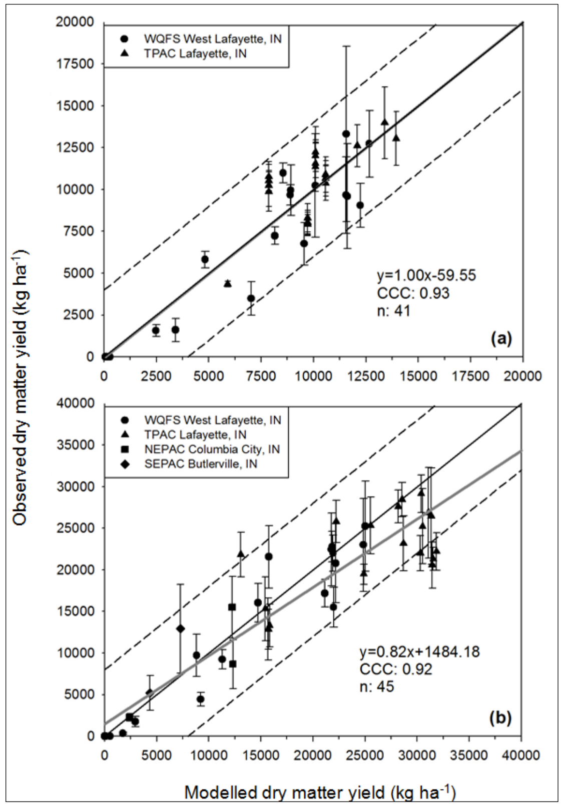

Fig 10. Calibration of the Agricultural Production Systems Simulator (APSIM) model for switchgrass and Miscanthus.

Switchgrass and Miscanthus models were created using APSIM Lucerne and APSIM Sugarcane modules as starting points, respectively, and calibrated as described in Figure 11. Observed v. modelled DM yield resulting of the validation of APSIM for (a) switchgrass and (b) Miscanthus was accomplished using data from: ND, North Dakota, NE, Nebraska, IL, Illinois, NY, New York, SD, South Dakota, IA, Iowa, IN, Indiana (independent of calibration data), TN, Tennessee, AR, Arkansas, TX, Texas, OK, Oklahoma, LA, Louisiana, VA, Virginia, CA, California, KY, Kentucky and NJ, New Jersey. Solid black line, dotted line and solid grey line represent 1:1 fit (i.e. y = x), +/- 20 percent of curve 1:1 value and linear equation fit to the data, respectively. The CCC and linear equation correspond to data from northern locations (close symbols) for switchgrass and the entire dataset for Miscanthus. Vertical bars represent the standard deviation in observed values. CCC is the concordance correlation coefficient. Validation of the switchgrass version of APSIM calibrated with IN data confirmed that the model could accurately predict biomass yield in northern locations (a); however, predicted biomass yields from APSIM did not agree with field biomass results from TX, VA, LA, OK and AR. Additional work is necessary to extend the inference space of this version of APSIM to these locations where lowland switchgrass varieties are commonly grown. Model predictions of Miscanthus biomass yield were validated by independent trials from around the US (b).

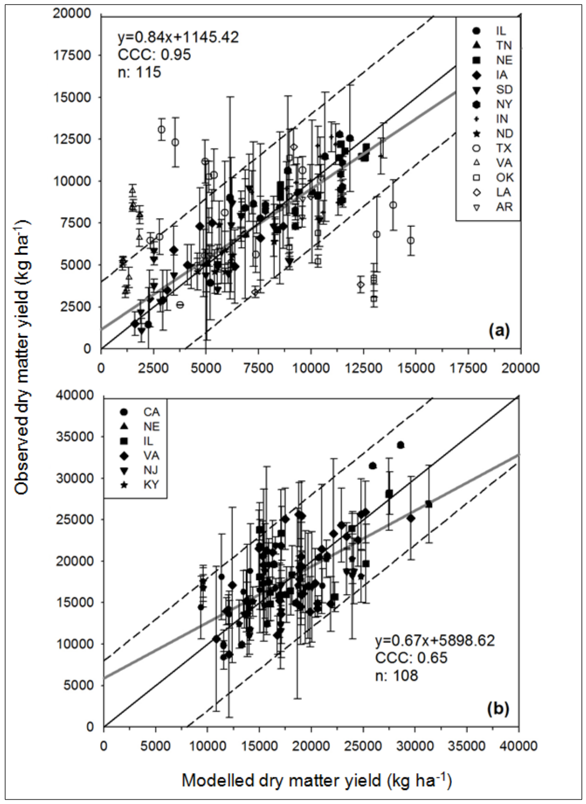

Fig 11. Validation of the Agricultural Production Systems Simulator (APSIM) model for switchgrass and Miscanthus.

Relative dry matter yield change of switchgrass and Miscanthus versus relative change (1.0=initial conditions) of plant parameters for three contrasting soil textures is shown in Figure 12. Switchgrass and Miscanthus were modelled using APSIM Lucerne and APSIM Sugarcane modules, respectively. The plant parameters analyzed were: radiation use efficiency, y_rue, (a, b); and extinction coefficient, y_ extinct_coef, (c, d). The value in the x-axis corresponds to the default values used in the sensitivity analysis. Broken lines indicate the baseline parameter and no changes in dry matter yield, respectively. Analysis was conducted with three soil types. Changing radiation use efficiency resulted in large changes in predicted biomass yield, and these were highly influenced by soil type for switchgrass (a, b). Increasing the extinction coefficient did not markedly alter predicted biomass production of either species, but decreasing this parameter reduced predicted biomass production of switchgrass (c).

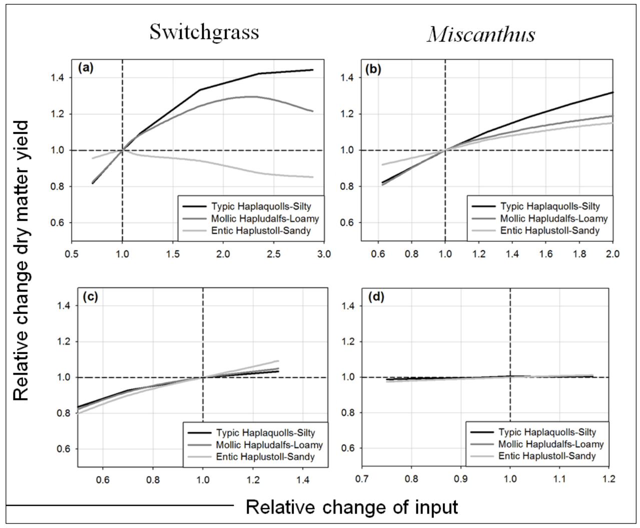

Fig 12. Sensitivity analysis of the Agricultural Production Systems Simulator (APSIM) model when recalibrated for switchgrass and Miscanthus.

Modeling the environmental footprint of these biomass systems continues using the Soil Water Assessment Tool (SWAT) led by Indrajeet Chaubey.

Recent activities include:

- Finalized the SWAT model for Upper Mississippi River Basin (UMRB)
- Continuing to evaluate impacts of drought on UMRB water quality, crop yield and hydrology.
- Continuing to evaluate hydrologic/water quality impacts of perennial bioenergy crop production in the UMRB.
- Developed a fuzzy logic based method to identify suitable marginal lands for bioenergy crop production.
- Developed a method to simulate the hydrologic/water quality impacts during the establishment period of perennial bioenergy grasses including ‘Shawnee’ switchgrass and Miscanthus.
- Evaluated the impacts of bioenergy crop production on marginal lands. A manuscript summarizing results is under internal review.

- **University of Illinois**
  - **Factor Analysis Plots**

- ✓ Biomass was harvested on September. 16, 2015 for H1 (post anthesis stage) and H3 treatments (alternate H1 and H2), and on December 18, 2015 for H2 (after killing frost) treatment
- ✓ All plant tissue samples were shipped to University of Nebraska-Lincoln on February 17, 2016 for compositional analysis.

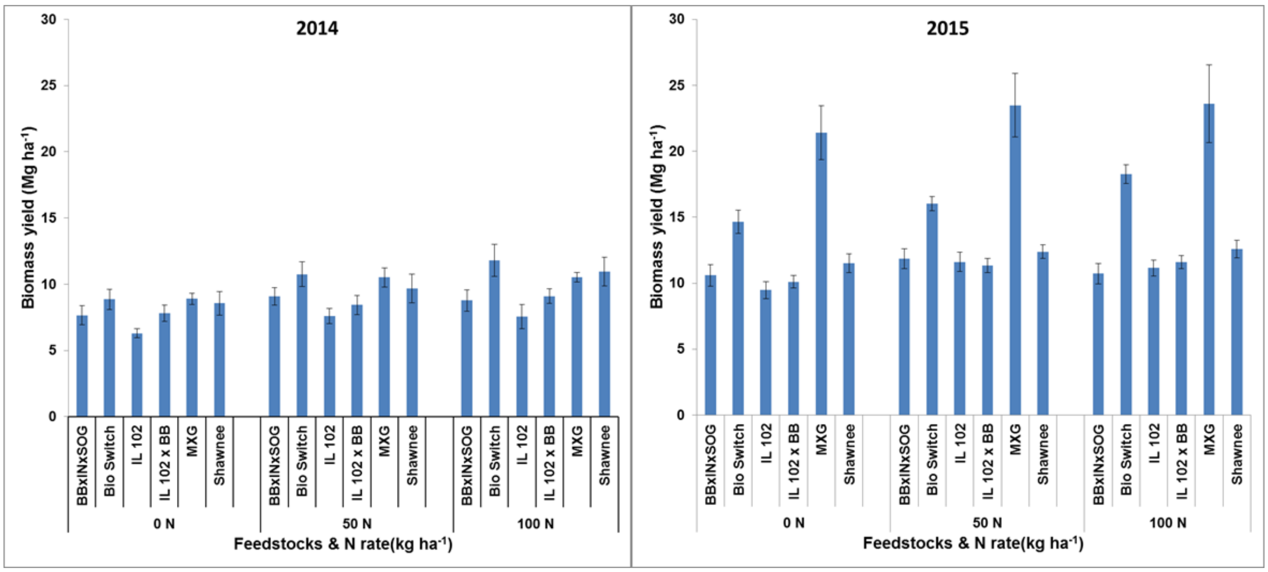

Fig 13. Plots Planted in 2012. Effects of N rate on biomass yield of High diversity mixture (BBxINxSOG), bioenergy switchgrass (Bio Switch), prairie cordgrass (IL102), *Miscanthus x giganteus* (MXG), and switchgrass (Shawnee) and prairie cordgrass and big bluestem mixture (IL102xBB), grown on wet marginal land during 2014 and 2015. Biomass yields were averaged across harvest treatment.

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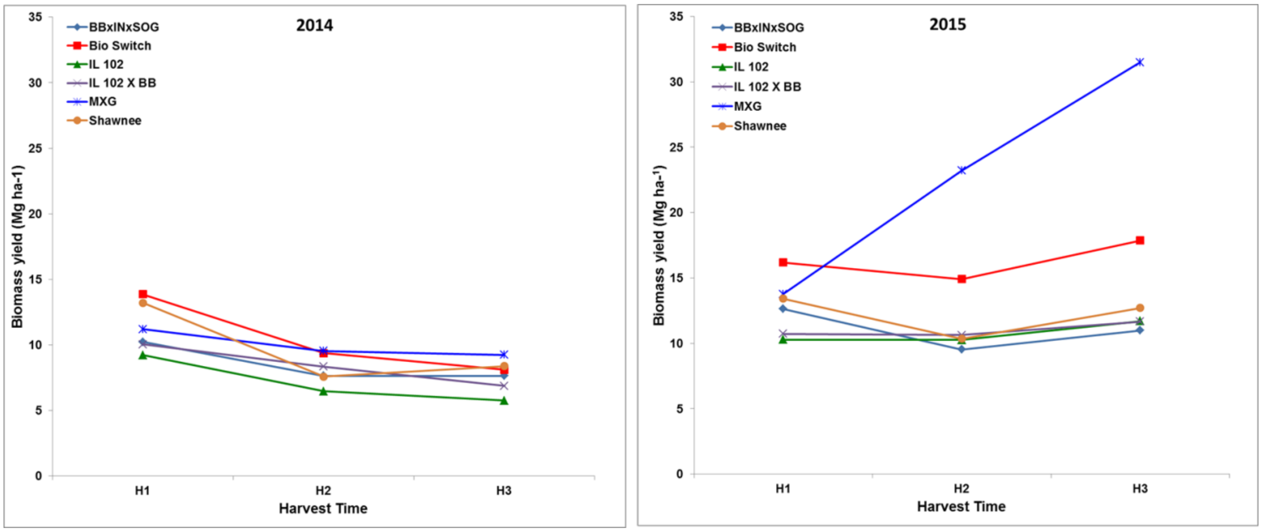

Fig 14. Plots Planted in 2012. Effects of harvest timing (H1: post anthesis stage, H2: after killing frost, H3: alternate H1 and H2) on biomass yield of High diversity mixture (BBxINxSOG), bioenergy switchgrass (Bio Switch), prairie cordgrass (IL102), *Miscanthus x giganteus* (MXG), and switchgrass (Shawnee) and two way mixture (IL102xBB), grown on wet, marginal land in Urbana, IL. Biomass yields were averaged across N rates.

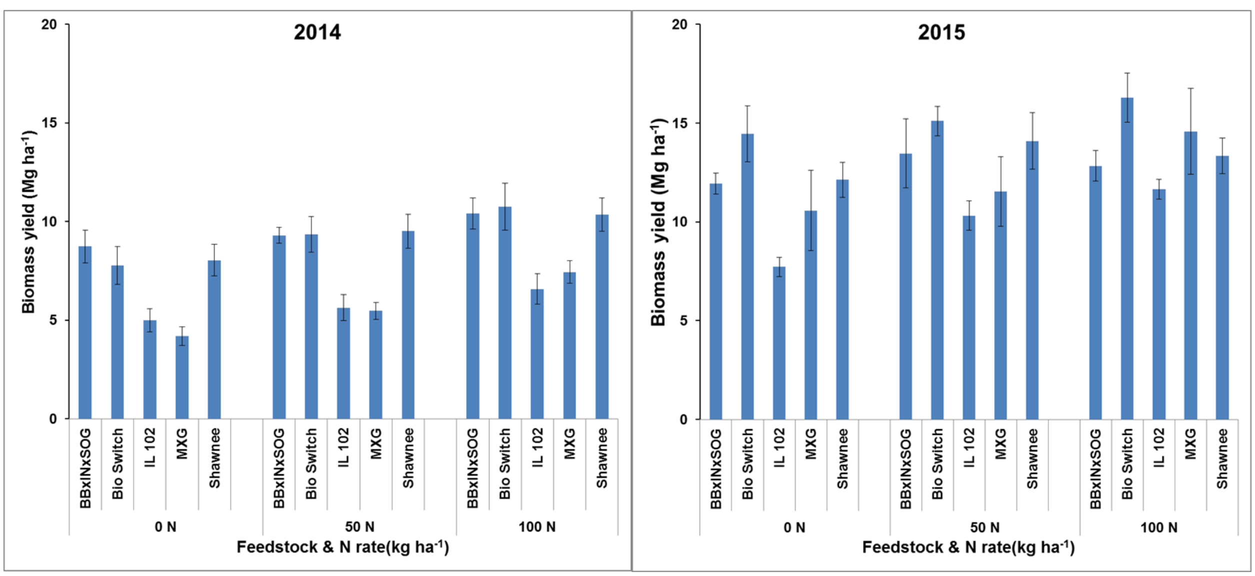

Fig 15. Plots Planted in 2013. Effects of N rate on biomass yield of High diversity mixture (BBxINxSOG), bioenergy switchgrass (Bio Switch), prairie cordgrass (IL102), *Miscanthus x giganteus* (MXG), and switchgrass (Shawnee), grown on wet marginal land during 2014 and 2015. Biomass yields were averaged across harvest treatments in Fig. 14.

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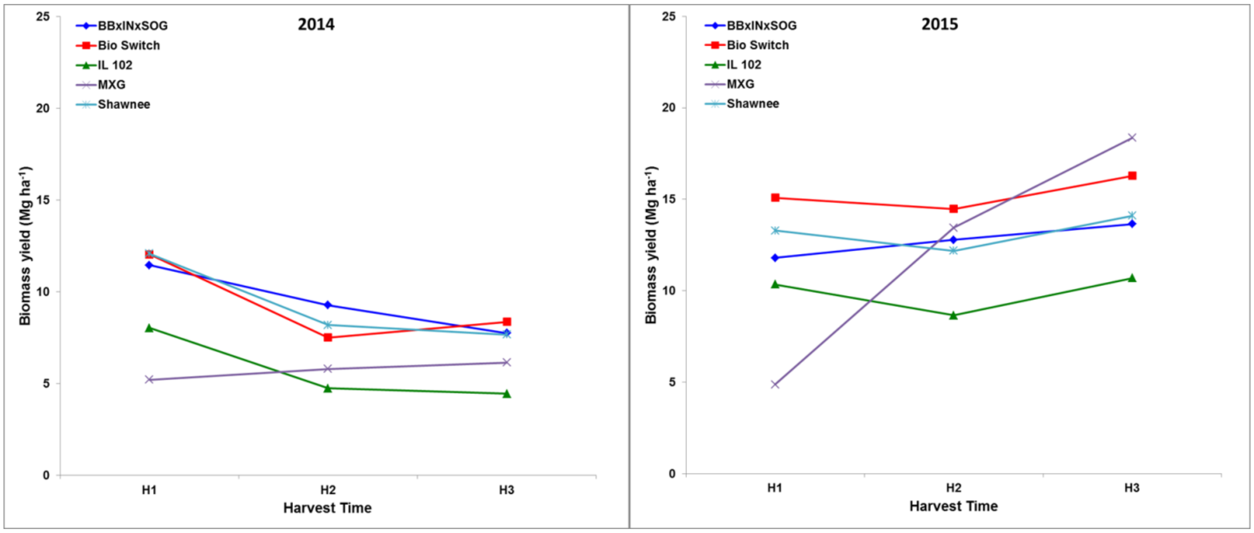

Fig 16. Plots Planted in 2013. Effects of harvest timing (H1: post anthesis stage, H2: after killing frost, H3: alternate H1 and H2) on biomass yield of High diversity mixture (BBxINxSOG), bioenergy switchgrass (Bio Switch), prairie cordgrass (IL102), *Miscanthus x giganteus* (MXG), and switchgrass (Shawnee) grown on wet marginal land in Urbana, IL. Biomass yields were averaged across N rates.

- **University of Minnesota**

Becker Factor Plots. This is the third treatment year, and timely precipitation made for robust growth where the soil is an excessively drained loamy sand. Dry matter yield on post-frost harvest (H2) plots is shown in Figure 17.

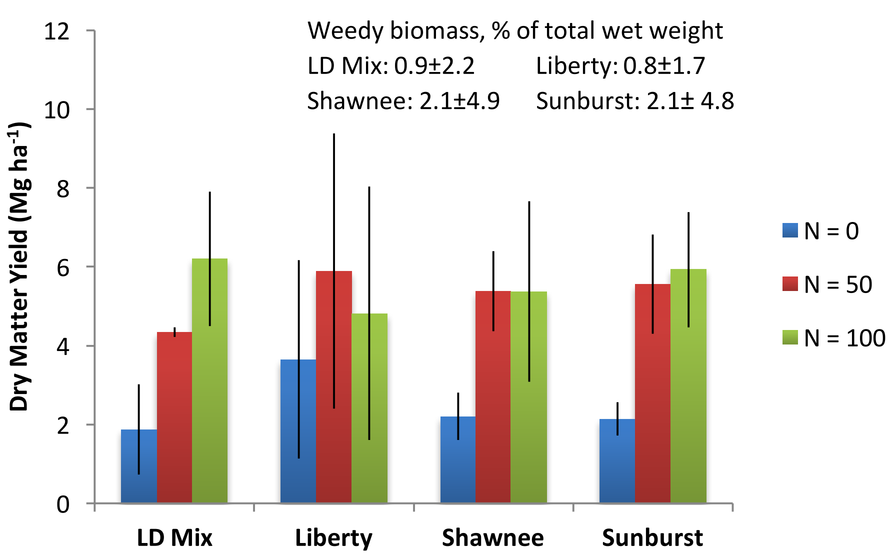

Fig 17. Oct. 26, 2015, dry matter yield on post-frost harvest (H2) grass plots at Becker, MN. Error bars

denote one standard deviation.

Lamberton Factor Plots. The Lamberton Factor Plots were established in 2013, making 2015 the second treatment year. Post-frost harvest (H2) and alternating harvest (H3) biomass yields are depicted in Figures 16 and 17. 'Liberty' exhibits winterkill stand loss, particularly resulting from the harsh winter of 2013-2014. Weeds have taken advantage of stand gaps despite early-season weed control efforts (see weedy biomass in Figs. 18 and 19).

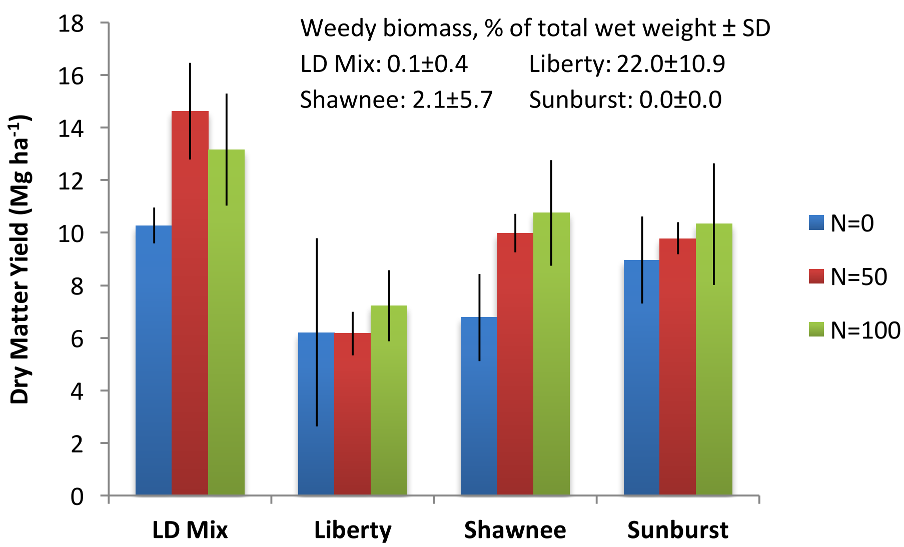

Fig 18. Nov. 2, 2015, dry matter yield on post-frost harvest (H2) grass plots at Lamberton, MN. Error bars denote one standard deviation.

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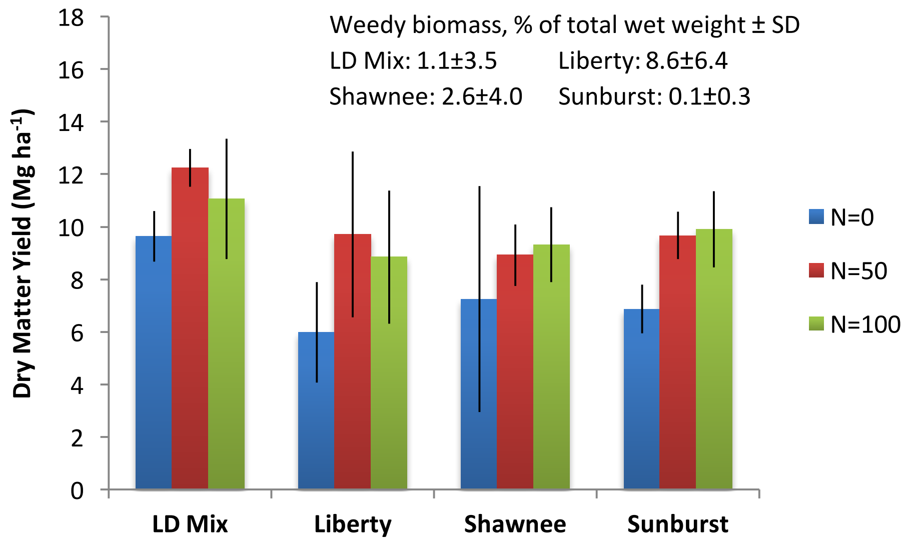

Fig 19. Nov. 2, 2015, dry matter yield on alternating harvest (H3) grass plots at Lamberton, MN. Error bars denote one standard deviation.

- **USDA-ARS, Lincoln**

  - **Undergraduate Student Hourly Employees Trained in all Aspects of the Scientific Process**

    David Walla, University of Nebraska Student.

  - **Graduate Students Trained**

    Jordan Leach, University of Nebraska Student, Agronomy, in process.

  - **Factor Analysis Plots**

    ✓ Yield data for 2012-2014 is being summarized.

    ✓ Feedstock samples collected in 2012, 2013, and 2014 have been processed and are being scanned and predicted.

    ✓ Feedstock plots were harvested after frost and 2015 samples are being processed.

    ✓ Plots are being maintained.

  - **System Analysis Plots**

    ✓ Samples collected in 2012, 2013, and 2014 are processed & are being scanned & predicted.

- ✓ Corn plots were harvested on 9/30/15 with a yield of 125.6 bu/acre and triticale cover crop planted. Triticale stands are very good.
- ✓ GHG samples from 2013-2015 are being summarized.
- ✓ VOM and elongated leaf height data are being summarized.
- ✓ Fields have been maintained, post-frost harvests completed in the harvest height study, and field-scale post-frost harvests have been completed. Data evaluation is in process.

- Factor analysis plots in two wetland sites in eastern North Dakota were evaluated.
- The study looking at the effects of Ryzup on switchgrass managed for bioenergy harvested after frost is being evaluated.
- The Crop/Livestock/Bioenergy Production System Demonstration site in eastern Nebraska is established. Ten acre fields of corn and soybean have been harvested and cover crops seeded. 'Liberty' switchgrass, 'Shawnee' switchgrass and 'Newell' smooth brome are being prepared for harvest. Corn was harvested on September 28, 2015 with a yield of 131.4 bu/acre. Soybean was harvested on October 1, 2015 with a yield of 47.2 bu/acre. Cover crop stand is excellent. CenUSA funds were leveraged to get additional funding to increase sampling intensity and graze this site in 2016.
- The field-scale herbaceous perennial feedstock research and demonstration site established in cooperation with Vermeer Manufacturing near Pella, Iowa is being prepared for post-frost harvest.
- We continued managing the annual and perennial feedstocks to supply CHP to an advanced ethanol fermentation plant. Teff and sorghum were harvested, and winter wheat is doing well.
- The warm-season grass grazing study for 2015 was completed, but the only valid data was grazing days due to wild steers that could not be kept in the proper pastures. This study will be terminated in 2016.
- A decision support tool that compares the returns from row crop production to the returns for perennial grasses for bioenergy developed in collaboration with CenUSA Co-Project Director Keri Jacobs and CenUSA Collaborator Chad Hart has been released (https://cenusa.iastate.edu/switchgrass-production-tool).
- Completed the following research updates:

- ✓ Presented information to the USDA-ARS Lincoln focus group on February 17, 2016.
- ✓ Accepted an invitation to serve on the organizing committee and present CenUSA information to the World Bioenergy Congress and Expo to be held in Rome, Italy in June, 2016.
- ✓ Submitted abstract on CenUSA research to the 24th European Biomass Conference and Exposition to be held in Amsterdam in June, 2016.
- ✓ Invited to present information to the University of Nebraska Extension Conference on March 16, 2016.

- **Plans for Next Quarter**
  - ✓ Continue processing 2015 biomass samples.
  - ✓ Continue scanning and predicting composition of 2012, 2013, & 2014 biomass samples.
  - ✓ Analyze and summarize field data.
  - ✓ Submit manuscripts on CenUSA projects.

▪ **USDA-ARS, Madison**

1. **Planned Activities**
   - Finish grinding 2015 samples.
   - Finish scanning 2015 samples on NIRS.
2. **Actual Accomplishments**

   Completed grinding and scanning of 2015 samples.
3. **Plans for Next Quarter**

   Prepare for 2016 season.
4. **Publications, Presentations, and Proposals Submitted**
   - Chaubey, I., Cibin, R., Frankenberger, J., Volenec, J. & S. Brouder. (2015). Integrated assessment of bioenergy, land use, and climate change on ecohydrologic response. Joint International Conference of American Society of Agronomy, Crop Science Society of American, and Soil Science Society of America, Nov. 17, Minneapolis, MN.

- Chaubey, I., Cibin, R., Frankenberger, J., Volenec, J. & S. Brouder. (2015). Biofuel-induced land use change impacts on hydrology and water quality. American Geophysical Union, Dec. 18, San Francisco, CA.
- Feng, Q., Chaubey, I., Her, Y., Cibin, R., Engel, B., Volenec, J. & X. Wang. (2015). Hydrologic/water quality impacts and biomass production potential on marginal lands. *Environmental Modelling and Software.* 72-230-238. DOI:10.1016/j.envsoft.2015.07.004.
- Krishnan, N., Cibin, R., Chaubey, I. & K.P. Sudheer. (2015). Impact of parameter uncertainty in land use planning decisions. Poster presented at the American Geophysical Union Conference, Dec. 18, San Francisco, CA.
- Rogovska, N., D.A. Laird, & D.L. Karlen. (2016). Corn and Soil Response to Biochar Application and Stover Harvest. *Field Crops Research*. 187:96-106. DOI: 10.1016/j.fcr.2015.12.013.

Objective 3. Feedstock Logistics

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

Iowa State University

1. Planned Activities

- Analysis of data collected during fall 2015 field drying experiments and comparison of results with empirical drying prediction models developed from controlled laboratory experiments.
- Continued development and evaluation of prototype real-time biomass moisture sensor for switchgrass and corn stover real-time biomass moisture sensor for switchgrass and corn stover.

2. Actual Accomplishments

In the last quarter, 27 drying experiments related to the later maturity stage of switchgrass were completed and another set of validation experiments will also be completed in the next month to validate the drying model developed for later stages of maturity. The drying rate data will be analyzed to evaluate the effect of weather conditions and swath density on drying characteristics of switchgrass. The drying models will also be compared to the field drying studies previously conducted in fall of 2015.

Also, the statistical analysis for evaluating the influence of rainfall amount and density on chemical composition change was also reevaluated according to a formula which accounts for dry matter loss in the results. The results show a significant influence of swath density and rainfall amount on K and Mg content of switchgrass. Switchgrass placed in high density (HD) windrows lost 6.2 percent K compared to a 19.6 percent and 22.3 percent in low (LD) and medium density (MD) windrows, respectively. Also, at low rainfall level of 8 mm, 6.3 percent K was lost compared to 17.7 percent at 75 mm. Similarly, switchgrass lost 17 percent and 11.5 percent Mg when it was placed in LD and MD windrows compared to 5.1 percent in HD windrows. Corn stover lost more K and Mg content in comparison to switchgrass as corn stover was more extensively conditioned during harvest. When, stover was placed in LD it lost 51.3 percent of K content compared to 28.2 percent in HD windrows. Also, corn stover lost 18.6 percent K at 8 mm of rainfall compared to 51.2 percent at 75 mm. In case of corn stover, a significant effect of swath density was also observed on ash content. A reduction of 56.7 percent in ash content was observed in exposed LD windrows compared to 16.1 percent in protected HD windrows. In case of switchgrass, no significant trend in ash content was observed but a decrease of up to 13.1 percent was observed. Fiber content containing cellulose and hemicellulose was least affected during the rainfall treatment. Slight changes were observed for both switchgrass and corn stover but no significant trend was observed.

Research on the development of sensors capable of predicting moisture content and bulk density of biomass feedstocks based on the dielectric measurements continued during this quarter.The development and design of the electronics for real-time biomass moisture sensor is continuing.

3. Explanation of Variance

No variance in planned activities has been experienced.

4. Plans for Next Quarter

Research activities planned during next quarter include:

- Continued analysis of data collected during drying experiments and validation of empirical drying prediction models developed from laboratory and field experiments.
- Continued development and evaluation of prototype real-time biomass moisture sensor for switchgrass and corn stover.

5. Publications, Presentations, and Proposals Submitted

Khanchi, A., Sharma, B., Sharma, A., Kumar, A., Tumuluru, J.S. & S. Birrell). (2016) “A review on effects of biomass preprocessing technologies on gasification performance and economic value of syngas.” Book chapter in "Biomass Preprocessing for Biofuels Production: Mechanical, Chemical, and Thermal Methods" (In review, CRC Press).

University of Wisconsin

1. Planned Activities

Our objectives for the quarter included:

- Complete work on the system to re-shape and re-compress round biomass bales;
- Investigate the means to achieve weight limited transport using modified large-square baler; and
- Continue to assess the economic viability of the various grass harvest and processing options by improving the economic model and begin integration of model results into the Integrated Biomass Supply Analysis and Logistics Model (IBSAL).

2. Actual Accomplishments

- Work was completed on round bale processing to enhance transport characteristics. The results showed that round bales could be re-shaped and re-compressed to achieve weight limited transport. Pressure-density relationships were modeled for a variety of biomass materials so that future design efforts could be supported. The re-compressed bales expanded too much after release from the pressing chamber, so improved restraint systems should be investigated.
- The bale press intended to compress large square bales to double density was tested. Several negative performance issues were identified and re-design to overcome these deficiencies is underway. The goal is to compare force, energy and density differences for recompressing round and square bales.
- An experimental baler from an independent inventor has been obtained. This baler does not use the typical reciprocating plungerhead approach to densification. It is intended to produce much greater biomass bale density than conventional approaches. Repair and modifications to this machine are now underway way to facilitate field testing in the spring.
- Software (ExtendSim 9.2) has been purchased to model the economic impact of drying rate, bale aggregation, harvest power requirements and bale density. This work will be conducted using the IBSAL model.

3. **Explanation of Variance**

None

4. **Plans for Next Quarter**

Our efforts in the next year will include:

- Complete work on modifying the experimental high-density baler and conduct initial field evaluation;
- Compress large-square bales and quantify pressure-density relationship;
- Continue to assess the economic viability of the various grass harvest and processing options using IBSAL, and
- Submit an additional two manuscripts for publication review.

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

- Lacy, N.C. (2016). Recompression of round bales of biomass feedstocks. Unpublished Master of Science Thesis, Department of Biological Systems Engineering, University of Wisconsin, Madison.
- Lacy, N.C. & K.J. Shinners. (2016). Reshaping and recompressing round biomass bales. (Submitted to *Transactions of ASABE*, January, 2016).

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

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

We focus on four overarching tasks:

- Task 1. Adapt existing biophysical models to best represent data generated from field trials and other data sources
- Task 2. Adapt existing economic land-use models to best represent cropping system production costs and returns
- Task 3. Integrate physical and economic models to create spatially explicit simulation models

representing a wide variety of biomass production options

- Task 4. Evaluate the life cycle environmental consequences of various bioenergy landscapes.

Iowa State University

1. Planned Activities

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

2. Actual Accomplishments

We have completed our first large scale scenarios using the detailed SWAT model for the Upper Mississippi River Basin and the Ohio Tennessee River Basin with USGS 12-digit subwatersheds.

A second set of scenarios using the extended 12-digit scenario models have been initiated using switchgrass and corn/soybean rotations as possible land use options. As a starting point on an extensive scenario testing for biofuels in the area with this large-scale hydrologic model, three cellulosic biofuel scenarios are tested: a) 50 percent corn stover removal from all the corn-soybean and continuous corn land with slopes <2 percent, b) the Shawnee switchgrass growth to all cropland with slopes >2 percent and to all pastureland and c) the cultivation of Miscanthus to all cropland with slopes >2 percent and to all pastureland as well. The model is executed for a recent 20-year period and the results are evaluated based on SWAT outputs on an annual basis.

Hydrology is not practically influenced compared to the baseline, however, sediments from HRUs entering streams have been significantly reduced under the growth of both perennial crops, but not under the stover removal scenario, which caused an expected slight sediment increase. A similar output is produced for P, which is strongly connected with sediments in SWAT. On the other hand, all scenarios resulted in reduced N losses to streams and rivers which are reflected to a considerably reduced N load in the Mississippi river downstream. Crop and biomass yields were also estimated across the landscape and based on the updated SWAT growth routines for perennials they are very promising for biofuel production.[1] These papers were presented at the SWAT Conference in Purdue on October 14-16, 2015. Based on the work presented at the SWAT conference, we are producing a series of papers for a special issue.

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[1] As previously noted, these papers were presented at the SWAT Conference in Purdue on October 14-16, 2015. Based on the work presented at the SWAT conference, we are producing a series of papers for a special issue.

3. **Explanation of Variance**

No variance has been experienced.

4. **Plans for Next Quarter**

We are participating in a special issue for the *Journal of the American Water Resource Association* on SWAT modeling with respect to bioenergy. We will lead a paper entitled “Policy Implications from Multi-Scale Watershed Models of Biofuel Crop Adoption across the Corn Belt,” which will provide an overview to the set of papers in the special issue. The paper will discuss the findings of the modeling studies and highlight their implications for the environmental and economic performance of their respective agroecosystems. The potential for policy design to improve the performance of these systems based on the findings of the modeling studies will be a focal point of the paper. This work will also be presented to the CenUSA leadership team, project graduate students and the Advisory Board at the March 2016 CenUSA Co-Project Director Monthly meeting.

We will continue to adapt existing biophysical models to best represent field trials and other data and to adapt existing economic land-use models to best represent cropping system production costs and returns. We have also been developing scenarios of specific interest to the goals of CenUSA including the optimal placement of switchgrass to achieve a range of environmental improvements while producing energy. To do so, we have initiated work with colleagues from Purdue and plan model comparisons between watersheds at multiple locations. We have two selected small watersheds selected (one in Iowa and one in Indiana). Appropriate SWAT versions and code have now been agreed upon as have a set of scenarios. The two watersheds are the Boone River Watershed in Iowa and the Indian Creek watershed in Indiana.

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

Valcu, A,. Kling, C. L. & P Gassman. (2015. “The Optimality of Using Marginal Land for Bioenergy Crops: Tradeoffs between Food, Fuel, and Environmental Services. (Under review at the *Northeast Agricultural and Resource Economics Association Journal*, December 2015).

National Science Foundation. (2015). FEW: Coupling Economic Models with Agronomic, Hydrologic, and Bioenergy Models for Sustainable Food, Energy, and Water Systems. $46,000.

University of Minnesota

1. **Planned Activities**

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.

Task 5. Employ the modeling systems to study the design of policies to cost effectively supply ecosystem services from biomass feedstock production.

2. **Actual Accomplishments**
This quarter, we focused on parameterizing the GREET model with inputs from our spatially-explicit switchgrass life cycle air pollutant inventories. In particular, we provided descriptions of pathways in switchgrass production and conversion linked to state-level economic production costs. We also investigated emissions of fugitive dust in switchgrass production and transport, with the goal of adding this process to GREET.

3. **Explanation of Variance**

No variance has been experienced.

4. **Plans for Next Quarter**

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

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

- Hill, J., Tajibaeva, L. & S. Polasky. Climate Consequences of Low-Carbon Fuels: The United States Renewable Fuel Standard. *Energy Policy*. (In review).

Post-Harvest

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

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

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

1. **Planned Activities**

- **Techno-economic Analysis**

We estimated the "Minimum Product Selling Prices" (MPSP), "Maximum Investment Cost" (MIC), and the uncertainty of the prices of the different lignin-derived chemicals.

- **Prepare and Characterize Biochar**

  We obtained the missing Dissolved Organic Carbon (DOC) data and completed work on the biochar aging and anion exchange capacity (AEC) stability during oxidation manuscripts. The peak temperature used to separate biochar volatile matter from fixed C during proximate analysis will be evaluated and compared with H:C ratios to better distinguish labile and recalcitrant biochar fractions.

2. Actual Accomplishments

- **Techno-economic Analysis**

  To increase the profitability of bio-refineries, all three components of lignocellulosic biomass, that is cellulose, hemicellulose and lignin, have to be appropriately transformed into high revenue products. Cellulose is the most abundant non-food biomass followed by lignin. The pulp and paper industry produces more than one million tons of lignin per year, and its abundance is expected to increase as more bio-based bio-refineries come online. Another source of lignin is ethanol production from corn stover which is readily and abundantly available in the U.S. Lignin can be considered as a waste, burnt for the energy production or used to make biochar.[2,3] Lora et al., mentions that approximately 1 to 2 percent of the total lignin is converted into other products.[4] Lignin value-added products will not only produce more revenue, but also they will improve the fuel production variability. Little investigation, if any has been done on the economics of lignin value-added products, therefore, our focus is on the lignin component streams from a lignocellulosic ethanol plant and how to utilize them to produce value-added products. Minimum product selling price (MPSP), maximum investment cost (MIC), and uncertainty analysis are reported.

  In this analysis, we assumed a lignocellulosic ethanol bio-refinery that processes 2000 metric ton/day of corn stover. The different processes involved to produce ethanol are handling and processing, pretreatment and conditioning, saccharification and

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[2] Ghaffar S.H. & M. Fan. Structural analysis for lignin characteristics in biomass straw. (2013). *Biomass and Bioenergy*: 57:264–79. DOI:10.1016/j.biombioe.2013.07.015.

[3] Doherty, W., Mousavioun, P., & C.M. Fellows. (2011). Value-adding to cellulosic ethanol: Lignin polymers. *Ind Crops Production*: 33:259–76. DOI:10.1016/j.indcrop.2010.10.022.

[4] Lora, J.H. & W.G. Glasser. Recent Industrial Applications of Lignin: A Sustainable Alternative to Nonrenewable Materials. *J Polym Environ* n.d.:10:39–48. DOI:10.1023/A:1021070006895.

fermentation, ethanol distillation and dehydration, and solid separation and evaporation (Fig. 20).

Under storage, handling and processing, the corn stover is preprocessed, densified, and homogenized to a certain level and before the ethanol plant receives it under standard and/or agreed upon specifications like moisture content, particle size, soil levels, and ash content. Davis et al. report that it cost $80/dry ton of corn stover upon delivery at the bio-refinery.[5] Upon receiving the corn stover and before processing it into ethanol, it is washed and shredded. In the pretreatment and conditioning stage, dilute acid (steam and sulfuric acid) pretreatment is done so as to release five and six carbon sugars of hemicellulose.[6] A detailed description of the dilute acid pretreatment is described by Kazi et al.[7]

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[5] Davis, R., Tao, L., Tan, E., Biddy, M., Beckham, G., & C. Scarlata. (2013). Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbons: Dilute-Acid and Enzymatic Deconstruction of Biomass to Sugars and Biological Conversion of Sugars to Hydrocarbons. NREL/TP-5100-60223.National Renewable Energy Laboratory.

[6] Jones, S.B. & Zhu, Y. (2009). Preliminary Economics for the Production of Pyrolysis Oil from Lignin in a Cellulosic Ethanol Biorefinery. Pacific Northwest National Laboratory, Richland, WA.: United States. Dept. of Energy.

[7] Kazi, F.K., Fortman, J., Anex, R., Kothandaraman, G., Hsu, D., & A. Aden. (2010). Techno-Economic Analysis of Biochemical Scenarios for Production of Cellulosic Ethanol.

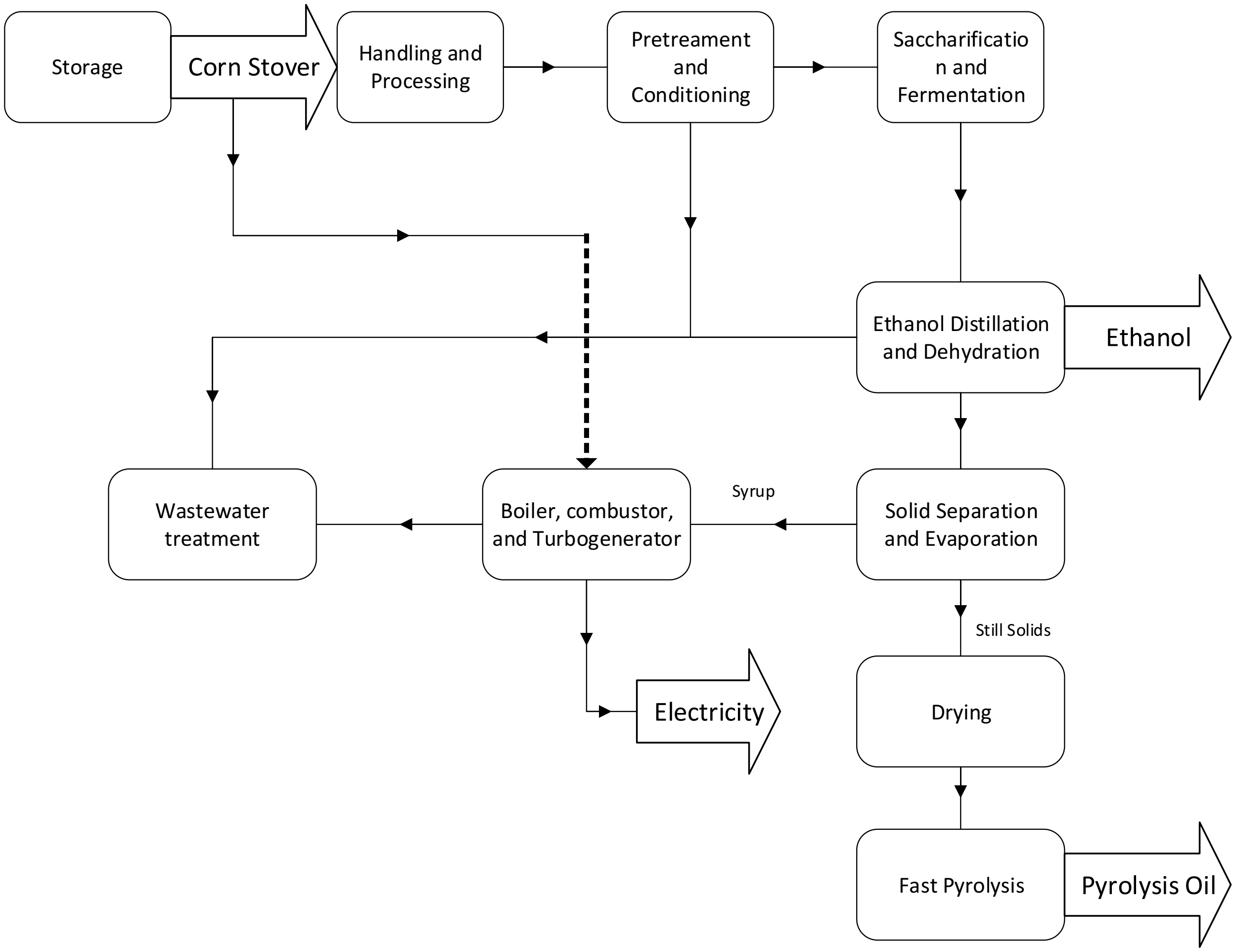

Fig 20. Ethanol and pyrolysis oil production process flowsheet.

For the following step to be successful, the products exiting the pretreatment must be neutralized to enable the release of cellulose six carbon sugars in the saccharification stage by adding ammonia to the whole pretreated slurry to change the pH from ~1 to ~5.[8] The next step involves saccharification (enzymatic hydrolysis) that is achieved using cellulose enzyme and co-fermentation of the slurry using *Zymomonas mobilis* to convert all sugars to ethanol. Distillation and solid-liquid separation follow so as to separate the dilute ethanol from solids and water. Vapor phase molecular sieve adsorption dehydration then ensures the purity of ethanol is 99 percent.[9] The wastewater treatment (WWT)

[8] Humbird, D., Davis, R., Tao, L., Kinchin, C., Hsu, D., & A. Aden. (2011). Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol. Dilute-Acid Pretreatment and Enzymatic Hydrolysis of Corn Stover. NREL/TP-5100-47764. National Renewable Energy Laboratory.

[9] Op. Cit. Davis, R. et al. (2013).

section utilizes aerobic and anaerobic digestion methods to treat wastewater and the biogas byproduct is delivered to the combustor.

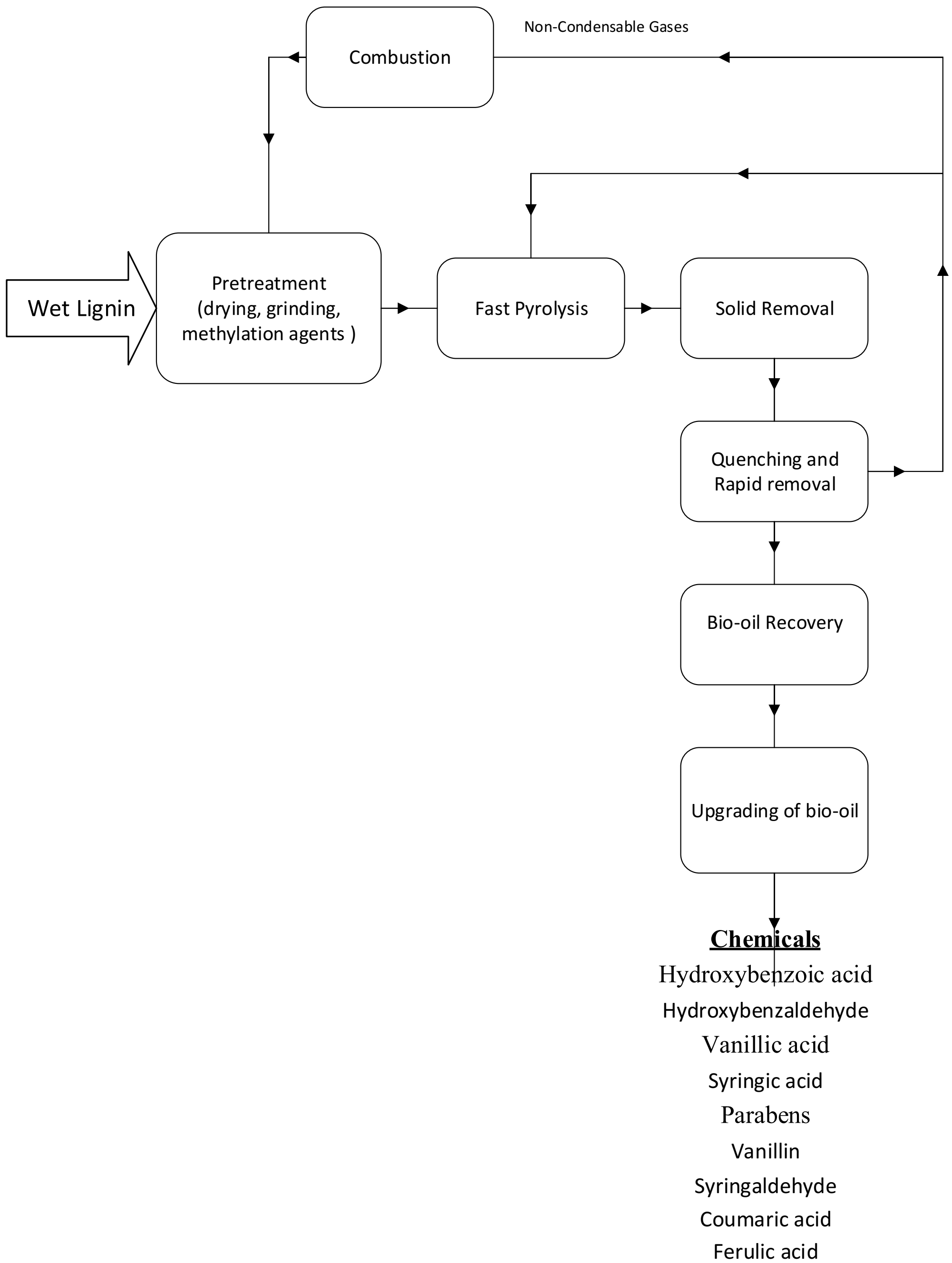

Fig 21. Fast pyrolysis process flowsheet of lignin.

The processes involved to produce value added chemicals from lignin are (Fig. 21): pretreatment of wet lignin, fast pyrolysis, solid removal, quenching and rapid removal, bio-oil recovery, and upgrading of bio-oil to the desired chemicals.

For economic analysis, the project lifetime is 20 years with an equity of 40 percent, 39 percent income tax rate, 8 percent loan interest, and 10 percent internal rate of return. Double declining balance depreciation is assumed with the depreciation period of the general plant being 10 years and 20 years for the steam. The construction period is three years with 8 percent of the capital investment spent in the first year whereas as 32 percent and 60 percent is spent in the second and third year respectively. Startup revenue, variable, and fixed costs are 50 percent, 75 percent, and 100 percent respectively.

Minimum Product Selling Prices (MPSP) is the price at which a product could be sold and generate a 10 percent internal rate of return for a given project. A low MPSP is attractive because it indicates greater margin for profitability. Maximum Investment Costs (MIC), on the other hand, describes the investment total at which a project generates a 10 percent internal rate of return for current market prices. A high MIC is preferable because it indicates a higher tolerance for capital risk. Due to lack of data, the uncertainty is done using Monte Carlo analysis assuming a triangular probability distribution (±20%) for the MPSP, MIC, and market price. The estimated MPSP and MIC for various lignin-derived chemicals are as shown in Table 4. The sale prices and purities were gathered from Fischer Scientific, and they were scaled up to a unit price per tonof the chemical.[10]

As shown in Table 4, MPSP values range from $65,000 to $2,920,000 per ton compared to between $94,000 and $50,940,000 sale prices. Attractive chemicals could be identified by a high yield and sale price and low MIC. Vanillin and Syringaldehyde are the most attractive chemicals in terms high yield. However, P-coumaric acid currently has the highest market sale price and MPSP.

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[10] Fisher, S. Fisher scientific. A thermo Fisher scientific brand. 2015. https://www.fishersci.com/us/en/home.html (accessed November 29, 2015).

Table 4. Estimated minimum product selling prices (MPSP) and maximum investment costs (MIC) for various lignin-derived chemicals.

	Yield from wheat straw (%) a[11]	Yield from maize stems (%) b[12]	Yield from rye straw (%) c[12]	Yield from rice straw (%) d[12]	Price ($/unit)	Purity	Scaled-up Price ($/tons)	MPSP ($/ton)	MIC ($)
P-Hydroxybenzoic acid	1.84	0.81	0.81	1.12	$176.54 for 500g		353,000	1,714,000	3.65E +08
P-Hydoxybenzaldehyde	2.94	2.48	1.84	1.59	$106.63 for 250g	95%	427,000	1,080,000	4.87E +08
Vanillic acid	1.87	0.034	0.47	0.36	$50.71 for 25g	99%	2,028,000	1,686,300	3.65E +09
Syringic acid - high	2.53	1.28	1.71	1.82	$61.1 for 10g	97%	6,110,000	1,246,400	3.40E +09
Syringic acid - low	2.53	1.28	1.71	1.82	$172.8 for 100g	97%	1,728,000	1,246,400	1.13E +09
Vanillin - high	20.32	10.49	20.32	15.49	$25.2 for 2g	99%	12,600,000	155,000	5.72E +10
Vanillic – low	20.32	10.49	20.32	15.49	$467.6 for kg	99%	94,000	155,000	6.21E +08
Syringaldehyde	18.04	13.05	15.28	13	$94.58 for 25g	98%+	3,783,000	175,000	1.42E +10
P-Coumaric acid - high	1.08	0.32	0.45	0.61	$50.94 for 1g	98%+	50,940,000	175,000	1.15E +10
P-Coumaric acid - low	1.08	0.32	0.45	0.61	$82.77 for 10g	98%+	8,277,000	2,920,000	2.06E +09
Ferulic acid - high	1.67	0.82	1.42	1.22	$62.86 for 5g	99.40%	12,572,000	1,888,000	4.54E +09
Ferulic acid - low	1.67	0.82	1.42	1.22	$246.55 for 100g	99.40%	629,000	1,888,000	4.47E +08
All chemicals considered	6.32	3.52	5.52	4.53			8,295,000	65,000	8.66E +10

Note: Yields of feedstocks when all chemicals are considered is an average.

The uncertainty of MPSP, MIC, and the market price of different chemicals and when all chemicals are considered to be produced are as shown in Figures 22, 23, and 24, respectively. Coumaric has the highest MPSP and market price whereas when all chemicals are considered, it presents the lowest selling price, as excepted. MIC is highest when all chemicals are considered at approximately $87 billion and lowest for

[11] Sun, R., & J. Tomkinson J. (2002). Comparative study of lignins isolated by alkali and ultrasound-assisted alkali extractions from wheat straw. *Ultrason Sonochem:* 9:85–93. DOI:10.1016/S1350-4177(01)00106-7.

[12] Xiao, B., Sun, X. & R. Sun R. (2001) Chemical, structural, and thermal characterizations of alkali-soluble lignins and hemicelluloses, and cellulose from maize stems, rye straw, and rice straw. *Polym Degrad Stab:* 74:307–19. DOI:10.1016/S0141-3910(01)00163-X

hydroxybenzoic acid at approximately $ 0.4 billion. Vanillin and Syringaldehyde with the highest yield each needs $53 and $14 billion of MIC, respectively, when considered.

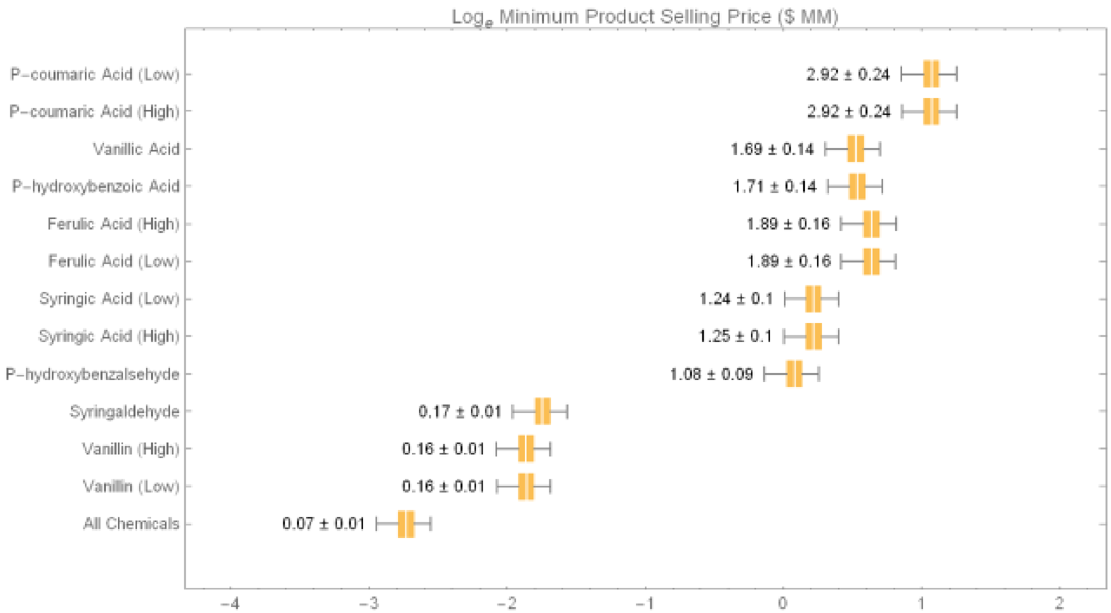

Fig 22. MPSP uncertainty.

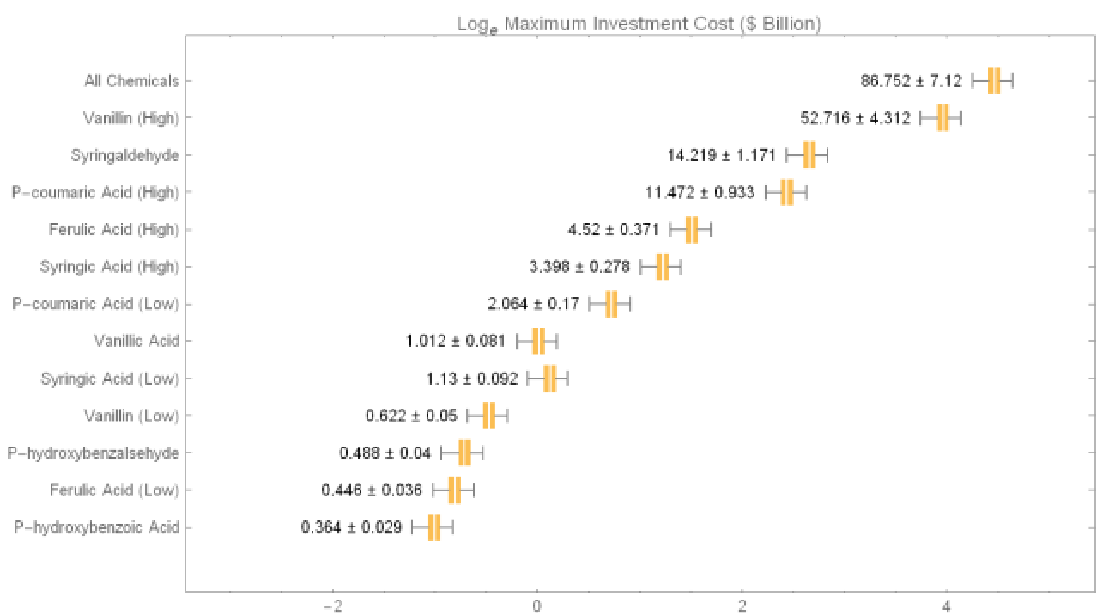

Fig 23. MIC uncertainty.

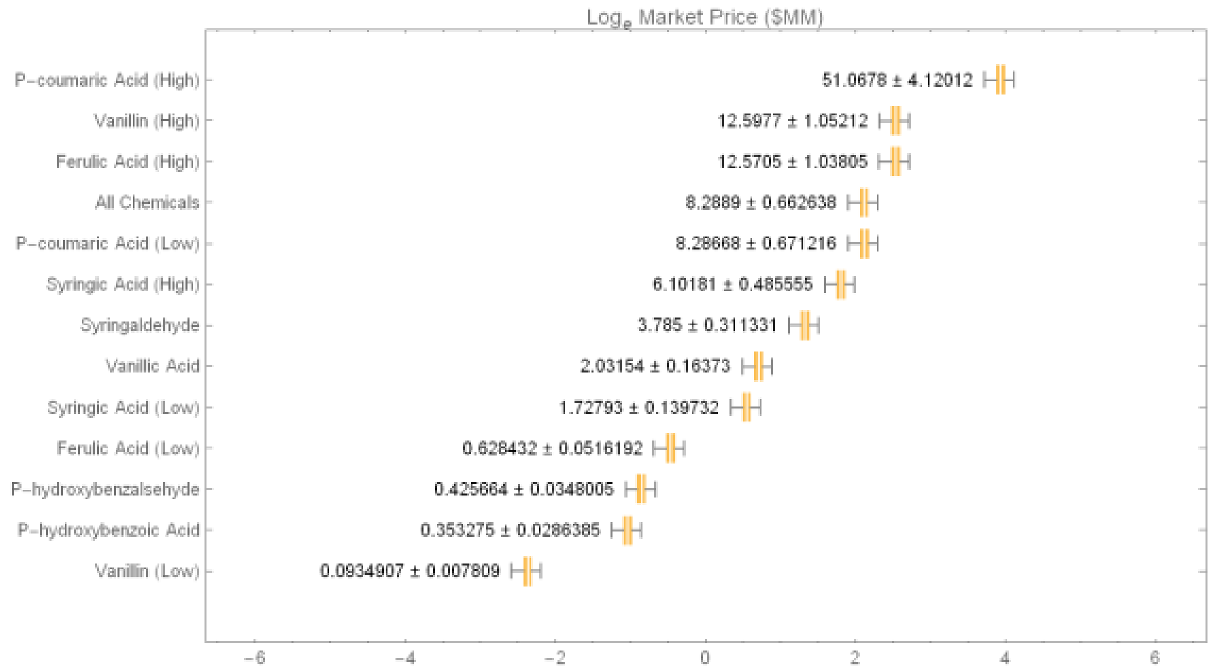

Fig 24. Scaled up chemical market price uncertainty.

✓ **Conclusions.**

- ➢ Coumaric acid has the highest MPSP and market price.
- ➢ Highest MIC is encountered when all lignin-derived chemicals are considered at $87 billion and this also presents the lowest selling price.
- ➢ Hydroxybenzoic acid requires the lowest MIC of $ 0.4 billion

- **Prepare and Characterize Biochar**

✓ The missing DOC data was obtained allowing us to complete work on a biochar aging manuscript which was submitted to the *Journal of Environmental Quality*. A second manuscript entitled *Accelerated ageing of biochars; impact on anion exchange capacity* was submitted to the journal *Carbon* and has received promising peer reviews. A response to the reviewers' comments and revised manuscript have been completed and submitted to the editor. Work continues on development of metal treated biochars, which are potential high value co-products of biomass pyrolysis. A manuscript entitled *Aluminum and iron biomass pretreatment and impacts on biochar anion exchange capacity* is nearly ready to be submitted for publication. Following are reports of ongoing laboratory research on biochar characterization.

- **Characterization of aging effects on water soluble DOC and labile components of biochars.** Ratios of absorbances in the UV-vis spectrum have been commonly used as a proxy for DOC concentrations of aqueous extracts. Here, we studied the E2/E3 and E4/E6 ratios to assess the quality of DOC in biochar aqueous extracts. The E4/E6 absorbance ratio of aqueous biochar extracts increased after aging, with the exception of the SS and CS biochars (Table 5). This suggests that the water-soluble organic compounds became more aliphatic/less aromatic during aging. Although, a higher E4/E6 ratio may also be related to lower molecular weight compounds and higher concentrations of COOH functional groups. Similarly, the E2/E3 ratios of extracts from aged biochars were higher (except for the HG and SG biochars) compared to the E2/E3 ratio for fresh biochar extracts. The E2/E3 ratio increased more as a result of aging for extracts from slow pyrolysis biochars whereas the E4/E6 ratio increased more for extracts from the fast pyrolysis and gasification biochars following aging. The results demonstrate a compositional change in the nature of water-soluble organic compounds upon aging that is consistent with a shift from pyrogenic to biogenic organic compounds. Water-soluble organic compounds are only a relatively small fraction of the total VM in the biochars and are likely an exclusive rather than representative fraction of the VM. Nonetheless, the changes in E4/E6 and E2/E3 ratios are indicative of the overall changes in the nature of biochar VM on aging and suggest that the laboratory aging and field aging processes are moving in the same direction.

  In general, total C content of biochars increased as a result of lab-aging whereas mixed results were obtained for field aged biochars, which is consistent with the observation of increased ash content (presumably due to the accumulation of clay in the field aged biochars). The largest increase in total C content was observed for the herbaceous SF (about 31%) and CF (about 26%) biochars, while biochars from hardwood feedstocks showed a smaller increase in total C content (2.25% - 3.65%) as a result of aging. Similarly, total N content of all biochars used during laboratory and field aging increased due to aging with the exception of CS and MNS (Table 5). In general, fast pyrolysis and gasification biochars had a larger increase in N content on aging while the slow pyrolysis biochars had a smaller increase in N content after aging. The labile (acid extractable) C content generally increased on aging for all FA biochars, whereas mixed results were obtained for the LA biochar samples. The highest increase was observed for HS2 biochar (~308%) and lowest was for SG biochar (~28%). Labile C (%) content increased linearly with percentVM for gasification biochars, decreased linearly for the fast pyrolysis biochars, and showed no clear trend for the slow pyrolysis biochars

(Fig. 25). The labile C fraction provides additional evidence for differences in the compositional chemistry of VM in gasification and fast pyrolysis biochars.

Table 5. Absorbance ratios, labile C and elemental composition of 11 fresh and 6 lab aged (LA) and 5 field aged (FA) biochars.

Biochar	Absorbance ratios		Labile C	Elemental Composition (%)		
	E_2/E_3	E_4/E_6	(%)	C	H	N
Fresh HF*	2.3 (0.07)	1.8 (0.05)	3.13 (0.25)	67.4 (0.09)	3.3 (0.03)	0.15 (0.001)
LA HF	4.3 (0.07)	9.02 (0.5)	6.27 (0.5)	68.9 (0.6)	3.3 (0.04)	0.22 (0.003)
Fresh HS1	2.02 (0.12)	1.4 (0.07)	2.81 (0.4)	76.6 (0.43)	2.7 (0.01)	0.38 (0.001)
LA HS1	7 (0.3)	2.6 (0.25)	2.32 (1.1)	79.4 (0.6)	2.85 (0.016)	0.43 (0.012)
Fresh HG*	6.5 (05)	5.7 (0.34)	2.68 (0.3)	82.7 (0.24)	1.57 (0.04)	0.29 (0.001)
FA HG	4.4 (0.44)	12.2 (1.4)	4.68 (0.3)	73.3 (0.51)	1.7 (0.03)	0.46 (0.0002)
Fresh SF*	1.26 (0.04)	10.5 (0.2)	2.81 (0.04)	53.1 (0.1)	2.95 (0.01)	0.63 (0.01)
LA SF	4.7 (0.1)	25 (6.7)	2.91 (0.8)	69.7 (0.2)	3.44 (0.01)	0.83 (0.009)
Fresh SS*	2.4 (0.3)	1.5 (0.23)	2.94 (0.7)	71 (0.36)	2.9 (0.04)	0.88 (0.01)
LA SS	9.02 (1.06)	1 (0.05)	1.91 (0.2)	73 (0.6)	3.14 (0.02)	0.98 (0.008)
Fresh SG*	5.18 (0.32)	7.6 (0.73)	7.8 (0.2)	63.4 (1.67)	1.57 (0.01)	0.59 (0.0004)
FA SG	3.8 (0.05)	10.3 (0.15)	10 (0.2)	59.4 (0.13)	2.43 (0.015)	0.98 (0.002)
Fresh CF*	2.3 (0.04)	4.6 (0.15)	5.18 (0.9)	52.4 (0.5)	2.6 (0.04)	0.46 (0.01)
LA CF	5.94 (0.04)	29.8 (6.8)	2.34 (0.7)	66.2 (0.54)	2.9 (0.03)	0.54 (0.02)
Fresh CS*	4.3 (0.12)	2.2 (0.16)	1.1 (0.4)	69.8 (0.2)	2.9 (0.02)	1.25 (0.01)
LA CS	11.8 (2.2)	1 (0.02)	2.14 (0.6)	77.6 (0.2)	3.1 (0.02)	1.1 (0.006)
Fresh CG*	1.09 (0.001)	5.4 (0.07)	6.5 (0.7)	51.9 (0.57)	2.02 (0.03)	0.84 (0.0005)
FA CG	3.8 (0.006)	12.9 (0.92)	10.9 (0.4)	57.4 (0.21)	2.15 (0.018)	0.93 (0.0006)
Fresh HS2*	3.2 (0.09)	2.2 (0.8)	4.13 (0.04)	84.2 (0.15)	2.75 (0.02)	0.4 (0.001)
FA HS2	6.4 (1.2)	5.8 (0.08)	16.87 (0.4)	72.6 (0.38)	2.7 (0.03)	0.6 (0.005)
Fresh MNS*	1.22 (0.02)	2.3 (0.6)	9.5 (0.7)	79.5 (0.45)	3.1 (0.01)	0.93 (0.01)
FA MNS	5.1 (0.04)	12.8 (0.5)	13.86 (0.9)	81.6 (0.5)	2.55 (0.03)	0.84 (0.002)

*HF = Hardwood fast pyrolysis, HG = hardwood gasification, HS = Hardwood slow pyrolysis, SF = soybean fast pyrolysis, SG = switchgrass gasification, SS = switchgrass slow pyrolysis, CF =cornstover fast pyrolysis, CG = corn stover gasifications, CS = corn stover slow pyrolysis, MNS = macadamia nut shell fast pyrolysis.

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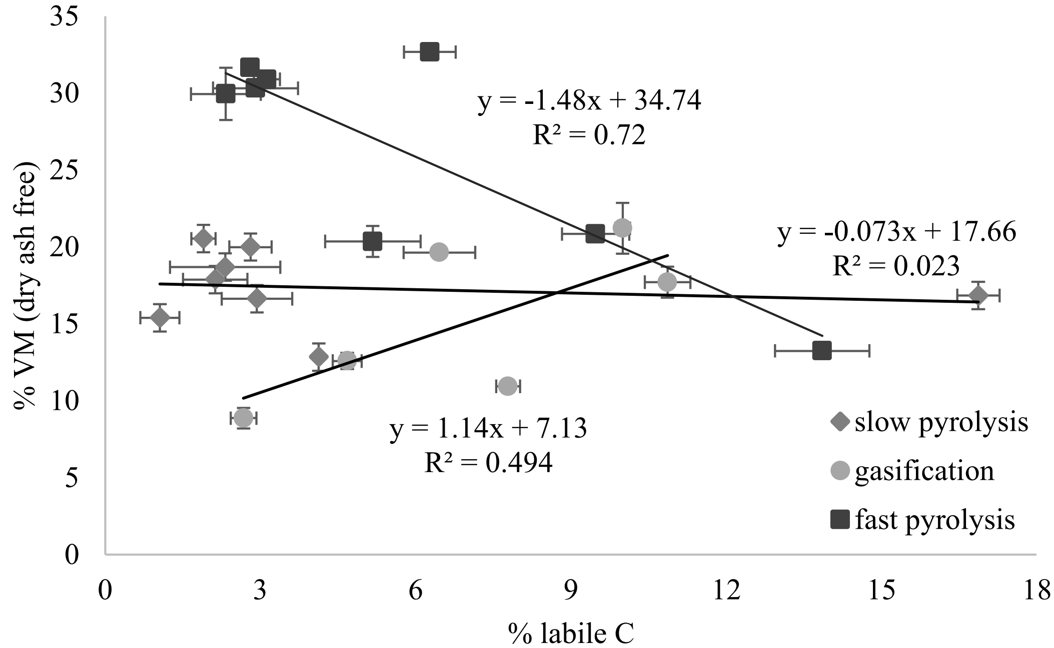

Fig 25. Relationship between % VM and % labile C of different biochars studied here

✓ **Investigations of the potential to produce biochar – zero valiant iron (BC-ZVI) composites are ongoing.** BC-ZVI are potentially high value catalysts that could be used to reductively dehalogenate TCE and other chlorinated solvents in environmental applications.

A small lab scale rotary kiln was built and used to conduct preliminary tests of ammonia activation of iron treated biochars. The analysis, however, showed no evidence of nitridization of ZVI in the biochars. We had hypothesized that nitridization would stabilize ZVI. Unfortunately, the failure to achieve nitridization of ZVI by ammonia activation means that alternate means of stabilizing ZVI are needed. Following are reports of other ongoing laboratory researched that is focused on producing BC-ZVI composites with stabilized ZVI.

➢ X-ray photoelectron spectroscopy (XPS) shows transformations that occurred during heating of BC-ZVI from 700 °C to 900 °C: decomposition of phosphates to phosphides yielding more paramagnetic Fe in BC-ZVI produced from DDG. This data supports results from XRD and XRF analysis which revealed evidence of iron phosphides in biochar prepared from DDG (Fig. 26).

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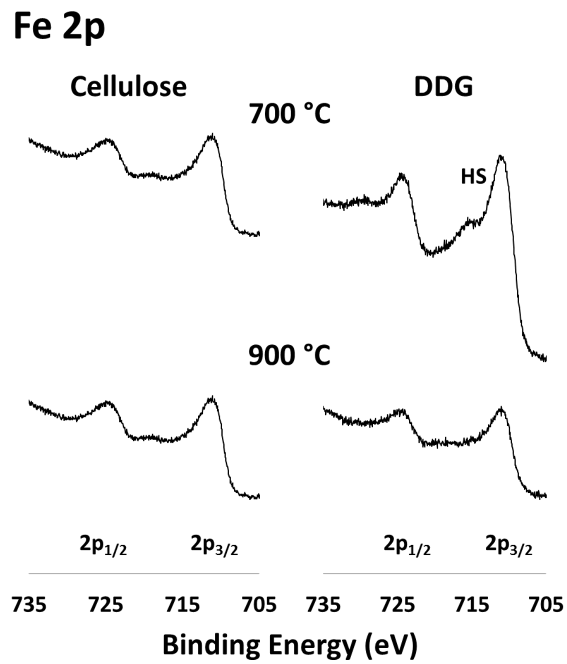

Fig 26. Fe2p XPS of biochars derived from cellulose and distillers dry grain (DDG).

We have previously shown that BC-ZVI composites can be produced from a variety of feedstocks, however, not all feedstocks yield stable ZVI appropriate for environmental applications due to rapid corrosion of ZVI in some biochars. Corrosion of Fe is described as a shell-core process by which oxidation occurs from the outside of a particle and proceeds toward the center and requires transport of electrons to an acceptor, typically diatomic oxygen (O_2), with diffusion of the latter into the lattice structure of ZVI. The electrical conductivity of Fe oxides that form during oxidation and the diffusivity of O_2 both influence the rate at which Fe corrodes. Examining the full width at half maxima of 001 x-ray diffraction (XRD) peaks of ZVI among BC-ZVI produced from cellulose, corn stover, red oak, and switchgrass reveals a consistent ZVI crystallite size among all biochars. However, ZVI in biochar produced from corn stover and switchgrass rapidly oxidized in a laboratory environment as evidenced by loss of the ZVI XRD reflections within one week. By contrast, ZVI in biochar produced from cellulose and red oak were stable against oxidation for over one month. Though oxidation of ZVI in these biochars occurred in a laboratory environment, the drastically different oxidation rates of ZVI among these biochars under the same conditions illustrate differences related to biochar and hence feedstock composition. Though BC-ZVI is intended to deliver corrodible Fe in environmental applications, corrosion that occurs too quickly cannot practically deliver the electron source needed for remediation of chlorinated organic compounds such as TCE in the soil.

The contrasting corrosion rates of ZVI in biochar produced from corn stover and switchgrass versus that of cellulose and red oak is related to association of ZVI with fayalite and the diffusivity of O_2 into ZVI crystallites. Figure 27 depicts SEM micrographs and corresponding elemental maps of Fe, Si, and chlorine (Cl) in fresh 900°C HTT BC-ZVI. Fe L series maps of biochar produced from corn stover and switchgrass reveal greater dispersion of Fe in these biochars while Fe in biochars produced from cellulose and red oak is more aggregated. Despite similar ZVI crystallite sizes, which only reflect statistically similar long range order of ZVI in these samples, aggregation of ZVI crystallites require diffusion of O_2 to greater depths within an Fe rich phase, thus slowing corrosion of ZVI. These contrasting Fe distributions partly account for the differences of ZVI corrodibility.

Association of Fe with Si observed in the elemental maps of biochars produced from corn stover and switchgrass support the identification of fayalite in the XRD patterns of these biochars. Fayalite is electrically conductive (Bradley et al, 1962) and increasing fayalite concentrations in solid solution with olivines and exsolved from ZVI phases has been shown to increase electrical conductivity of the composite (Hinze et al., 1981). Thus, fayalite facilitated corrosion of associated ZVI by enhancing electron transport during oxidation and also increasing defects site population in the ZVI continuum. Oxidation of both fayalite and ZVI is observed as transformation to quartz and hematite as revealed by XRD patterns of 900°C HTT BC-ZVI produced from corn stover and switchgrass. Thus, oxidation of fayalite and its association with ZVI, coupled with dispersion of ZVI phases caused the rapid corrosion of ZVI in BC-ZVI, indicating the need to select feedstocks low in Si for producing BC-ZVI with practical corrosion characteristics.

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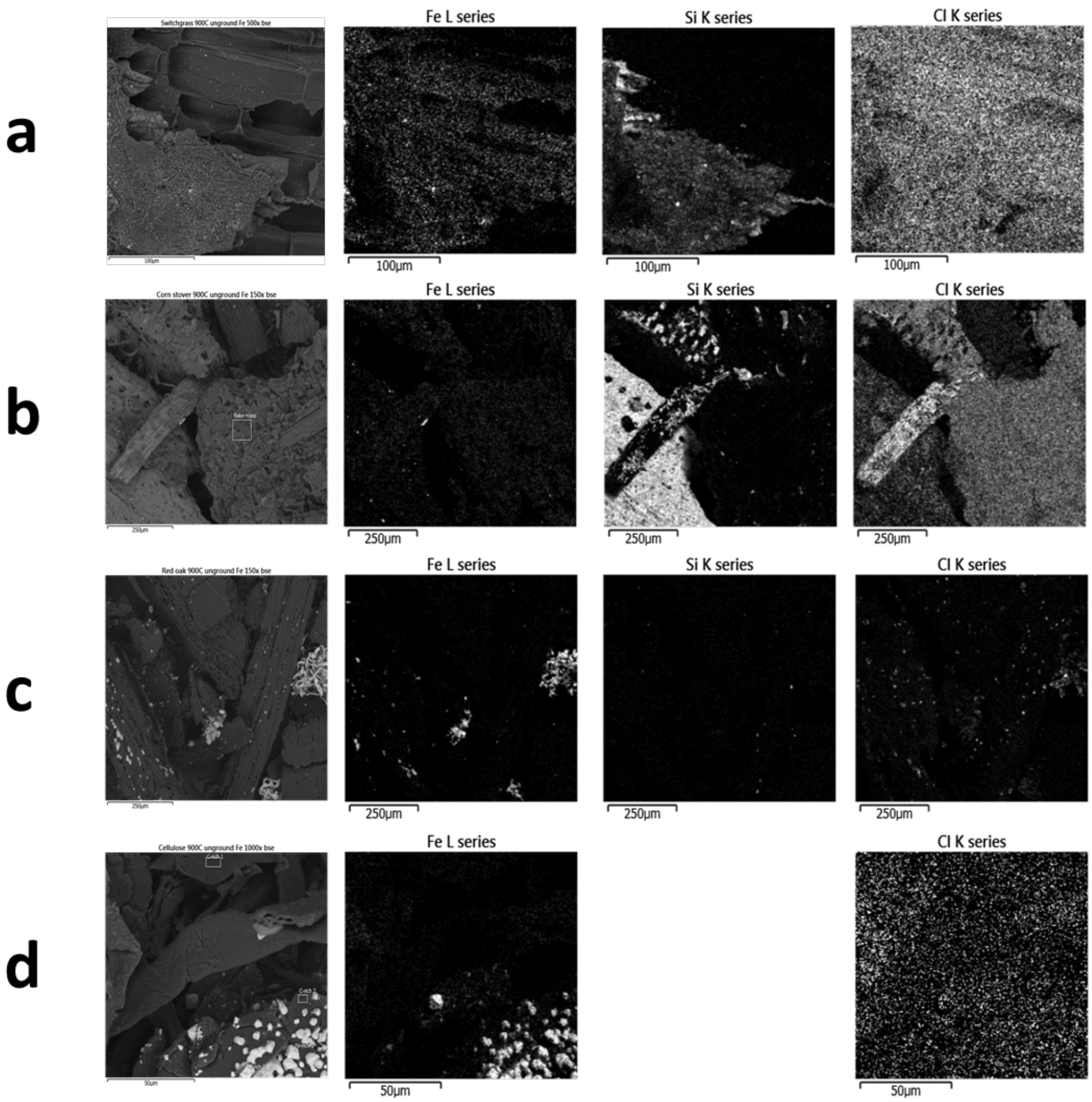

Fig 27. SEM micrographs and elemental maps of Fe, Si, and Cl of BC-ZVI. Letters indicate biochar feedstock; **a** (switch grass), **b** (corn stover), **c** (red oak), **d** (cellulose)

- A closer look (5000x magnification) at BC-ZVI produced from switchgrass at the HTT of 900°C reveals that surface Fe in this biochar was oxides in this biochar (Fig. 28). Some correlation is observed between Fe, Cl, and Si at closer magnification; however, as separate phases. The EDS spectra compare composition of an Fe rich phase in the left of the micrograph to an Fe poor region closer to the middle. Correlation of Si and Cl is more obvious than between Fe and Cl. The diffuse background of Cl and XRD evidence for sylvite indicate dispersion of nanometer scale sylvite crystallites scattered upon this biochar surface. Likewise, the concomitant presence of Si and absence of Fe in portions of the elemental maps and poor correlation of these elements in the EDS spectra illustrate different phases of different compositions and account for the combined quartz, sylvite, fayalite, and ZVI crystalline phases in this biochar. The small size of ZVI phases produced in this biochar and dispersion among other elements both contributed to rapid oxidation of ZVI. For purposes of environmental application, such BC-ZVI produced from switchgrass, corn stover, or other high Si feedstocks would exhibit rapid oxidation of ZVI with just storage and handling. Complete loss of ZVI may be achieved upon exposure to soil and water, rendering the product impractical. However, BC-ZVI from red oak and other lignocellulosic materials of low Si content are suitable for the production of BC-ZVI for environmental application as the ZVI corrodes slower.

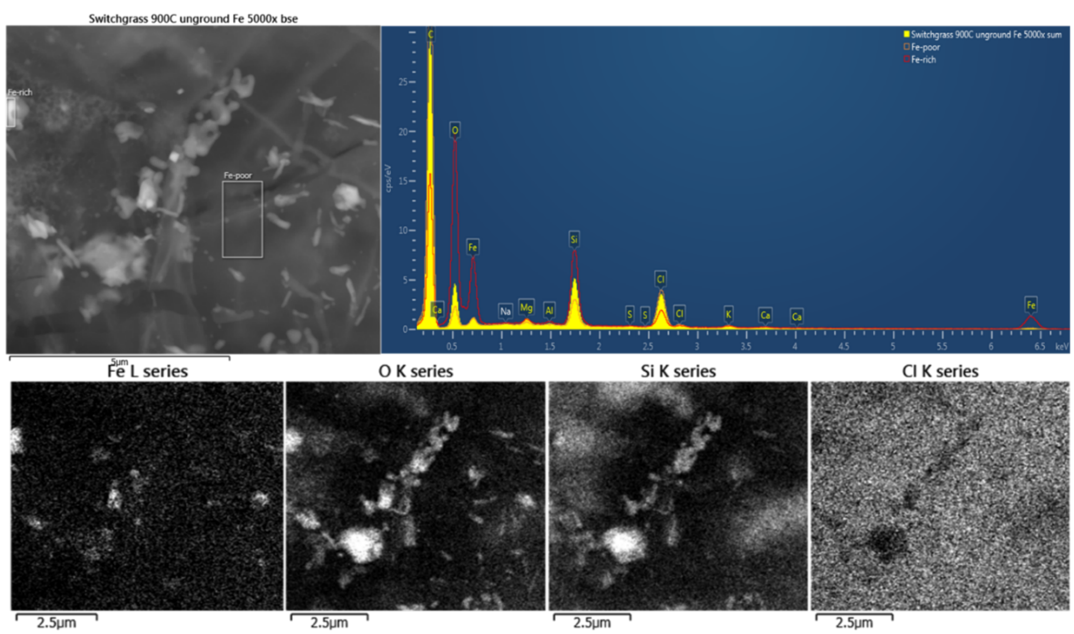

Fig 28. SEM-EDS analysis of BC-ZVI from switchgrass at 5000x magnification.

3. Explanation of Variance

Preliminary data on ammonia activation of biochars showed no evidence of nitridization of ZVI in biochar. Hence we are abandoning the idea of using ammonia activation to stabilize BC-ZVI composites. We have obtained more promising results by using cellulose and red oak biomass feedstocks for producing stable BC-ZVI composites.

4. Plans for Next Quarter

- **Techno-economic Analysis**

  Chemical recovery and purification systems, operating costs and capital costs will be investigated. Process models for chemical recovery with a focus on higher value chemicals will be developed.

- **Prepare and Characterize Biochar**

  The manuscript entitled "Aluminum and iron biomass pretreatment and impacts on biochar anion exchange capacity" will be completed. Laboratory research will assess pyrolysis and feedstock and temperature influences on the production of biochar-zero valent iron composites. A miscible displacement experiment will be designed and imitated to test the hypothesis that BC-ZVI are effective for dechlorination of trichloroethylene in soils.

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

   None.

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**

   - **Planned Activity A.** CenUSA co-project directors Keri Jacobs and Rob Mitchell and collaborator Chad Hart were working on a producer decision tool based on the project's parameters for perennial grass production. The expected output is a publicly-available decision aid on the CenUSA website and at Ag Decision Maker. The tool will be demonstrated to extension personnel. The components of the tool have been decided.

   - **Planned Activity B.** Continue work on a spatial model of biomass supply.

- **Planned Activity C.** Continue work on the economic feasibility of perennial grasses by modelling the cost optimization problem of a unique plant under different market structures. Initial findings suggest that residues from agriculture will not be available in sufficient quantities to meet the mandate at relatively low prices, and this will provide an opportunity for perennial grasses.

2. **Actual Accomplishments**

- **Planned Activity A.** Ongoing but nearing completion. This tool was rolled out in early December and is available on the CenUSA website (https://cenusa.iastate.edu/switchgrass-production-tool). The tool was presented at the Integrated Crop Management Conference at Iowa State University (December 2015).

- **Planned Activity B.** Ongoing. Hayes and Jacobs are working with industry partner DuPont to identify optimal market segmentations for biomass collection systems and contracting. This work is expected to be complete during summer, 2016.

- **Planned Activity C.** Ongoing.

3. **Explanation of Variance**

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

4. **Plans for Next Quarter**

During the third quarter of year 5 (Q3 Y5) our team will continue work on planned activities b and c above.

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

The CenUSA decision tool, *To Grow or Not To Grow: A Tool for Comparing Returns to Switchgrass for Bioenergy with Annual Crops and CRP* was published on the CenUSA website (https://cenusa.iastate.edu/switchgrass-production-tool).

Objective 7. Health and Safety

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

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

- The risks associated with producing feedstocks; and

- The risks of air/dust exposure.

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

    - **Planned Activities**

    Perform a series of runs to predict the risk difference between corn and switchgrass farming systems. Start a sensitivity analysis to determine factors contributing significantly to output variance. A technical paper proposal will be submitted to the International Society of Agricultural Safety and Health conference in June 2016.

    - **Actual Accomplishments**

    A series of runs or iterations were performed to predict the risk difference between corn and biofuel switchgrass farming systems. A total 500,000 iterations were used to complete the Monte Carlo output frequency distribution of the difference in risk between these two production systems. Corn productions systems had a higher likelihood of human injury than biofuel switchgrass production systems over a 10-year life cycle. Approximately 82 percent of the 500,000 iterations were negative values implying corn production systems risk was greater than biofuel switchgrass production systems. Conversely, approximately 28 percent of the 500,000 iterations were positive values implying biofuel switchgrass production systems risk was lesser than corn production systems.

    Sensitivity analysis to determine factors contributing significantly to output variance was conducted. The results identified harvest operations to be the largest contributing factor. This corresponds with expectations derived from the published research that harvest time is the critical injury time for the agricultural industry.

    A technical paper proposal was submitted to the International Society of Agricultural Safety and Health conference 2016. The proposed technical paper is still under review and the acceptance is expected in early May.

    - **Explanation of Variance**

    None to report.

    - **Plans for Next Quarter**

    Final calculations of risk between production systems will be completed and potential areas for model improvement will be identified for future efforts. A technical paper will be written for the International Society of Agricultural Safety and Health professional improvement committee. The preparation of a peer review journal article that shares the results of the model will begin.

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

  Ryan, S.J., Schwab, C.V. & G.A. Mosher. (2015). Agricultural Risk: Development of a probabilistic risk assessment model for measurement of the difference in risk of corn and biofuel switchgrass farming systems. ISASH Paper No. 15-01. International Society for Agriculture Safety and Health, International Meeting Normal, Illinois. ISASH Urbana, IL.

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

- **Planned Activities**

  Receive approval for modifications to the human subjects study and authorization to start selection of subjects.

- **Actual Accomplishments**

  Approval was not obtained at the time of this report. The approval process remains ongoing.

- **Explanation of Variance**

  Human Subject approval was not obtained. Additional efforts are needed to complete this part of the task.

- **Plans for Next Quarter**

  Receive approval for modifications to the human subjects study.

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

  No publication, presentations or proposal submitted from this task.

Education and Outreach

Objective 8. Education

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

- 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 a 10-week summer internship program modeled on the highly successful NSF REU (research experience for undergraduates) program. Subtask 2B is **training graduate students** via a two-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

- **Conversion Module 3 (Harvesting)**

  Edit pre-existing module on UNL PaSSeL site and bring on-line in new OSU Moodle site.

- **Module 9 (Enterprise Budgeting)**

  Add case study content with new cost estimation tool by Jacobs and Mitchell to draft module.

- **Conversion Modules 12 thru 15**

  Continue content refinement and on-line conversion.

- **Module 16**

  Complete initial draft of content.

2. Actual Accomplishments

- **Conversion Module 3 (Harvesting)**

  Edits were made to the lesson content on the UNL PaSSeL site and these will be brought on-line in the OSU Moodle site in the second quarter.

- **Module 9 (Enterprise Budgeting)**

  Refinement of draft content continues.

- **Module 13 (Biochemical Conversion)**

  Moodle lessons continue to be developed.

- **Module 16**

Draft content nearly complete.

- **Bioenergy MOOC**

  ✓ Manuscript *Learning from online modules in diverse instructional contexts* submitted for publication in IJELL.

  ✓ Course development nearly complete.

  ✓ Approval of The Ohio State University (OSU) institutional review board being sought.

3. Explanation of Variance

The lessons for Module 3 (Harvesting) were edited, but will not be brought on the OSU Moodle site until next quarter. This delay will not affect completion of any work.

4. Plans for Next Quarter

- **Module 3 (Harvesting)**

  Bring edited lessons online to Moodle site.

- **Module 13. (Preprocessing of Biomass Feedstocks)**

  Refine and add content to existing rough draft.

- **Module 14 (Biochemical Conversion)**

  ✓ Complete draft of initial Moodle lessons.

  ✓ Complete anaerobic digestion content draft.

- **Module 15 (Thermochemical Conversion)**

  ✓ Complete gasification and pyrolysis draft content lessons.

  ✓ Identify audio/video clips from past CenUSA presentations and other sources that can be used in the Moodle module.

- **Conversion Modules 17 (Introduction to Conversion)**

  ✓ Complete draft content.

  ✓ Begin drafting Moodle lesson.

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).
- Update program website to reflect 2016 program and research project opportunities.
- Promote the undergraduate internship program and encourage application submissions, working with lists of underrepresented minority students generated by ISU graduate college, and through job-posting boards at regional institutions, and by communication with Agronomy and Engineering department chairs at partner institutions.

2. Actual Accomplishments

- Obtained research project descriptions from faculty members. We plan to place a total of 13 students in the summer of 2016; five at Iowa State, two at Purdue University, four at the University of Nebraska, Lincoln, and two at the University of Wisconsin, Madison. These placements were selected due to the continued research activities within these project objectives, namely feedstock development (Objective 1), feedstock production (Objective 2), logistics (Objective 3), and feedstock conversion/refining (Objective 5).
- Promoted the undergraduate internship program to encourage application submissions as detailed above.
- Created a detailed schedule for the 2016 undergraduate internship program.
- Website content for the undergraduate internship program was updated to reflect the 2016 program and project opportunities.
- 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 as well as at Purdue, University of Nebraska, Lincoln, and the University of Wisconsin, Madison.

3. Explanation of Variance

None.

4. **Plans for Next Quarter**

- Continue to promote the undergraduate internship program and encourage application submissions through the March 1, 2016 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 approximately March 10, 2016 with selections and rankings of students requested from faculty by March 20.
- Highly ranked students, as indicated by faculty hosts, will be phone interviewed the weeks of March 21 and March 28, 2016.
- First offers to students beginning March 21, second offers to students beginning March 28 with cohort (13 students) finalized on April 15.
- 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. **Actual Accomplishments**

   None as this was strictly a PY2 and a PY4 program activity. No forward planning is required.

2. **Explanation of Variance**
   None.

3. **Plans for Next Quarter**

   None as this was strictly a PY2 and a PY4 program activity. No forward planning is required.

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

   None.

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

1. **Planned Activities**

   This series will no longer be offered, however, graduate students will be invited to participate in critical project meetings as objectives disseminate findings in this final year.

2. **Actual Accomplishments**

   None as this was strictly a PY1 - PY4 program activity. No forward planning is required.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

   None as this was strictly a PY1 - PY4 program activity. No forward planning is required.

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

Objective 9. Extension and Outreach

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

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

- **Extension Staff Training/eXtension Team**

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

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

  This team covers the areas of:

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

- Certified Crop Advisor training.

- **Economics and Decision Tools Team**

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

- **Health and Safety Team**

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

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

  This team focuses on two separate areas:

  - **Youth Development.** The emphasis is on developing a series of experiential programs for youth that introduce the topics of biofuels production, carbon and nutrient cycling, and biochar as a soil amendment.
  - **Broader Public Education/Master Gardener.** These programs acquaint the non-farm community with biofuels and biochar through a series of outreach activities using the Master Gardener volunteer model as the means of introducing the topics to the public.

- **Evaluation/Administration Team**

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

- **Extension Staff Training/eXtension Team**

  1. **Planned Activities**

     - Implement the November Harvest Social Media Plan.
     - Produce six stories for the December BLADES newsletter.
     - Continue working on production of the plant breeding and legacy videos.
     - Continue maintenance of eXtension CenUSA index.

2. Actual Accomplishments

- **CenUSA eXtension Website**

  - ✓ Continued updating and maintenance of CenUSA eXtension website: (http://articles.extension.org/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa)

  - ✓ The CenUSA eXtension web site received 4,054 page views by 2,843 users this quarter. Of these 78 percent were new sessions, averaging 1.2 pages per visit. Average time on page is 5.52 minutes.

  - ✓ Compared to last year, same quarter, CenUSA eXtension usage has significantly increased; page views and users are both up by 78 percent. However, this quarter shows a slump from the previous quarter (August – October, 2015). We attribute this to the end of the year holidays.

  - ✓ The "Switchgrass (*Panicum virgatum*) for Biofuel Production" publication remains the publication with the largest viewership this quarter, accounting for 23 percent of page views (1,755 views).

  - ✓ The top 10 states accessing CenUSA articles were IL, NY, MN, PA, NJ, IA, CA, MI, TN, TX and VA, with use from throughout the US and world; England and Ontario, Canada consistently have topped the international use.

- **Website.** The CenUSA web site had 1,049 visitors this quarter. These visitors logged a total of 2,853 pageviews during 1,401 sessions. Pageviews are the total number of pages that visitors looked at during their time on the site. A session qualifies as the entire time a user is actively engaging with the site. If activity ceases for an extended period of time, and the user returns, a new session is started. The CenUSA website had 1,646 visitors this quarter. These visitors logged a total of 3,765 pageviews during 2,074 sessions. Pageviews are the total number of pages that visitors looked at during their time on the site. A session qualifies as the entire time a user is actively engaging with the site. If activity ceases for an extended period of time, and the user returns, a new session is started.

- **Vimeo**. During this quarter, the 49 CenUSA videos archived on Vimeo have had 272 plays or views. The 49 videos also had 4,442 loads; 4,050 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 means the video was saved to their hard drive (users usually do this because they have limited internet connectivity which does not allow for live streaming of video). Once the video is downloaded, it is available on their computer to watch at their convenience.

- **YouTube**. CenUSA videos are also posted on YouTube, and those videos have been viewed 959 times between November 1, 2015 and January 31, 2016. Of these, 561 views were from the United States. Demographic analytics report an audience that is 85 percent male and 15 percent female. Our viewers ranged in age from 13-65+. The top 3 represented age groups were 25-34 (38%), 35-44 (17%), and 55-64 (15%). Users find our videos through various avenues, which are referred to as 'traffic sources." Our top 4 traffic sources for this quarter include: YouTube search, YouTube suggested videos, referrals from other web sites and direct URL usage. Forty-seven percent of our views came from users accessing videos through the YouTube Search. YouTube suggested videos accounted for 24 percent of our views. Referrals from outside YouTube (Google Search or access through external web sites) account for 17 percent of video views. Views from direct URL usage accounted for 4.4 percent of video views.

- **Twitter**. Twitter traffic consists of followers who subscribe to our account and "follow" our tweets (announcements). Followers can "favorite" a tweet, or retweet it to share with their own followers. They can also "mention" us by tagging CenUSA bioenergy's twitter account in their own tweets. During this quarter, our tweets were retweeted a total of 109 times. Followers tagged CenUSA tweets as a favorite 50 times, and mentioned us 91 times. CenUSA bioenergy also has 743 followers currently, up from 667 followers last quarter.

- **Facebook**. By the end of January 2016, CenUSA's Facebook page had 229 likes, up from 225 the previous quarter. Our most liked post from this quarter received 24 likes. The highest daily reach of the quarter had a total reach of 426 individuals.

- **BLADES Newsletter**. The CenUSA communications team published one newsletter this quarter in December, and was sent to 877 people, with 282 unique opens (33%). This issue featured six e-stories:

  ✓ FDC Enterprises Building the Perennial Grass Energy Supply Chain (http://blades-newsletter.blogspot.com/2015/12/fdc-enterprises-building-perennial.html).

  ✓ CenUSA Perennial Grass Research "Yields" Impressive Results (http://blades-newsletter.blogspot.com/2015/12/cenusa-perennial-grass-research-yields.html).

  ✓ Planting Perennial Grasses in the Midwest to Reduce Water Pollution (http://blades-newsletter.blogspot.com/2015/12/planting-perennial-grasses-in-midwest.html).

- ✓ To Grow or Not to Grow: New Switchgrass Decision Tool (http://blades-newsletter.blogspot.com/2015/12/everything-switchgrass-producer-needs.html?utm_source=December+2015+Issue+-+BLADES&utm_campaign=Oct+15+CenUSA+Bioenergy+Newsletter&utm_medium=email).
- ✓ 100 Grannies March on Washington (http://blades-newsletter.blogspot.com/2015/12/100-grannies-march-on-capitol.html).
- ✓ Harvesting Bales from Start to Finish (http://blades-newsletter.blogspot.com/2015/12/harvesting-bales-from-start-to-finish.html).

3. Explanation of Variance

None noted.

4. Plans for Next Quarter

- Finish production and editing of the plant breeding video and post to Vimeo.
- Begin new fact sheet or research summary on new "Willingness to Produce" data from CenUSA collaborator's Richard Perrin study.
- Publish and distribute 2 newsletters: February and April 2016 editions.
- Continue production and editing of 7-10 minute CenUSA legacy video that documents the CenUSA project since its inception. Add additional video clips to the legacy video including: student poster session, biochar, crop harvesting and economics. Summarize concise list of achievements over the project's 5 years and add intro and ending transitions and voice overs.
- Continue maintenance of CenUSA eXtension index (http://articles.extension.org/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa).

5. Publications, Presentations, Proposals Submitted

- BLADES Newsletter, December 2015 (http://blades-newsletter.blogspot.com/p/dec-15.html).

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

1. Planned Activities

- **Indiana**

  Presentation at Huntington County annual meeting.

- **Iowa**

  Harvest switchgrass plots at Southeast Iowa Research and Demonstration farm and demonstration plots of farmer cooperator Phil Winborn's farm.

- **Minnesota**

  ✓ Presentation at Crops, Soil, and Agronomy Societies of America's annual meeting.

  ✓ Complete post-frost grassland assessment and harvest.

- **Nebraska**.

  Harvest biomass at each CenUSA demonstration site.

2. Actual Accomplishments

- **Indiana**

  Gave a presentation at the Huntington County annual meeting. Discussed perennial grasses and promoted CenUSA Perennial Grass Decision Tool. 35 people attended (26 males and nine females).

- **Iowa**

  Harvested switchgrass plots at Southeast Iowa Research and Demonstration farm and demonstration plots at farmer cooperator Phil Winborn's farm.

- **Minnesota**

  ✓ Anne Sawyer presented at the Crops, Soil and Agronomy Societies of America's Annual Meeting. She discussed CenUSA plots, including establishment, yield, nitrogen uptake and rhizosphere microbial structure in 'Shawnee', 'Liberty' and 'Sunburst' switchgrass.

  ✓ Completed post-frost grassland assessment and harvest.

- **Nebraska**

  Harvested biomass at each of the CenUSA demonstration sites.

3. Explanation of Variance

None noted.

4. Plans for Next Quarter

- **Indiana**
  - ✓ Brainstorm possible CenUSA comprehensive workshop.
  - ✓ Assist Pam Porter on CenUSA Legacy video.
- **Iowa**
  - ✓ Fertilize switchgrass demonstration plots.
  - ✓ Discuss and share the perennial grass decision tool in agronomy newsletter sent to growers and landowners in southeast Iowa.
- **Minnesota**
  - ✓ Interact with SWCDs in selected Minnesota counties to identify landowners or growers who might be interested in completing the switchgrass decision tool.
  - ✓ Continue processing grass samples from demonstration plots for further testing. Package and ship to UNL per project protocol. Prepare fertilizer treatments for 2016 demonstration plot.
- **Nebraska**
  - ✓ Fertilize CenUSA biomass demonstration plots at each location.
  - ✓ Control weeds in demonstration plots as needed.
  - ✓ Accept requests for CenUSA presentations through University of Nebraska Speakers Bureau.
  - ✓ Initiate a conference call with stakeholders to discuss the topic of perennial grasses in a resilient agricultural landscape.
  - ✓ Farm magazine articles.
  - ✓ Possible youth teaching.

5. Publications, Presentations, Proposals Submitted

None submitted.

Economics and Decision Tools

1. Planned Activities

- Complete work on prototype U of MN Crop Budget Tool (http://cropbudget.apec.umn.edu/).
- Continue to promote use of Ag Decision Maker Perennial Grass Tool (http://www.extension.iastate.edu/AgDM/crops/html/a1-29.html).
- Complete analysis of the survey conducted with farmers and land owners in the CenUSA region regarding their willingness to produce switchgrass at different price points.

2. Actual Accomplishments

- The University of Minnesota Crop Budget Tool is largely done, but there is one last bug in the seed cost calculations in the detailed budget report. The programmer has moved over to another project for most of his time, but is also working part-time on fixing the bug.
- Conducted two training sessions on the *Switchgrass Decision Tool* at the Integrated Crop Management Conference on December 2, 2015 in Ames, IA. There were 62 participants in the sessions (58 males and 4 females).
- Continued outreach and promotion of the CenUSA *Switchgrass Decision Tool*. Data for January, 2016 is not yet available, but in November-December, 2015, 62 individuals accessed the CenUSA switchgrass pdf about the Decision Tool (http://www.extension.iastate.edu/AgDM/crops/pdf/a1-29.pdf) and 23 completed the Decision Tool Spreadsheet (http://www.extension.iastate.edu/AgDM/crops/html/a1-29.html). This brings May-December 2015 totals for Decision Tool outreach to:
  - ✓ 267 individual downloads of the CenUSA switchgrass pdf.
  - ✓ 336 individual completions of the CenUSA *Switchgrass Decision Tool*.
- Completed analysis of survey responses from 1043 farmers and landowners in the CenUSA region. Analysis revealed that about 10 percent of farm operators would produce switchgrass for biofuel at a price of $60/ton; 25 percent would do so at $75/ton and the mean price necessary for production was $84/ton. Landowners responses to the prospect of leasing out their land for someone else to produce switchgrass for biomass indicated they were less willing to lease than to produce themselves, with $80/ton necessary to convince the first 10 percent to lease, and a

mean willingness to lease land for switchgrass production of $95/t.

3. **Explanation of Variance**

None.

4. **Plans for Next Quarter**

- Finalize prototype U of MN Crop Budget Tool (http://cropbudget.apec.umn.edu/).
- Continue promotion, outreach and education about *Switchgrass Decision Tool*.
- Include information about the farmer/land owner survey in communications product.

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

See above.

- **Health and Safety**

See Objective 7.

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

- **Youth Development**

1. **Planned Activities**

- **Indiana**

✓ Continue to finish edits on curriculum and supporting materials and launch web portal for access to all Purdue developed CenUSA Youth Extension and education materials.

✓ Complete draft of journal article focused on 4-H Renewable Energy Science Workshops.

✓ Continue collaboration in Indiana State 4-H and Indiana Corn Board to create "Teens Teaching…" model for Bioenergy. Training for first teams of teens to be held in March, with supporting materials for the teaching teams under development currently.

✓ Continue work on electronic companion materials for demonstration plot signage.

- **Iowa**

Host CenUSA C6 sessions at:

- ✓ 4-H Region 20 Food to Fuel Event, Nov 11.
- ✓ Cedar Valley STEM Festival, Nov 12.
- ✓ Region 1 STEM Festival, Nov 14.
- ✓ YouthFest, Nov 17.
- ✓ Ames High School Presentation, Nov 20.
- ✓ FIRST LEGO League, Jan 16

2. Actual Accomplishments

- **Indiana**

  - ✓ Proposal accepted for HASTI 2016 – Houser Association of Science Teachers.
  - ✓ Continued work on electronic companion materials for demonstration plot signage.
  - ✓ Final edits to high school curriculum.
  - ✓ Collaborated with Indiana State 4-H and Indiana Corn Board to create "Teens Teaching Model for Bioenergy." Training for first teams of teens to be held in March 2016, with supporting materials for the teaching teams currently under development.

- **Iowa**

  Conducted C6 Outreach for a total of 410 participants:

  - ✓ 4-H Region 20 Food to Fuel Event, Nov 11, 2015, 21 participants.
  - ✓ Cedar Valley STEM Festival, Nov 12, 2015, 134 participants.
  - ✓ Region 1 STEM Festival, Nov 14, 2015, 30 participants.
  - ✓ YouthFest, Nov 17, 2015, 23 participants.
  - ✓ Ames High School Presentation, Nov 20, 2015, 28 participants.
  - ✓ FIRST LEGO League, Jan 16, 2015, 24 participants.

A subset of the participants completed the survey process for C6 to gage learning and attitudes – results are below (Figs. 29 & 30):

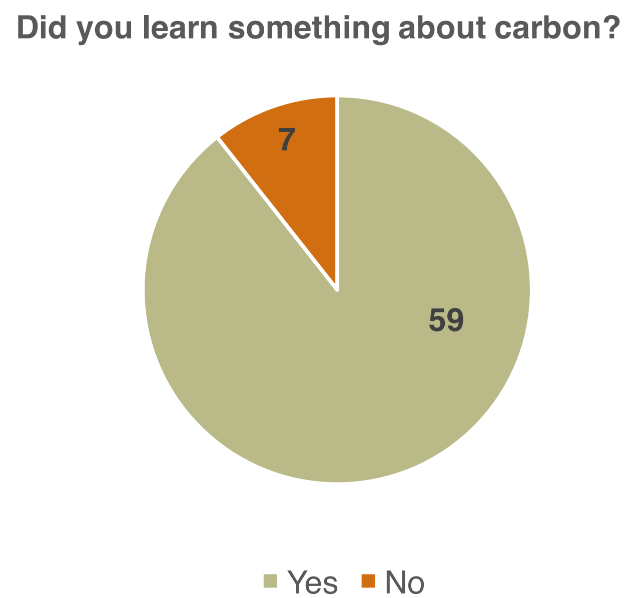

Fig 29. Playing C6 BioFarm at Iowa State Fair – Carbon Kowledge

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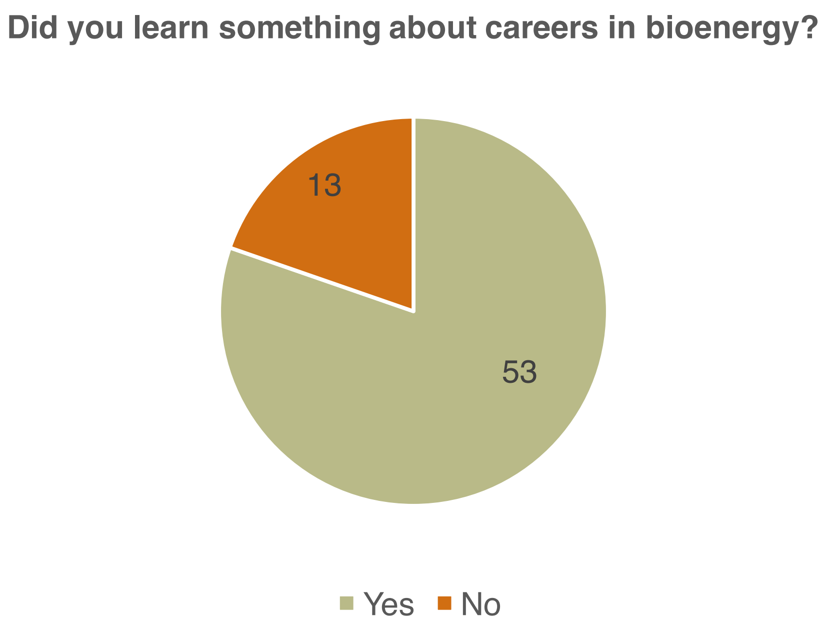

Fig. 30. Playing C6 BioFarm at Iowa State Fair – Bioenergy Careers

3. Explanation of Variance

The Indiana program transitioned work load from Matt Kararo (graduate student) to Melissa Voigt (post doc).

4. Plans for Next Quarter

- **Indiana**

  ✓ Finish edits on curriculum and supporting materials and launch web portal for access to all Purdue developed CenUSA Extension and education materials.

  ✓ Submit journal article focused on 4-H Renewable Energy Science Workshops to Journal of Extension.

  ✓ Continue collaboration with Indiana State 4-H and Indiana Corn Board to create "Teens Teaching…." Model for Bioenergy. Training for first teams for teens to be held in March.

  ✓ Continue development of supporting materials for "Teens Teaching…" model for Bioenergy.

  ✓ External review of curriculum and electronic companion materials for demonstration plot signage for publication requirements.

- **Iowa**

  Host CenUSA C6 sessions at the following events:

  ✓ Cedar Rapids STEM Festival, February 23.

  ✓ Taking the Road Less Traveled, March 31.

  ✓ Tama County Family STEM Festival, April 3.

  ✓ Northeast Iowa Family STEM Festival, April 7.

  ✓ Drake University STEM Festival, April 14.

  ✓ Dubuque Family STEM Festival, April 16.

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

   Proposal accepted for HASTI 2016 – Hoosier Association of Science Teachers.

Broader Public Education/Master Gardener Program

The Master Gardener program segment of the CenUSA Extension objective concluded last quarter. However, the project team is in the process of summarizing the data from their 4-years of biochar demonstration gardens and is preparing an extension publication on the topic.

Evaluation and Administration

1. **Planned Activities**

- Collect information from CenUSA Extension teams and prepare reports.
- Continue support for development of CenUSA C6 Youth app, videos, and iBook.
- Meet with CenUSA Extension teams to budget for no-cost extension.
- Present session about CenUSA Extension at the *Nexus of Food, Energy and Water* Conference in Washington D.C. on January 20th, 2016.

2. **Actual Accomplishments**

- Collected and prepared reports.
- Worked with CenUSA Youth Team to prepare and submit IRB request for research

project to be conducted summer and fall of 2016.

- Worked with CenUSA Extension teams in IA, NE, MN, IN to budget for no-cost extension.
- Presented session about CenUSA Extension at the Nexus of Food, Energy and Water Conference in Washington D.C. on January 20, 2016.

3. Explanation of Variance

None.

4. Plans for Next Quarter

- Develop survey instruments, conduct analysis of surveys completed by participants, and produce reports summarizing impact of CenUSA Extension efforts.
- Support C6 team to continue development of educational materials targeting K-12 youth.
- Meet with all CenUSA Extension teams to continue planning and orchestrating to meet deliverables in the CenUSA work plan.
- Collect information from CenUSA team members and prepare reports

5. Publications, Presentations, Proposals Submitted

None this quarter.

Objective 10. Commercialization

▪ Sub Objective 10A. Archer-Daniels-Midland

The Commercialization Objective was initiated in project year 4 (2015-2015) to evaluate near and long-term commercialization prospects for products produced from perennial grasses grown on marginal land. It involves two commercial partners, ADM and Renmatix, who are evaluating CenUSA feedstocks in their conversion processes.

1. Planned Activities

In the last report, the proprietary pretreatment method was applied to several types of technical lignins (acetosolv lignin, supercritical hydrolysis lignin, and alkali lignin) and agglomeration was presented for all the lignin tested. The mechanisms of lignin agglomeration during pyrolysis were studied. The lignin pyrolysis char was characterized by FTIR. The lignin pyrolysis oil was upgraded by HZSM-5 in a tandem micropyrolyzer system under both helium and hydrogen atmosphere.

In this period, to investigate the effect of biomass resources and extraction methods on the thermochemical conversion of lignin, three biomass sources: corn stover, red oak, and loblolly pine were used as feedstock for lignin extraction. Different extraction methods: milled lignin, organosolv lignin, alkali lignin, and klason lignin, were applied to compare the structure changes after different processes. The lignin structure was analyzed by TGA, elemental analysis, FTIR, and GPC.

2. Actual Accomplishments

- **Extraction of Lignin from Different Biomass Resources**

  ✓ **Biomass Preparation for Lignin Extraction.** Corn stover, red oak, and loblolly pine were milled for 30 min at 400 rpm using a planetary ball mill (Retsch PM100). The ball milled samples were treated by ethanol to remove extractives. The extractive free samples were dried at 105°C for 24 hours.

  ✓ **Milled Lignin Process.** The extractives free biomass sample was milled in a planetary ball mill for 48 hours, the ball milled sample was extracted by dioxane: water (96;4, v/v) for 24 hours and repeaed once. The lignin was further purified and dried at 50°C.

  ✓ **Organosolv Lignin Process.** A solvent mixture of ethanol and water (125 ml ethanol and 125 ml water) was used for lignin extraction. A 15-g sample of biomass and 1.5 g sulfuric acid were added to the mixture. The solution was transferred into a 500 ml parr reactor, the reactor was heated to 180°C then cooled down. The solution was filtered through filter paper (Whatman 42), the filtrate was precipitated in 750 ml water, and the solid residue was collected and dried at 50°C.

  ✓ **Klason Lignin Process.** The biomass sample was treated using 72 percent sulfuric acid at 30°C for 1 hour, then water was added to dilute the sulfuric acid concentration to 4 percent, heated to 121°C using an autoclave for 1 hour. The solution was then filtered and the solid residue was dried at 50°C.

  ✓ **Alkali Lignin Process.** The biomass sample was treated with 5 percent of NaOH (10 g sample/220 ml extractant) at 50°C for 6 hours. After reaction, the solution was neutralized with 6 M HCl to pH 5.5. The hemicellulose was removed by precipitation in 3 volumes of ethanol. After evaporation of ethanol, the alkali soluble lignin was precipitated at pH 1.5. The solid lignin residue was washed with acidified water (pH 1.5-2.0) and then dried at 50°C.

Acetosolv lignin from corn stover was provided by ADM.

- **Proximate Analysis (TGA)**

✓ The proximate analysis was performed in a TGA (TGA/DSC 1 STARe system, Mettler Toledo). Approximately 10 mg of lignin samples were placed in a crucible, heated to 105°C at 10°C/min, and held at that termperature for 40 minute, after which heating continued to 900°C at 10°C/min where the temperature was held for 20 minutes, then air was introduced to combust the residue for ash content.

✓ The results are listed in Tables 6 to 8. Clearly, the milled lignin has highest yield of volatiles (69.08%). The volatiles were generated by cleaving the C-O-C ether bond and C-C bond at different temperature stages. All other extracted lignins have lower yields of volatiles, which indicates that the ether bonds and some of the C-C bonds were destroyed during the extraction process. Among these lignins, klason lignin has the least yield of volatiles. Accordingly, milled lignin has low yield of fixed carbon since it is riche in oxygen in its structure. The ADM acetosolv lignin has the highest yield of fixed carbon, which means its structure was more condensed because of the removal of C-O-C bond during extraction process. Klason lignin has a relatively high ash content which was from its original corn stover biomass (3.49% of ash).

✓ Similarly, for lignins from red oak and loblolly pine, the milled lignin has higher yield of volatile matter since it preservesoriginal ether bonds which can be broke down at 200-300°C. And organosolv lignin produces a higher yield of fixed carbon than milled lignin.

Table 6. Proximate analysis of corn stover lignins from different extraction methods.

		Moisture	Volatiles	Fixed C	Ash
Corn stover	Milled	2.81	69.08	27.81	0.31
	Organosolv	4.21	64.00	30.99	0.80
	ADM acetosolv	2.15	60.97	36.56	0.32
	Klason	2.42	58.93	32.42	6.23
	Alkali	1.94	64.37	32.85	0.83

Table 7. Ultimate analysis of red oak lignins from different extraction methods.					
		Moisture	Volatiles	Fixed C	Ash
Red oak	Milled	1.82	70.9	26.72	0.56
	Organosolv	2.92	54.86	40.53	1.7

Table 8. Ultimate analysis of loblolly pine lignins from different extraction methods.					
		Moisture	Volatiles	Fixed C	Ash
Lob. Pine	Milled	2.78	62.9	33.7	0.64
	Organosolv	3.91	58.7	36.9	0.48

- **Ultimate Analysis (CHNS-O)**

Ultimate analysis was conducted in an elemental analyzer (Vario Micro Cube, Elementar), and the results were listed in Tables 9 to 11. The milled lignin have lower yield of carbon and higher yield of oxygen since it preserves most C-O-C bond while the organosolv lignins lost oxygen during extraction process. All the lignin samples contained a low amount of nitrogen and sulfur.

Table 9. Ultimate analysis of corn stover lignins from different extraction methods.						
		N%	C%	H%	S%	O%
Corn Stover	Milled	0.46	58.42	4.74	0.04	36.35
	Organosolv	0.78	64.00	4.95	0.2	30.07
	ADM Acetosolv	1.63	62.58	4.7	0.24	30.86

Table 10. Ultimate analysis of red oak lignins from different extraction methods.						
		N%	C%	H%	S%	O%
Red oak	Milled	0.36	57.48	4.68	0.08	37.41
	Organosolv	0.24	61.3	4.49	0.76	33.22

Table 11. Ultimate analysis of loblolly pine lignins from different extraction methods.						
		N%	C%	H%	S%	O%
Lob. Pine	Milled	0.18	59.69	4.93	0.03	35.19
	Organosolv	0.3	65.65	5.13	0.05	28.86

- **GPC Analysis**

The lignin samples were acetylated prior to GPC analysis. Briefly, 100 mg of lignin was reacted with 3 ml of pyridine and 3 ml of acetic anhydride at 80°C in an oil bath for 3 hours, with continuous agitation.

Since the milled lignin extraction process is a relatively mild process, the original C-O-C ether bonds were not cleaved. The GPC results (Tables 12 to 14) show that milled lignin has a higher average molecular weight than organosolv lignins. This proves that during the organosolv process, lignin was decomposed to smaller sizes due to bond cleavage. The molecular weight of ADM acetosolv lignin is lower than milled lignin, but higher than organosolv lignin (prepared in lab scale).

Table 12. GPC analysis of corn stover lignins from different extraction methods.

		MW*	MN**	Polydispersity (PD)
Corn Stover	Milled	3858	2523	1.53
	Organosolv	1937	1206.5	1.61
	ADM Acetosolv	3198	1421	2.25

Table 13. GPC analyis of red oak lignins from different extraction methods.

		MW*	MN**	Polydispersity (PD)
Red oak	Milled	4659	2150	2.18
	Organosolv	1803	1139	1.59

Table 14. GPC analysis of loblolly pine lignins from different extraction methods.

		MW*	MN**	Polydispersity (PD)
Lob. Pine	Milled	5364	2749	1.96
	Organosolv	2229	1109	2.01

*MW is “weight average molecular weight (avg. molecular weight of molecules/polymers)
**MN = “number average molecular weight (weight of sample/number of molecules

- **FTIR Analysis of Different Lignins**

FTIR (Nicolet iS10 Smart iTR, Thermoscientific) was applied to investigate the structure change between milled lignin and organosolv lignin (Figs. 31 to 33). The band at 1750-1650 cm^{-1} represents C=O stretch in ketones, carbonyls, aldehydes and carboxylic acids. All the organosolv lignins show a decrease in this region, which can be caused by the removal of oxygen-containing functional groups. The aromatic stretch shows an increase (1600-1500 cm^{-1}), which means that the weak bonds in lignin side chains were broken down and the oxygen-containing functional groups were removed so that the lignin became more condensed. Another significant change in the lignin IR spectrum was the decrease of the C-O group (1080-1030 cm^{-1}) which indicates that the cleavage of the C-O-C ether bonds occurred during the extraction process.

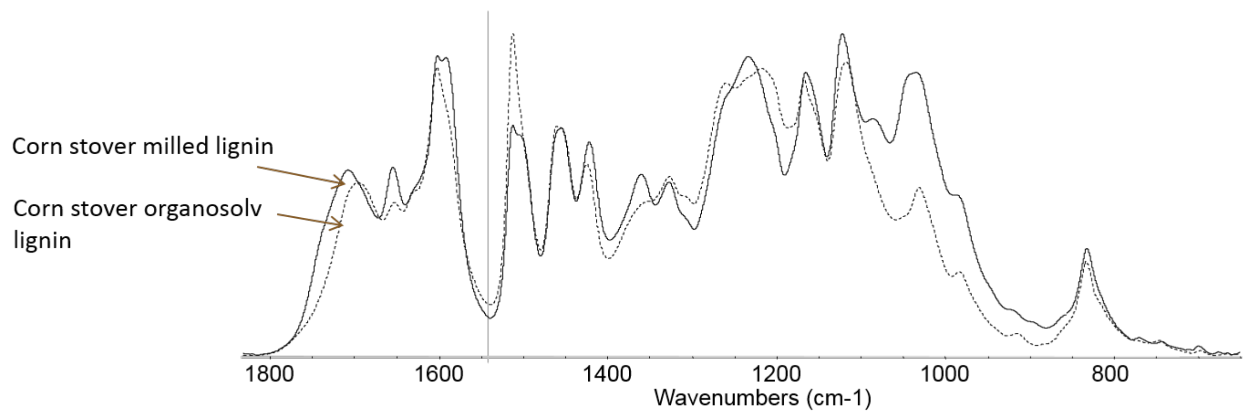

Fig 31. FTIR spectra of milled and organosolv lignin from corn stover.

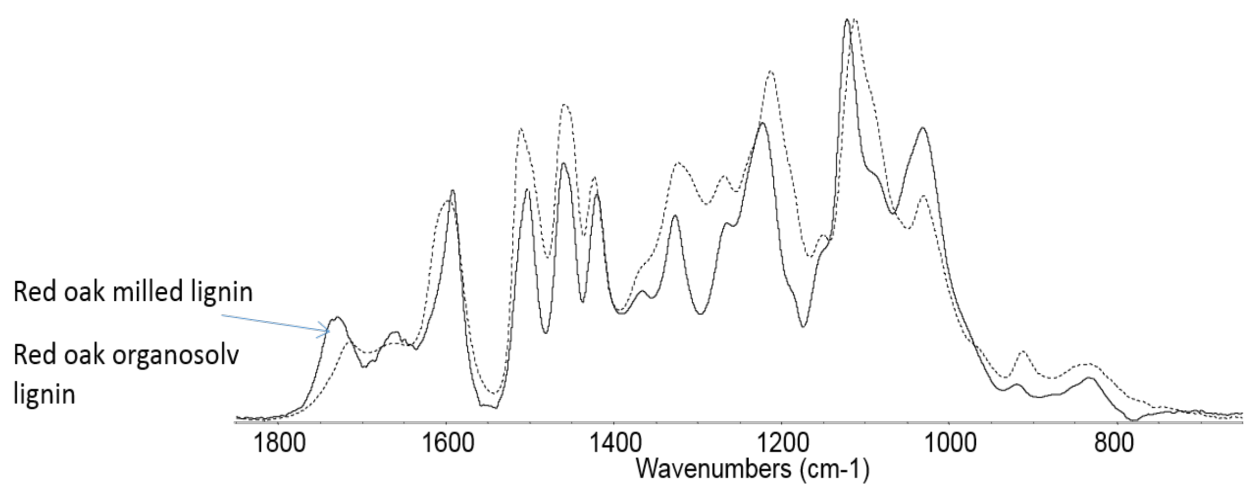

Fig 32. FTIR spectra of milled and organosolv lignin from red oak.

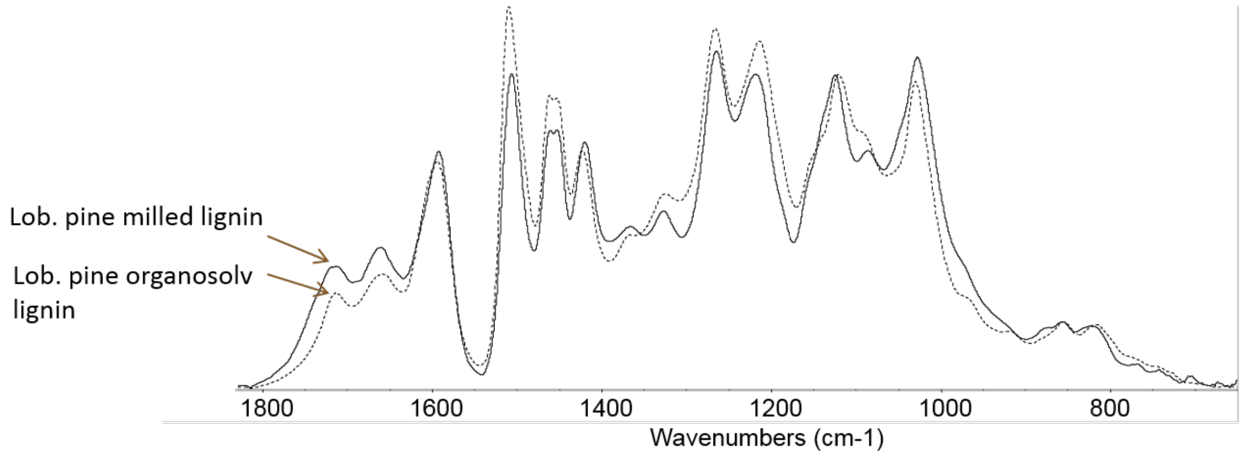

Fig 33. FTIR spectra of milled and organosolv lignin from loblolly pine.

- **Brief Summary Based on Results**

  ✓ Corn stover, red oak, and loblolly pine were prepared for lignin extraction. Lignin was extracted by different processes (milled, organosolv, alkali, and klason) and analyzed by TGA, CHNS-O, GPC, and FTIR.

  ✓ Proximate analysis showed that milled lignin contains more volatile and less fixed carbon than other extracted lignins. Ultimate analysis shows that milled lignin contains the highest amount of oxygen since it preserves the ether bonds. The GPC results show that the organosolv process significantly reduced the molecular weight of lignin. The FTIR analysis proves that the C-O-C bond cleavage, removal of C=O bonds, and increase of aromatic structure.

3. **Explanation of Variance**

   None noted.

4. **Plans for Next Quarter**

   - Study the pyrolysis and catalytic pyrolysis of different lignin samples.
   - Analytic technique of 2D HSQC NMR will be used for analysis of lignin structure.

- **Sub-Objective 2. Renmatix**

1. **Planned Activities**

   - **Task 10c-1.** Final report on lignin characterization by ^{13}C-NMR.

- **Task 10c-2.** Final report on removal of hemicellulose by water at subcritical conditions on selected biomasses.

- **Task 10c-3.** Refining of sugar samples and fermentation testing from both biomasses. Samples of C5 and C6 sugar streams to be sent for testing to CenUSA collaborator Bruce Dien at the USDA ARS. Data analysis for the development of a conceptual manufacturing process and economics for the processing of switchgrass and corn stover using Renmatix's Plantrose® Technology.

2. **Actual Accomplishments**

- **Task 10c-1.** Lignin characterization work is complete. The report is in review. The ^{13}C-NMR data has confirmed results from 2D NMR analysis. Lignin preparations were isolated from corn stover (CS), switchgrass (SG) and big bluestem (BBS) for structural characterization by advanced NMR methods. As grass lignin is very heterogeneous across morphological regions of the cell wall, two types of classical isolation methods were used to obtain more representative information: "Milled Wood Lignin" (MWL) and cellulolytic enzyme lignin (CEL). The protocols were optimized (milling time and intensity) for these specific biomasses to obtain high yield of isolated lignins without excessive lignin degradation during isolation.

  The isolated lignin preparations (3x2) were characterized with an advanced quantitative 2D HSQC, ^{13}C and ^{31}P NMR method using a Bruker 950 MHz spectrometer equipped with the CryoProbeTM technology. First, the 2D NMR values were normalized per the sum of S+G+H units for relative comparison according to the current most popular methodology. The results were further translated into an absolute mode per 100 Ar (aka mole %) using ^{13}C NMR as the reference. The ^{13}C NMR and ^{31}P NMR have also provided additional structural info. The results show that CS lignins have the highest S/G ratio and BBS lignin the lowest. The CS lignin contains very high amounts of conjugated acid moieties, especially coumarates (CA) (about 50 mol %), along with ferrulates (FA) and benzoates (BA); their amounts are significantly higher than in SG and BBS lignins. The amounts of the main lignin interunit linkages, β-O-4 structures, are similar (40-45%) in the lignins studied. The amounts of β-5 and β-β structures are significantly lower (4-9 and 2.3-5.5% correspondingly), while other identified lignin moieties are minor. The major lignin-carbohydrate linkages are phenyl glycoside structures (about 10%); benzyl ether and γ-ester lignin-carbohydrate linkages are of low abundance. Tricin moieties are present in the lignins in the range of 5 percent (CS and SG lignins) to 10 percent (BBS lignin).

- **Task 10c-2.** A report on the screening of conditions for the removal of hemicellulose from switchgrass and corn stover has been completed. This report includes results for the effect of time and temperature on the maximum extraction yield of sugars from corn stover and switchgrass when subjected to a hydrothermal process. Samples were provided by the USDA-ARS-PA office located in Lincoln, Nebraska. The initial study was carried out using a small bench top reactor. Data from this study was correlated using the P-factor to bracket the conditions for the maximum yield. With optimal conditions found, both biomass species were then tested in a pilot scale digester to simulate conditions closer to commercial scale. The focus of the analysis was on major sugars found in the hemicellulose of each biomass species.

  The main conclusions from this work were as follows:

  ✓ There was good overall hemicellulose sugar yield – 69 percent for corn stover and 66 percent for switchgrass. The yield of xylan was 65 percent for stover and 61 percent for switchgrass. These correspond to non-optimized results. A subsequent more comprehensive study could find better conditions for improved sugar yield.

  ✓ The initial bench top screening showed good xylan yield for corn stover but rather low yield for SG (42%) at similar severities (P-factor). A pre-wash step was employed to considerably increase xylan yield (up to ~60%) on switchgrass.

  ✓ Final composition of reacted solids is very similar between the two species, low in xylan and other minor sugars and high in glucan (40-48%) and lignin (23-24%). Xylan conversion was slightly higher in corn stover with 69 percent; switchgrass had a 63 percent xylan conversion.

  ✓ Screening results for the auto-hydrolysis of corn stover and switchgrass were verified at a pilot scale using a 20-liter batch digester and a process closer to commercial scale was simulated.

- **Task 10c-3 Pilot Scale**. determine potential economic feasibility of switchgrass and corn stover conversion into sugars and lignin via Renmatix's Plantrose® Technology.

  As mentioned in the Year 5 1st Quarter Report, both biomasses were run through the Renmatix BCU continuous pilot unit for both hemicellulose and supercritical hydrolysis. Positive results from the pilot plant runs were obtained for both biomasses showing both good yields and conversions for C5 and C6 sugars. No technological nor operational drawbacks were encountered for either biomass based on the pilot work. The C5 and C6 raw sugar streams have been refined into final C5 and C6 product. Both final products have passed standard fermentation testing for production of ethanol meaning these are good quality sugar products for a bio-refinery. Samples of crude lignin have been produced as well. In addition, samples of C5 and C6 sugar streams were sent for testing to CenUSA collaborator Bruce Dien at the USDA ARS.

Data from piloting trials has been compiled and a manufacturing concept has been proposed for the production of C5 and C6 monomeric sugars from switchgrass and corn stover.

3. **Explanation of Variance**

- **Task 10c-1.** Lignin characterization by NMR final report was delayed by equipment issues that were discussed in previous reports.
- **Task 10c-2.** No variance.
- **Task 10c-3.** No variance.

4. **Plans for Next Quarter**

- **Task 10c-3.** A techno-economic analysis for the processing of corn stover and switchgrass will be completed this quarter based on the proposed manufacturing process.
- **Task 10c-4.** Production of larger sample (< 10 kg) of crude lignins will start during this quarter. Samples will be prepared in coordination with ISU for its delivery and sample preparation. These samples will be tested for conversion into value added products.

5. **Publications / Presentations / Proposals Submitted**

- RD-2015-015 "CenUSA Screening of conditions for the removal of hemicellulose by hydrothermal process."
- RD-2016-006 "Evaluating lignin and LCC structure in non-wood biomass from ISU-R1."

http://cropbudget.apec.umn.edu Exhibit 1

Enterprise and environmental budgets

Welcome

Hello, welcome to the University of Minnesota Biomass Crop Enterprise and Environmental Budgeting Tool for biomass, forage, agroforestry, and annual crops. This tool was designed to calculate the breakeven price needed to cover the costs of producing biomass from conventional and alternative feedstocks. These include crop residues from corn and energy crops like switchgrass, mixed grasses, shrub willow, hybrid poplar, and agroforestry systems that combine both woody and herbaceous crops.

Get started!

What can it do?

Warranty

Supported

To use the tool, you will need to create an account. Once registered, select your state, county, and nearest weather station and define your site(s) and field(s). Then you will need to define your current farm management practices as well as alternative energy cropping practices for economic and environmental comparison. This worksheet provides a convenient way to organize all the information you will need to complete the tool.

Register and start!
More information about the tool
Farm data worksheet
User guide
See an example budget

Specifically, this tool computes the costs and returns per acre to produce biomass crops or any of a variety of other competing annual and perennial feed and food crops in the north central U.S.. The tool guides you through describing your farm management practices including alternative future management scenarios. The tool also provides an environmental report, comparing changes in soil carbon storage and soil erosion between your current management practices and future scenarios.

This tool is based on research conducted by Drs. William Lazarus, Gregg Johnson, and Dean Current. This calculator is provided 'as is' and without warranties as to performance. Because of the unique and varied circumstances of agricultural production, no warranty of merchantability or fitness for a particular purpose is offered.

This research was supported by funding from the North Central Sun Grant Center at South Dakota State University through a grant provided by the US Department of Energy Office of Biomass Programs under award number DEFG36-08GO88073, and by CenUSA Bioenergy under Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture.

Exhibit 2

Crops > Other > Specialty Crops

Estimated Cost of Establishment and Production of “Liberty” Switchgrass

File A1-29
Written May, 2015

pdf format

xlsx file
Use this decision tool to estimate costs of establishment and returns for raising switchgrass.

The current Renewable Fuels Standard was passed in 2007. In it, Congress proposed a significant shift in biofuel production, targeting the development of cellulosic energy sources. As part of that effort, the U.S. Department of Agriculture (USDA) established a series of grants to spur development of alternative biofuel sources. Some of the work from those grants has reached the stage where commercial development of cellulosic feedstocks for biofuel is feasible.

Switchgrasses have been a popular target crop for bioenergy development for several reasons: they are a perennial crop that can produce harvestable yields for several years between seedings; they can be produced on marginal cropland, but can also offer significant environmental benefits; and there are a number of varieties that are suited to the conditions in the central U.S.

The “Liberty” switchgrass variety, developed by a team from the USDA-Agricultural Research Service in Lincoln, Nebraska, led by Rob Mitchell and Ken Vogel, is a high-yielding, winter-tolerant switchgrass that was specifically created for bioenergy use. Liberty switchgrass is a cross of two other switchgrass varieties: Summer, a variety that has proven to be very hardy, surviving the winters in the upper Midwest and Kanlow, a high-yielding switchgrass from the Southern Plains. This report presents production cost estimates for Liberty and an example case for Liberty switchgrass production, detailing inputs required and procedures involved in establishment, yearly operation, and harvest.

Establishment of Liberty Switchgrass

Similar to row crop, improvements have been made to increase production and ease the costs and effort to grow perennial grasses. Native warm-season grasses, such as big bluestem, indiangrass, and switchgrass, have a reputation for being difficult to establish and taking at least a couple of years to produce a usable stand. But new cultivars, such as Liberty, and new technology have made it feasible to plant grasses in one year and have a harvestable crop the next year.

In the central Great Plains and Midwest, warm-season grasses, such as Liberty, can be planted 2 or 3 weeks before to 2 or 3 weeks after the recommended planting dates for corn, typically from late April to early June. A recommended practice for preparing land for grass or forage production is to plant the field with herbicide tolerant soybeans the year prior (Mitchell, et al., 2005)[1]. This set-up helps in three ways: 1) weed issues can be addressed as the soybean crop develops, 2) the soybean crop provides income from the field during the preparation for grass production, and 3) soybean stubble has proven to be an excellent cover for grass establishment. Historically, weed pressure has been the major reason switchgrass stands are hard to establish. The soybean crop in the previous year allows the producer to create a clean seed bed prior to planting Liberty. In addition, some herbicides can be used immediately after planting Liberty.

Liberty should be seeded with at least 30 pure live seed per square foot, depending on the quality of the seed. Nitrogen fertilizer is not recommended during the planting year since it will encourage weed growth, increasing competition for the grass seedlings. Soil tests are recommended prior to planting. Since warm-season grasses, such as Liberty, are deep rooted, soil samples should be taken to a depth of 5 feet. When phosphorus is less than 10 parts per million), fertilize with phosphate at 20-40 pounds per acre before planting to encourage root growth and promote rapid establishment. Given a good grass stand and good management, it is possible to harvest 2-3 tons of dry matter per acre in the establishment year.

Production Practices after Establishment

Once the grass is established, it should compete very well with any weeds, limiting the need for large scale herbicide applications. However, if broadleaf weeds are an issue, an early spring application of herbicide is feasible. Nitrogen fertilization is also recommended, with the general rule of thumb of 10 pounds of nitrogen per acre for each ton of expected yield per acre. The typical fertilization window would be in late April to early May.

Harvesting

Like many plants, Liberty switchgrass senesces in the fall when nutrients translocate to the roots, making the nutrients available for plant growth in the following spring. So harvest is targeted after a killing frost, once all of the green has faded from the plant bases. In the establishment year, the harvest cut should leave at least 6 inches of stubble in the field. In the following years, the minimum amount of stubble reduces to 4 inches. As with other grasses, there is a tradeoff of delaying harvest between biomass loss, usually due to leaf loss, and a lower moisture content that makes the grass biomass more suitable for combustion, processing, or storage. Also, some patience is required during harvesting to produce clean bales to deliver to the energy plant for combustion or processing.

Estimated Costs of Production

The estimated cost of production for Liberty switchgrass is presented in four sections, reflecting particular production years in the life of this perennial crop. The first section and table 1 present production cost estimates for pre-establishment. Section 2 estimates costs of production in the establishment year. Utilizing an amortization factor, a pro-rated estimate is also provided illustrate the yearly cost of establishment spread across the life of the stand. Section 3 provides cost of production estimates for the second year of production. Since grass stands mature by year 3, the cost estimates are assumed to remain the same from year 3 and beyond. These estimates are shown in section 4. For the last 3 sections, the production costs are divided into (i) pre-harvest machinery costs, (ii) operation costs, and (iii) harvesting costs. For simplicity, we have not considered storage and transportation costs to the processing facility in this report.

Information used in developing this budget was obtained from existing agronomic research, expert opinions, and economic data such as the 2014 Iowa Farm Custom Rate Survey (AgDM, File A3-10). Input prices, fertilizer, chemical and seed costs were taken from existing crop enterprise budgets published by Iowa State Extension or from enterprise budgets developed by USDA-ARS and Extension services at other universities.

Assumptions for the Budget

Based on the above discussion on Liberty switchgrass establishment and production, we have made the following specific assumptions for developing this cost budget.

1. Yield is assumed to be 6 dry tons per acre.
2. The stand-life is assumed to be 10 years.
3. The land charge is assumed to be the average cash rental rate for land under current use of improved pasture. Cash Rental Rates for Iowa 2014 Survey (AgDM, File C2-10) reports that the state average cash rent for improved pasture is $77/acre.
4. A herbicide tolerant crop (round-up ready soybeans) is assumed to be grown in the year prior to planting Liberty as part of pre-establishment field preparation.
5. A winter cover crop (oats) is assumed to be grown in the winter before Liberty establishment to help weed and soil erosion control.
6. Production costs of roundup ready soybeans and oats are taken from readily available existing crop budgets at Iowa State Extension.
7. The only fertilizer application in year one would be in the case where phosphorus is found to be short. From year two forward, it is assumed to follow the recommended level by agronomic research to recover annual estimated nutrient removal:

Nitrogen - 10 lbs. per ton of biomass removed.

8. Seed prices are assumed at $15 per pound. It is assumed 5 pounds of seed would be required per acre. In year two, it is expected that 10% of the field would need to reseeded.
9. For weed control, it is assumed that before planting, a *burndown* is applied, and after planting, a pre-emergence herbicide will be applied. A second pass of pre-emergence herbicide will be applied in the following years as well.
10. In year one, a reduced yield equal to 50% of maximum potential yield is assumed. From year 2 forward, the harvest yield is expected to reach the maximum potential.
11. Biomass will be harvested in large square bales weighing 1,500 pounds.
12. The interest rate for pro-rating establishment costs is assumed to be 8%, while on operating expenses the interest rate is assumed to be 5%.

1. Cost of production in year 0 (Pre-establishment)

In the year before planting Liberty switchgrass (called here year 0), an herbicide tolerant crop (round-up ready soybeans) is assumed to be grown as part of the pre-establishment field preparation. Following the soybean production, a winter cover crop (oats) is grown to help weed and soil erosion control. For production cost of these pre-establishment crops, we utilize the per acre production cost of *Herbicide Tolerant Soybeans following Corn* production from Iowa State University Extension publication “*Estimated Costs of Crop Production in Iowa – 2014*”, AgDM File A1-20. Since we apply a separate land charge in this budget, we estimate the cost of production per acre for soybeans to be the total production cost per acre minus the land rental payment. For oats as the winter cover crop, we impute the per-acre cost of production estimates from Iowa State University’s Extension publication “*Cover Crop Cost Calculator,*” assuming 70 pounds of seeds per acre will be sown.

Since we are considering conversion of land from pasture or grassland, we include the costs of conversion for soybean production. We assume the field preparation would incorporate brush mowing, disking, and soil finishing. The total cost for converting the field for pre-establishment crop production is $67.60 per acre. The cost of production for soybeans is $268.85 per acre and the cost for the winter cover crop, oats, is $31.39 per acre. Including the rent for land, the total cost in year 0, the pre-establishment year, is $444.84 per acre.

2. Cost of production in year 1 (Establishment)

The costs incurred in year 1 are for establishment of the Liberty stand. Pre-harvest machinery includes equipment for herbicide spreading and seed planting. No nitrogen fertilizer application in the first year is assumed. However, fertilizer and lime application rates can vary with the soil conditions. A soil test prior to planting would give information about required nutrient application rates. In our example, total establishment pre-harvest machinery cost in year one is $31.15 per acre. Total operating cost to be incurred on soil testing, herbicides, and seed totals to $89.72 per acre. Assuming an interest rate of 5% on an 8 month operating loan to finance establishment costs and operating expenses in year 1 results in a total interest payment of $4.03. Given that Liberty can produce a harvestable yield in the first year roughly equal to half of the long-term expected yield, harvesting cost of $77.80 are included in year 1. Total costs of production in year one are estimated at $279.70.

3. Cost of production in year 2

In year 2, an additional application of a pre-emergence herbicide is recommended as part of establishment. Total pre-harvest machinery cost plus cash rent for land is an estimated $105.60 per acre. Total operating expenses on fertilizer and herbicides would be $32.80. Given a 10% reseeding rate, an additional $7.50 per acre is used for seed. An interest payment of $2.30 will be incurred. Total harvesting costs including mowing, baling, windrowing, and moving to storage would sum to approximately $141.40. Total cost of production in year two is $289.60 per acre.

4. Cost of production in year 3 and beyond

Since establishment is completed by year 2, production costs from year 3 and beyond are expected to remain the same. In year 3, production costs include operating expenses, a land charge and a harvest cost. Production costs include machinery cost and land rent of $89.55, operating expenses of $32.80, and an interest expense of $1.51. From year 3, maximum yield of 6 tons/acre is expected to be harvestable. Total harvesting costs would be $141.40. Total cost of production is $265.26 per acre.

Total Establishment Cost

All of the establishment costs are incurred in year 0 and year 1. From year 2 forward, all other costs are production costs. Combining the establishment costs across the first couple of years, total establishment cost excluding interest expense totals $642.71 per acre. A stand life of 10 years and an 8% interest rate implies a prorated yearly establishment cost of $95.78 per acre.

Table 1: Cost of pre-establishment field preparation and crop production in year 0

	Price Per Unit	Units Used	Cost
Land charge	$77.00/Acre	1 Acre	$ 77.00
Field preparation			
Brush mowing	$10.00/Pass	1 Pass	10.00
Disking, tandem	$14.20/Pass	2 Passes	28.40
Soil finishing	$14.60/Pass	2 Passes	29.20
Crop production			
Herbicide tolerant crop (soybeans)	$268.85/Acre	1 Acre	268.85
Winter cover crop (oats)	$31.39/Acre	1 Acre	31.39
Total cost of field preparation and pre-establishment			367.84
Total Cost			**$ 444.84**

Table 2: cost of production in year 1

	Price Per Unit	Units Used	Cost
Land charge	$77.00/acre	1 acre	$ 77.00
Pre-harvest machinery operations			
Spraying chemical	$7.55/pass	2 passes	15.10
Seed drilling	$16.05/acre	1 acre	16.05
Total establishment machinery cost			31.15
Operating expenses			
Soil test (test covers 5 acres)	$8.00/soil test	0.20	1.60
Seed	$15/pound	5 pounds	75.00
Herbicide			
Pre-emergence	$0.21/ounce	32 ounces	6.72
Post-emergence	$0.20/ounce	32 ounces	6.40
Total operating cost			89.72
Interest on operating and establishment expenses	5 percent for 8 months		4.03
Harvest machinery operations			
Swathing	$14.20/acre	1 acre	14.20
Baling	$12.60/bale	4 bales	50.40
Moving to storage	$3.30/bale	4 bales	13.20
Total harvesting cost			77.80
Total Cost			**$ 279.70**

Table 3: Cost of production in year 2

	Price Per Unit	Units Used	Cost
Land charge	$77.00/acre	1 acre	$ 77.00
Pre-harvest machinery operations			
Fertilizer spreading	$5.00/pass	1 pass	$ 5.00
Spraying chemical	$7.55/pass	1 pass	$ 7.55
Seed drilling	$16.05/acre	1 acre	$ 16.05
Total pre-harvest machinery cost			$ 28.60
Operating expenses			
Seed	$15/pound	0.5 pounds	$ 7.50
Fertilizer			
Nitrogen (n)	$0.44/pound	60 pounds	$ 26.40
Herbicide			
Post-emergence	$0.20/ounce	32 ounces	$ 6.40
Total operating cost			$ 40.30
Interest rate on operating expenses	5 percent for 8 months		$ 2.30
Harvest machinery operations			
Swathing	$14.20/acre	1 acre	$ 14.20
Baling	$12.60/bale	8 bales	$100.80
Moving to storage	$3.30/bale	8 bales	$ 26.40
Total harvesting cost			$141.40
Total Cost			**$289.60**

Table 4: Cost of production in year 3			
	Price Per Unit	Units Used	Cost
Land charge	$77.00/acre	1 acre	$ 77.00
Pre-harvest machinery operations			
Fertilizer spreading	$5.00/pass	1 pass	5.00
Spraying chemical	$7.55/pass	1 pass	7.55
Total pre-harvest machinery cost			12.55
Operating expenses			
Fertilizer			
Nitrogen (n)	$0.44/pound	60 pounds	26.40
Herbicide			
Post-emergence	$0.20/ounce	32 ounces	6.40
Total operating cost			32.80
Interest rate on operating expenses	5 percent for 8 months		1.51
Harvest machinery operations			
Swathing	$14.20/acre	1 acre	14.20
Baling	$12.60/bale	8 bales	100.80
Moving to storage	$3.30/bale	8 bales	26.40
Total harvesting cost			141.40
Total Cost			**$265.26**

[1] Rob Mitchell, Ken Vogel, Bruce Anderson, and T. J. McAndrew. “Renovating Pastures with Glyphosate Tolerant Soybeans.” Forage and Grazinglands: Online, April 2005, doi:10.1094/FG-2005-0428-01-BR.

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Exhibit 3

cenusa bioenergy

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

BLADES

A look at CenUSA's New Generation of Bioenergy

June 14 | Nov 14 | Feb 15 | April 15 | June 15 | Oct 15 | Dec 15 | Sept 14 | Mar 16

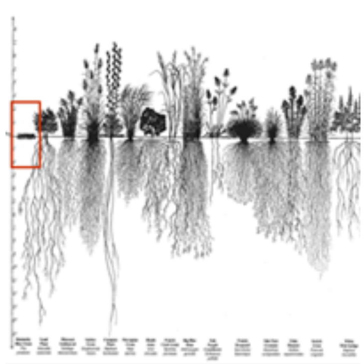
FDC Enterprises Building the Perennial Grass Energy Supply Chain

Having planted 280,000 acres of native grasses, FDC Enterprises is at the forefront of national efforts to commercialize sustainable, next generation fuels. CenUSA sat down with Tom Schwartz, FDCE Vice President to talk about the company's business case for perennials.

READ MORE

CenUSA Perennial Grass Research "Yields" Impressive Results

Iowa Agricultural engineer, Greg Brenneman has been conducting



Planting Perennial Grasses in the Midwest Reduce Water Pollution

Switchgrass root systems can absorb nitrates and reduce

To Grow or Not to Grow: New Switchgrass Decision Tool

Establishing new plots of switchgrass can be complicated.

research on the growth of switchgrass for the past three years. He spoke at the Bioenergy Field Tour demonstrating his team's research at the Iowa State Research and Demonstration Farm near Crawfordsville.

Learn more

drinking water contamination. Learn why Nebraska conservationists think switchgrass is beneficial to people, wildlife, and the environment.

Learn more

A team of CenUSA researchers have teamed up to redesign a switchgrass decision-support tool that helps simplify the process to make sure producers get the most out of their land.

Discover more

100Grannies March on Washington

100Grannies Founder Barbara Schlachter has taken a stand to solve the issues surrounding climate change. She led seven other "grannies" on a mission to Capitol Hill to capture the attention of our nation's leaders.

Follow their journey

Harvesting Bales from Start to Finish

Researchers at CenUSA Bioenergy discuss cost-cutting techniques to improve the efficiency of the harvesting process and reveal how to save money as the bale travels from farm to facility.

Read more

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

Stay Connected with CenUSA

Visit CenUSA website

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

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

United States Department of Agriculture

National Institute of Food and Agriculture

Resources from CenUSA - Sustainable Production and Distribution of Bioenergy for the Central USA

Exhibit 4

Farm Energy - March 31, 2016 (20160331) Print (http://www.printfriendly.com)

CenUSA Bioenergy (http://www.cenusa.iastate.edu/) is a coordinated research and education effort investigating the creation of a regional system in the Central US for producing advanced transportation fuels from perennial grasses 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 in soil and increasing carbon sequestration.

CenUSA Bioenergy researchers from Iowa State University, Purdue University, University of Wisconsin, University of Minnesota, University of Nebraska, University of Illinois and the USDA Agricultural Research Service cover topics of interest to producers and growers in the following resources. Learn more about the CenUSA Bioenergy Project.

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- Plant Breeders Create New and Better Switchgrass Varieties for Biofuels (/pages/70389/plant-breeders-create-new-and-better-switchgrass-varieties-for-biofuels) - Michael Casler, USDA-ARS

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- Research Summary: Near-Infrared (NIR) Analysis Provides Efficient Evaluation of Biomass Samples (/pages/70496/research-summary:-near-infrared-nir-analysis-provides-efficient-evaluation-of-biomass-samples) - Bruce Dien, USDA-ARS
- Research Summary: Research Finds Strong Genetic Diversity in Switchgrass Gene Pools (/pages/70383/research-summary:-research-finds-strong-genetic-diversity-in-switchgrass-gene-pools) - Michael Casler

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- Switchgrass and Perennial Grasses, Biomass and Biofuels- Part 2 (http://farmenergymedia.extension.org/video/part-2-switchgrass-and-perennial-grasses-biomass-and-biofuels) - Ken Vogel, USDA-ARS
- Switchgrass Production Industry Perspectives (http://farmenergymedia.extension.org/video/david-stock-switchgrass-production-industry-perspectives) - David Stock, Stock Seed Farms

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- Plant Pathogen Risk Analysis for Bioenergy Switchgrass Grown in the Central USA (http://farmenergymedia.extension.org/video/plant-pathogen-risk-analysis-bioenergy-switchgrass-grown-central-usa) - Gary Yuen
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Module 2. Sustainable Feedstock Production

Fact Sheets

- Estimated Cost of Establishment and Production of “Liberty” Switchgrass: (http://www.extension.iastate.edu/agdm/crops/html/a1-29.html) Perennial Grass Decision Support Tool - Mainul Hoque, Georgeanne Artz, Chad Hart

- Switchgrass (Panicum virgatum) for Biofuel Production (/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production) - Rob Mitchell, USDA-ARS (related PDF handout (/sites/default/files/Factsheet3.GrowingSwitchgrassforBiofuels.pdf))
- Storing Perennial Grasses Grown for Biofuel (/pages/70635/storing-perennial-grasses-grown-for-biofuel) - Kevin Shinners
- Switchgrass (Panicum virgatum L) Stand Establishment: Key Factors for Success (/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success) - Rob Mitchell (related PDF handout (/sites/default/files/FactSheet4.SwitchgrassStandEstablishment.pdf))
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- Successfully Harvest Switchgrass Grown for Biofuel (/pages/68054/successfully-harvest-switchgrass-grown-for-biofuel) ; Kevin Shinners, Pam Porter (related PDF handout (/sites/default/files/Factsheet1.OptimizingHarvest.pdf))
- Control Weeds in Switchgrass (Panicum Virgatum L.) Grown for Biomass (/pages/70396/control-weeds-in-switchgrass-panicum-virgatum-l-grown-for-biomass) - Rob Mitchell, USDA-ARS

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- Switchgrass Establishment, Weed Control, and Seed Quality (http://farmenergymedia.extension.org/video/switchgrass-establishment-weed-control-and-seed-quality) – Rob Mitchell
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- Competition for Land Use: Why would the rational producer grow switchgrass for biofuel? (http://farmenergymedia.extension.org/video/competition-land-use-why-would-rational-producer-grow-switchgrass-biofuel) - Keri Jacobs
- An Overview of Switchgrass Diseases (http://vimeo.com/70354275) - Stephen Wegulo
- Perennial Herbaceous Biomass Biomass Production and Harvest in the Prairie Pothole Region of the Northern Great Plains (http://farmenergymedia.extension.org/video/perennial-herbaceous-biomass-biomass-production-and-harvest-prairie-pothole-region-northern) - Susan Rupp

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- Harvesting Native Grass for Biofuel Production (+Captions) (http://farmenergymedia.extension.org/video/harvesting-native-grass-biofuel-production-captions) – Rob Mitchell
- Optimizing Harvest of Perennial Grasses for Biofuel (http://farmenergymedia.extension.org/video/optimizing-harvest-perennial-grasses-biofuel) – Kevin Shinners, Pam Porter (related PDF handout (/sites/default/files/Factsheet1.OptimizingHarvest.pdf))
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- Biofuel Quality Improved by Delaying Harvest of Perennial Grass (/pages/73615/research-summary:-biofuel-quality-improved-by-delaying-harvest-of-perennial-grass) - Emily Heaton

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Module 3. Feedstock Logistics: Harvest & Storage

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Module 4. System Performance: Economics, Environment, Modeling, Analysis and Tools

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- Management Practices Impact Greenhouse Gas Emissions in the Harvest of Corn Stover for Biofuels (/pages/70634/research-summary:-management-practices-impact-greenhouse-gas-emissions-in-the-harvest-of-corn-stover) - Virginia Jin
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- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird

Journal Publications

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Module 5. Feedstock Conversion and Biofuels Co-Products

Case Studies

- Renmatix Processes Biomass into Sugars for Industrial Use (/pages/73640/renmatix-processes-biomass-into-sugars-for-industrial-use)

Fact Sheet

- Fast Pyrolysis Efficiently Turns Biomass into Renewable Fuels (/pages/72722/fast-pyrolysis-efficiently-turns-biomass-into-renewable-fuels) - Robert Brown
- Biochar: Prospects of Commercialization (/pages/71760/biochar:-prospects-of-commercialization) - David Laird and Pam Porter
- Master Gardeners' Safety Precautions for Handling, Applying and Storing Biochar (/sites/default/files/MasterGardenerSafetySheet20120412.pdf) - Charles Schwab and Mark Hanna

Research Summary

- Biochar Can Improve the Sustainability of Stover Removal for Bioenergy (/pages/68052/research-summary:-biochar-can-improve-the-sustainability-of-stover-removal-for-bioenergy) - David Laird
- 2014 Extension Master Gardener's CenUSA Biochar Demonstration Gardens (https://cenusa.iastate.edu/files/2014_cenusa_master_gardener_final_report_.pdf) : *Is biochar a good soil amendment for home gardens?* - Lynn Hagen

Webinars

- Thermochemical Conversion of Biomass to Drop-In Biofuels (http://farmenergymedia.extension.org/video/thermochemical-conversion-biomass-drop-biofuels) – Robert Brown
- Thermochemical Option: Biomass to Fuel (http://farmenergymedia.extension.org/video/thermochemical-option-biomass-fuel) – Robert Brown

Instructional Video

- Biochar: An Introduction to an Industry (http://farmenergymedia.extension.org/video/biochar-introduction-industry) - David Laird
- Biochar 101: An Intro to Biochar (http://farmenergymedia.extension.org/video/biochar-101-intro-biochar) - Kurt Spokas
- University of Minnesota Extension Master Gardener Biochar Research Summary (http://farmenergymedia.extension.org/video/university-minnesota-extension-master-gardener-biochar-research-summary) - Julie Weisenhorn
- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird

Journal Publications

- Index of Recent Biochar Publications (/pages/72947/recent-publications-about-biochar)
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- Thilakaratne, R., Brown, T., Li, Y., Hu, G., & Brown R.C. (2014). Mild catalytic pyrolysis of biomass for production of transportation fuels: a techno-economic analysis. Green Chemistry, DOI: 10.1039/C3GC41314D.
- Zhang, Y., Hu, G., & Brown, R. C. (2013). Life cycle assessment of the production of hydrogen and transportation fuels from corn stover via fast pyrolysis. Environ. Res. Lett. 8, 025001 doi:10.1088/1748-9326/8/2/025001.

Module 6. Markets and Distribution

Fact Sheet

- The Economics of Switchgrass for Biofuel (/pages/71073/the-economics-of-switchgrass-for-biofuel) - Richard Perrin

Research Summary

- Competition For Land Use: Why Would a Rational Producer Grow Switchgrass for Biofuel? (/pages/72596/research-summary:-competition-for-land-usewhy-would-a-rational-producer-grow-switchgrass-for-biofuel) - Keri Jacobs

Webinar

- Competition for Land Use: Why would the rational producer grow switchgrass for biofuel? (http://farmenergymedia.extension.org/video/competition-land-use-why-would-rational-producer-grow-switchgrass-biofuel) - Keri Jacobs
- Switchgrass Production Industry Perspectives (http://farmenergymedia.extension.org/video/david-stock-switchgrass-production-industry-perspectives) - David Stock

Instructional Video

- Commercialization Update: Opportunities for Perennial Biofeedstocks (http://farmenergymedia.extension.org/video/cenusa-commercialization-update-rob-mitchell) - Rob Mitchell

Journal Publications

- 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.
- Kauffman, N. & Hayes, D. (2013)The Trade-off between Bioenergy and Emissions with Land Constraints. Energy Policy 54, 300-310, 2013.
- Jacobs, K. Perennial Grasses for Bioenergy in the Central United States: Updates on Economics and Research Progress. 2013 ICM Conference Proceedings, Iowa State University.

Module 7. Health and Safety

Fact Sheets

- Master Gardeners' Safety Precautions for Handling, Applying and Storing Biochar (/sites/default/files/MasterGardenerSafetySheet20120412.pdf) - Charles Schwab and Mark Hanna

Webinar

- Safety Issues in On-Farm Biomass Production (https://learn.extension.org/events/1406) - Douglas Schaufler

Research Summary

- Safety and Health Risks of Producing Biomass on the Farm (/pages/71921/research-summary:-safety-and-health-risks-of-producing-biomass-on-the-farm) - Douglas Schaufler

Journal Publications

- Schaufler, D. H., Yoder, A.M., Murphy, D. J., Schwab, C.V. & Dehart. A.F. *Safety and Health Hazards in On-Farm Biomass Production & Processing (http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1896&context=abe_eng_pubs)* . (2014). ASABE Journal Agricultural Safety and Health.
- Yoder, A.M., C. V. Schwab, P. D. Gunderson, and D. J. Murphy. 2013. Safety and Health in Biomass Production, Transportation and Storage. Journal of Agromedicine. DOI: 10.1080/1059924X.2014.886539 (http://www.ncbi.nlm.nih.gov/pubmed/24911681) .
- Ryan, S. J., C. V. Schwab, and G. A. Mosher. 2015. Development of a probabilistic risk assessment model to measure the difference in Safety risk of corn and biofuel switchgrass farming systems. Journal of Agricultural Safety and Health (Submitted).

Technical Papers

- Ryan, S. J., C. V. Schwab, and G. A. Mosher. 2015. Agricultural Risk: Development of a probabilistic risk assessment model for measurement of the difference in risk of corn and biofuel switchgrass farming systems. International Society for Agricultural Safety and Health summer conference Bloomington-Normal, Illinois. ISASH Paper No. 15-01. ISASH Urbana, IL 61801.
- Yoder Aaron M., D.J. Murphy, and A.F. DeHart. 2013. A Technical Review on Safety in On-Farm Biomass Production and Storage Systems: Status and Industry Needs. American Society of Agricultural and Biological Engineers. Technical Paper No. 1620568.

"Formal" Educational Programs and Curriculum

In order to prepare the next generation of workers for the emerging bioeconomy, CenUSA is providing interdisciplinary training and engagement opportunities for undergraduate and graduate students; and developing a bioenergy curriculum core for the Central region of the United States.

- Developing a New Supply Chain for Biofuels: Contracting for Dedicated Energy Crops (http://passel.unl.edu/communities/index.php?idinformationmodule=1130447221&idcollectionmodule=1130274200) - Corinne Alexander

Extension Programs

Upcoming CenUSA Webinars (https://learn.extension.org/events/tag/cenusa)

Archived CenUSA Webinars (http://farmenergymedia.extension.org/videos?type=webinar&field_terms_tid=All&keywords=cenusa&sort_by=field_video_date_value&sort_order=DESC)

Biochar Demonstration (http://blogs.extension.org/mastergardener/tag/cenusa-bioenergy/) - Extension Master Gardener reports

- Three years on, Master Gardeners talk about the rewards and challenges of volunteering at Minnesota's three CenUSA biochar test sites. http://blogs.extension.org/mastergardener/2014/09/16/research-experience-wasp-nests-teamwork-and-sprinklers-gone-wild/ (http://blogs.extension.org/mastergardener/2014/09/16/research-experience-wasp-nests-teamwork-and-sprinklers-gone-wild/) -
- Bringing research to blossom with U of M Extension Master Gardeners - http://blog.lib.umn.edu/umnext/news/2014/02/bringing-research-to-blossom-with-u-of-m-extension-master-gardeners.php (http://blog.lib.umn.edu/umnext/news/2014/02/bringing-research-to-blossom-with-u-of-m-extension-master-gardeners.php)
- Fond du Lac Community Master Gardeners contribute to CenUSA biochar research and teach kids about growing food, too. http://blogs.extension.org/mastergardener/2014/12/02/2014-cenusa-bioenergy-project/ (http://blogs.extension.org/mastergardener/2014/12/02/2014-cenusa-bioenergy-project/)
- 2012 Extension Master Gardener Annual Report - http://www.extension.umn.edu/garden/master-gardener/coordinators/reporting/2012_emg_annual_report.pdf (http://www.extension.umn.edu/garden/master-gardener/coordinators/reporting/2012_emg_annual_report.pdf)
- Biochar: A New Lease on Life, p4, Spring 2014 UMN Master Gardener Update. www.extension.umn.edu/garden/master-gardener/about/docs/ne_newsletter__spring_2014_2.pdf (http://www.extension.umn.edu/garden/master-gardener/about/docs/ne_newsletter__spring_2014_2.pdf)
- Dirt-O-Rama - Is Is Biochar Good for Home Gardens? - www.arboretum.umn.edu/dirtscience.aspx (http://www.arboretum.umn.edu/dirtscience.aspx)
- U of M scientists, Master Gardeners part of team to analyze biofuel production and land use. http://discover.umn.edu/news/environment/u-m-scientists-master-gardeners-part-team-analyze-biofuel-production-and-land-use (http://discover.umn.edu/news/environment/u-m-scientists-master-gardeners-part-team-analyze-biofuel-production-and-land-use)

CenUSA Social Media: Ask an Expert, Newsletter, Facebook, Twitter

Ask an Expert (https://ask.extension.org/groups/1848/ask) - our specialists will answer your questions on growing perennial grasses for biofuel, pyrolysis, biochar and more.

BLADES Newsletter (http://blades-newsletter.blogspot.com/) - your source for the latest information on grass-based bioenergy research, policy and industry breakthroughs, innovative educational programs and upcoming events.

Facebook (https://www.facebook.com/CenusaBioenergy)

Twitter @ cenusabioenergy (https://twitter.com/cenusabioenergy)

CenUSA Bioenergy Resources by MediaType

(*same resources as above, but organized by type*)

Fact Sheets, Guides and Articles

- Index of recent Biochar Publications (/pages/72947/recent-publications-about-biochar)
- Fast Pyrolysis Efficiently Turns Biomass into Renewable Fuels (/pages/72722/fast-pyrolysis-efficiently-turns-biomass-into-renewable-fuels) - Robert Brown

- Biochar: Prospects of Commercialization (/pages/71760/biochar:-prospects-of-commercialization) - David Laird and Pam Porter
- The Economics of Switchgrass for Biofuel (/pages/71073/the-economics-of-switchgrass-for-biofuel) - Richard Perrin
- Storing Perennial Grasses Grown for Biofuel (/pages/70635/storing-perennial-grasses-grown-for-biofuel) - Kevin Shinners
- Plant Breeders Create New and Better Switchgrass Varieties for Biofuels (/pages/70389/plant-breeders-create-new-and-better-switchgrass-varieties-for-biofuels) - Michael Casler
- Switchgrass (Panicum virgatum) for Biofuel Production (/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production) - Rob Mitchell (related PDF handout (/sites/default/files/Factsheet3.GrowingSwitchgrassforBiofuels.pdf))
- Switchgrass (Panicum virgatum L) Stand Establishment: Key Factors for Success (/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success) - Rob Mitchell (related PDF handout (/sites/default/files/FactSheet4.SwitchgrassStandEstablishment.pdf))
- Logistical Challenges to Switchgrass (Panicum virgatum L.) as a Bioenergy Crop (/pages/68053/logistical-challenges-to-switchgrass-panicum-virgatum-l-as-a-bioenergy-crop) - Amy Kohmetscher, Stuart Birrell
- Test Plots Show How Perennial Grasses Can Be Grown for Biofuels (/pages/68155/test-plots-show-how-perennial-grasses-can-be-grown-for-biofuels) - Rob Mitchell, Jeff Volenec - (related PDF handout (/sites/default/files/Factsheet2.PerennialGrassEnergyDemoPlots.pdf))
- Successfully Harvest Switchgrass Grown for Biofuel (/pages/68054/successfully-harvest-switchgrass-grown-for-biofuel) - Kevin Shinners, Pam Porter (related PDF handout (/sites/default/files/Factsheet1.OptimizingHarvest.pdf))
- Control Weeds in Switchgrass (Panicum Virgatum L.) Grown for Biomass (/pages/70396/control-weeds-in-switchgrass-panicum-virgatum-l-grown-for-biomass) - Rob Mitchell

Research Summaries

- Competition For Land Use: Why Would a Rational Producer Grow Switchgrass for Biofuel? (/pages/72596/research-summary:-competition-for-land-usewhy-would-a-rational-producer-grow-switchgrass-for-biofuel) - Keri Jacobs
- Safety and Health Risks of Producing Biomass on the Farm (/pages/71921/research-summary:-safety-and-health-risks-of-producing-biomass-on-the-farm) - Douglas Schaufler
- Management Practices Impact Greenhouse Gas Emissions in the Harvest of Corn Stover for Biofuels (/pages/70634/research-summary:-management-practices-impact-greenhouse-gas-emissions-in-the-harvest-of-corn-stover) - Virginia Jin
- Near-Infrared (NIR) Analysis Provides Efficient Evaluation of Biomass Samples (/pages/70496/research-summary:-near-infrared-nir-analysis-provides-efficient-evaluation-of-biomass-samples) - Bruce Dien, USDA-ARS
- Biochar Can Improve the Sustainability of Stover Removal for Bioenergy (/pages/68052/research-summary:-biochar-can-improve-the-sustainability-of-stover-removal-for-bioenergy) - David Laird
- Biofuel Quality Improved by Delaying Harvest of Perennial Grass (/pages/73615/research-summary:-biofuel-quality-improved-by-delaying-harvest-of-perennial-grass) - Emily Heaton
- Minnesota Watershed Nitrogen Reduction Planning Tool (/pages/67624/minnesota-watershed-nitrogen-reduction-planning-tool) - Bill Lazarus
- Research Finds Strong Genetic Diversity in Switchgrass Gene Pools (/pages/70383/research-summary:-research-finds-strong-genetic-diversity-in-switchgrass-gene-pools) - Michael Casler

Archived Webinars (http://farmenergymedia.extension.org/videos?type=webinar&field_terms_tid=All&keywords=cenusa&sort_by=field_video_date_value&sort_order=DESC)

- Switchgrass Economics in the North Central Region of the USA (Captioned) (http://farmenergymedia.extension.org/video/switchgrass-economics-north-central-region-usa-captioned) - Richard Perrin
- Competition for Land Use: Why would the rational producer grow switchgrass for biofuel? (http://farmenergymedia.extension.org/video/competition-land-use-why-would-rational-producer-grow-switchgrass-biofuel) - Keri Jacobs
- An Overview of Switchgrass Diseases (http://vimeo.com/70354275) - Stephen Wegulo
- Perennial Herbaceous Biomass Biomass Production and Harvest in the Prairie Pothole Region of the Northern Great Plains (http://farmenergymedia.extension.org/video/perennial-herbaceous-biomass-biomass-production-and-harvest-prairie-pothole-region-northern) - Susan Rupp
- Switchgrass and Perennial Grasses, Biomass and Biofuels, Part 1 (Captions)

(http://farmenergymedia.extension.org/video/part-1-switchgrass-and-perennial-grasses-biomass-and-biofuels-captions) – Ken Vogel

- Switchgrass and Perennial Grasses, Biomass and Biofuels, Part 2 (http://farmenergymedia.extension.org/video/part-2-switchgrass-and-perennial-grasses-biomass-and-biofuels) – Ken Vogel
- Switchgrass Establishment, Weed Control, and Seed Quality (http://farmenergymedia.extension.org/video/switchgrass-establishment-weed-control-and-seed-quality) – Rob Mitchell
- No-Till Drill Calibration Training Video (+Captions) (http://farmenergymedia.extension.org/video/no-till-drill-calibration-training-video-captions) – Rob Mitchell
- Switchgrass and Bioenergy Crop Logistics (http://farmenergymedia.extension.org/video/switchgrass-and-bioenergy-crop-logistics) – Stuart Birrell
- Switchgrass Cost of Production (http://farmenergymedia.extension.org/video/switchgrass-cost-production) - Marty Schmer
- Switchgrass Production Industry Perspectives (http://farmenergymedia.extension.org/video/david-stock-switchgrass-production-industry-perspectives) - David Stock
- Thermochemical Conversion of Biomass to Drop-In Biofuels (http://farmenergymedia.extension.org/video/thermochemical-conversion-biomass-drop-biofuels) – Robert Brown
- Thermochemical Option: Biomass to Fuel (http://farmenergymedia.extension.org/video/thermochemical-option-biomass-fuel) – Robert Brown

Instructional Video (https://vimeo.com/cenusabioenergy/videos)

- Link to the CenUSA Vimeo Site (https://vimeo.com/cenusabioenergy/videos) ; Link to the CenUSA YouTube Site (https://www.youtube.com/user/CenusaBioenergy)
- Sustainability in Bioenergy: A Nation Connected (https://www.youtube.com/watch?v=e3mXOt2a5uI&feature=youtu.be) - US Department of Energy
- CenUSA Bioenergy 2015 Summer Undergraduate Research Internship (https://vimeo.com/115007243) - Raj Raman
- Biochar: An Introduction to an Industry (http://farmenergymedia.extension.org/video/biochar-introduction-industry) - David Laird
- Biochar 101: An Intro to Biochar (http://farmenergymedia.extension.org/video/biochar-101-intro-biochar) - Kurt Spokas
- Commercialization Update: Opportunities for Perennial Biofeedstocks (http://farmenergymedia.extension.org/video/cenusa-commercialization-update-rob-mitchell) - Rob Mitchell
- University of Minnesota Extension Master Gardener Biochar Research Summary (http://farmenergymedia.extension.org/video/university-minnesota-extension-master-gardener-biochar-research-summary) - Julie Weisenhorn
- Plant Pathogen Risk Analysis for Bioenergy Switchgrass Grown in the Central USA (http://farmenergymedia.extension.org/video/plant-pathogen-risk-analysis-bioenergy-switchgrass-grown-central-usa) - Gary Yuen
- Entomology Research: Examining Insect Populations and Exploring Natural Plant Resistance (Captions) (http://farmenergymedia.extension.org/video/cenusa-entomology-research-examining-insect-populations-and-exploring-natural-plant-resistance) - Tiffany Heng-Moss
- Enhancing the Mississippi Watershed with Perennial Bioenegy Crops (http://farmenergymedia.extension.org/video/enhancing-mississippi-watershed-perennial-bioenergy-crops) - Pam Porter
- 2012 CenUSA Bioenergy Overview (http://farmenergymedia.extension.org/video/2012-cenusa-bioenergy-overview)
- CenUSA Bioenergy-Opportunities in Biofuel (http://farmenergymedia.extension.org/video/cenusa-bioenergy-opportunities-biofuel)
- 2012 CenUSA Bioenergy Farmer Focus (http://farmenergymedia.extension.org/video/2012-cenusa-bioenergy-farmer-focus) - Kevin Ross
- Intro to No-Till Drill Calibration for Switchgrass (+Captions) (http://farmenergymedia.extension.org/video/intro-no-till-drill-calibration-switchgrass-captions) – Rob Mitchell
- Switchgrass Planting Practices for Stand Establishment (http://farmenergymedia.extension.org/video/switchgrass-planting-practices-stand-establishment) – Rob Mitchell
- How to Measure Stand Establishment Using a Grid (http://farmenergymedia.extension.org/video/how-measure-stand-establishment-using-grid) – John Gurtzky
- Harvesting Native Grass for Biofuel Production (+Captions)

(http://farmenergymedia.extension.org/video/harvesting-native-grass-biofuel-production-captions) – Rob Mitchell
- Optimizing Harvest of Perennial Grasses for Biofuel (http://farmenergymedia.extension.org/video/optimizing-harvest-perennial-grasses-biofuel) – Kevin Shinners
- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird

Midwest Bioenergy Outreach Videos

- Learn about Biofuels in "3 Minutes" (https://vimeo.com/channels/mbo)
- Learn about Biofuels in Depth (http://vimeo.com/channels/mboindepth)

Classroom Curriculum - see above (#Educational%20Programs%20and%20Curriculum)

Frequently Asked Questions - FAQs

- What effects do corn stover removal rates have on greenhouse gas emissions from cropland?
- Can the use of conservation tillage help reduce greenhouse gas emissions from cropland soils where residues are used for biofuel?
- How can I get a switchgrass crop to dry faster in the field once it's been cut for biomass?
- How high should I cut switchgrass which is grown for biomass?
- Can I use my regular haying equipment to harvest switchgrass grown for biofuel?
- Why is it important to be able to grow a consistent and uniform supply of a biomass feedstock?
- Should I fertilize switchgrass when I plant it?
- When should I plant switchgrass?
- Will switchgrass grow well in my region?
- How can I get a switchgrass crop to dry faster in the field once it's been cut?
- How high should I cut switchgrass? I am growing it as a bioenergy crop.
- Can I use my regular haying equipment to harvest switchgrass grown as a biofuel?
- How can I reduce dry matter losses to a biomass crop during storage?
- Will weeds be a problem after my switchgrass stand is established?

CenUSA Bioenergy Overview

CenUSA is supported by Agriculture and Food Research Initiative (http://www.csrees.usda.gov/funding/afri/afri_synopsis.html) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

Checking in with CenUSA

CenUSA Bioenergy Communications Intern Jake Miller interviewed Jay Van Roekel, Biomass Business Unit Manager at Vermeer Corporation and CenUSA Advisory Board member in October 2015.

How did Vermeer become involved? How do they feel about the involvement?

Well, we've had a long relationship with Iowa State. Including Jill Euken and Stuart Birrell and I think that was part of it. I think it was relationships and Vermeer's work supporting biomass renewable energy projects. Vermeer also provides a commercial perspective side for CenUSA. You need a blend of research and commercial. At Vermeer we've been open and involved and supportive of renewable energy and I think that's how we ended up being asked to participate and it's been fun. It was really neat for me to go through the breeding or the development of the different plants, I learned a lot about the early processes, what happens before it even hits the fields.

Recent harvest releases? Harvest equipment in development?

Every year we're improving our baler or grinder line. That's kind of Vermeer's mentality. You identify a weak link and try to get rid of it in the following season, so it's maybe not a new model but every year we're improving our product line. That includes when we harvest or grind up these new types of crops or materials. If a machine was developed for corn stalks and now you're dealing with switchgrass there are certain parts of the process that need to be looked at, so we're always doing little things. Yes, we are in development of some new harvesting and processing equipment.

Every year we're improving our baler or grinder line. That's kind of Vermeer's mentality.

Is there anyway Vermeer technology can bring down the cost of production?

Well, I think that's everybody's goal. To bale faster or more-dense bales, less down time I think is one of the things that gets overlooked pretty often. It's more than baling another mile an hour faster or putting another 50 pounds in a bale. It's being able to bale all day every day. So, a lot of our on-going focus is in improving as well as educating our new customers on how to use their new equipment. Anytime you buy new equipment, a car for example, you're going to be a little less efficient when you operate it, so how can we close that gap to reasonable use of a product? And trying to work on our training modules and our customer training. That's really important; uptime training to get the most out of the new products that we have.

It doesn't seem like products are going down in price, right? So you have to get more out of them, whether it's technology, general performance, or uptime one of those things has to get better. Putting an electronic GPS tracking auto steer piece doesn't come for free, so it has to come out in your performance to overcome those additional costs

How do you educate people on your products? Getting the most out of your products?

As far as operator's manuals go our goal is that every call that would come into a dealer or Vermeer with a question we can tell that person to turn to page "X" and there's your answer. We want a thorough manual. Unfortunately, many people don't thoroughly read their manuals. It's easier to just call someone. So, it's a goal of Vermeer, and our dealers, to deliver the product to the field and do a good walk around with a new customer, actually operate the product with them, show them the different adjustments. So, really a hands on delivery approach I think does as much as anything. We also offer a followup after a day or two because once they get on their own they may have questions. We've also had new operator training schools.

Well, I think that's everybody's goal. To bale faster or more-dense bales …

Jay Van Roekel

How do customers react? Helps keep customers?

Absolutely, if they have a bad experience and don't get the help to cure an issue they're going to look somewhere else. There are a lot of good choice on the market so you have to really excel in the after sale portion. I don't care what color machine it is, it's going to go out and bale the first couple of months, right, it's new and doing what it's supposed to do. You set yourself apart by taking care of the customer. We believe that with our smaller product line, short lines as some people call them in the ag world, we're focused so we should excel and now more about how to use them than someone with a full line.

How did the switchgrass fields outside of Vermeer come about?

The Vermeer family owns several farms in the area and they've been very supportive of biomass and renewable energies of all types. It had been talked about before that the land close to Vermeer could be used for energy crops. Our involvement with CenUSA created the perfect opportunity. We have ten acres of land with three different plots. Rob Mitchell helped establish it, we're harvesting the plots and giving him the data.

Check in with these harvest resources from CenUSA Bioenergy at http://cenusa.iastate.edu/ResourceLibraryItems

- **Fact Sheets**
  Storing Perennial Grasses Grown for Biofuel
  Logistical Challenges to Switchgrass (Panicum virgatum L.) as a Bioenergy Crop
  Successfully Harvest Switchgrass Grown for Biofuel

- **Switchgrass Production Decision Tool**
  Estimated Cost of Establishment and Production of "Liberty" Switchgrass Instance

- **Instructional Videos**
  Harvesting Native Grass for Biofuel Production (+Captions)
  Optimizing Harvest of Perennial Grasses for Biofuel

- **Webinars**
  Switchgrass and Bioenergy Crop Logistics

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

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