cenusa bioenergy

Annual Progress Report

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

November 2017

Agriculture and Food Research Initiative Competitive Grant

No. 2011-68005-30411

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

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

Annual Report Executive Summaries

August 1, 2016 – July 31, 2017

EXECUTIVE SUMMARY – FEEDSTOCK DEVELOPMENT OBJECTIVE

The Feedstock Development Objective continues to focus on developing perennial grass cultivars and hybrids that can be used on marginal cropland in the Central United States to produce biomass for energy.

Co-Project Directors

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

Significant Accomplishments

- All data has been collected and received at central locations.
- Several manuscripts are in various stages of preparation, including:
  - A summary of biomass yield improvements across 13 field-trial locations.
  - Nitrogen demand associated with breeding for increased biomass yield.
  - Biomass quality associated with breeding for increased biomass yield.
  - Multi-location survey of insect populations in switchgrass and big bluestem trials.
  - Conversion efficiency of ‘Liberty’ switchgrass.
  - Epidemiology of switchgrass rust.

EXECUTIVE SUMMARY – SUSTAINABLE FEEDSTOCK PRODUCTION SYSTEMS

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

Co-Project Directors

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

Significant Accomplishments

- **Iowa State University**

  Our CenUSA Objective 2 efforts have focused on writing and publishing during the last year. We have maintained the CenUSA system plots at Armstrong Research Station, but as we have spent our CenUSA funding we used funds from another project to support the plots and collect one last year of data.

- **Purdue University**

  - High switchgrass yields can be obtained on soils considered marginal for soil test phosphorus (P) and potassium (K). Levels of these nutrients known to reduce yield of alfalfa and maize have little influence on switchgrass yields. Thus, deploying switchgrass on low fertility sites in the landscape may be an excellent strategy for co-production of food/feed and biomass.
  - Annual application of modest amounts of nitrogen (N) fertilizer annually (~75 kg N/ha) results in higher yields of *Miscanthus* than does application of higher levels (~150 kg/ha) on alternate years and allowing internal N cycling to provide N to growing shoots.
  - After extensive analysis of cell walls and other compositional traits we can conclude that yield of cellulose, hemicellulose, lignin, sugar, and starch per hectare is largely determined by biomass yield and not by concentrations of these biomass constituents *per se*.

- **University of Illinois**

  - By the end of this project year, we completed three years biomass production of five energy crops on a wet marginal land with two environmental replications. The field biomass yield data demonstrated that perennial energy crops can be successfully grown for biomass production on wet marginal lands while improving ecosystem services such as water quality.

- Biomass samples collected from each plot during the growing season of 2016 were ground and sent to the U.S. Dairy Forage Research Center for laboratory analysis of biomass quality traits. Nutrients and minerals in biomass were measured to quantify the nutrient removal by energy crops grown on a wet marginal riparian buffer. The data indicated that harvest management and species had significant impacts on nutrient removal.

- **University of Minnesota**

  - We completed near-anthesis and post-frost harvest activities and sample processing for the factor plots at Lamberton and Becker, Minnesota.

  - **Anne Sawyer Dissertation**

    Anne Sawyer completed her dissertation using data collected from CenUSA. She defended her dissertation on June 15, 2017 and officially graduated July 31, 2017. Using her work, we are preparing three manuscripts for publication (See dissertation abstracts below).

    - **Chapter 1. Switchgrass and Mixed Perennial Biomass Production as Affected by Nitrogen Fertility and Harvest Management**

      Biofuel production using native perennials on marginal soils can reduce U.S. dependence on foreign oil and curtail greenhouse gas emissions without diminishing food crop production. In this research, we quantified biomass production and nitrogen (N) removal as a function of harvest regime (anthesis and post-frost) and N application rate (0, 56 and 112 kg N ha^{-1}) on two marginal sites in Minnesota. We examined three switchgrass (*Panicum virgatum* L.) monocultures, including 'Liberty,' a new bioenergy variety, and three polycultures: grass-only, grass-legume, and grass-legume-forb. At Becker, post-frost harvest yields totaling 11.0 Mg ha-1 over three years were achieved in 'Sunburst' and 'Shawnee,' while 'Liberty' produced 7.0 Mg ha-1 when fertilized at 112 kg N ha-1 yr-1. At Lamberton, post-frost harvest yields in 'Shawnee,' 'Sunburst' and 'Liberty' totaled 32.5, 29.9 and 21.2 Mg ha-1 respectively, over three years, when fertilized at 56 kg N ha-1 yr-1. Yields of the low-diversity (LD) grass mix were similar to 'Shawnee' switchgrass at both locations. Yield differences between harvest regimes varied by cultivar and location, although most feedstocks produced similar or greater yields in the post-frost harvest. Our results indicate that maximum biomass production can be achieved with either a well-adapted switchgrass variety or LD grass mix fertilized with 56 kg N ha-1 annually, post-establishment, on a moderately productive loam soil, and with 112 kg N ha-1 annually on an excessively drained sandy soil. While producers may have flexibility in harvest timing for some feedstocks in the first few years following establishment, a post-frost harvest regime will remove less N and promote stand longevity with fewer inputs over time.

- **Chapter 2. Rhizobacteria Community Structure as a Function of Cultivar and Nitrogen in Switchgrass Grown on Two Marginal Soils**

  Switchgrass is a native perennial grass and promising biofuel crop that can be used for production on marginal agricultural lands. As such, research into the switchgrass rhizosphere microbiome has been ongoing in an effort to identify patterns in microbial communities that may be beneficial for increasing sustainability in production. In this study, we examined the effects of cultivar and nitrogen (N) fertilization on rhizosphere bacterial community structure in switchgrass grown on two marginal soils. We selected two upland forage cultivars, 'Sunburst' and 'Shawnee,' as well as the first lowland bioenergy switchgrass adapted for production in USDA hardiness zones 4, 5, and 6, 'Liberty'. We found that that existing soil characteristics primarily shaped switchgrass rhizosphere communities, but both cultivar and N fertilization also influenced microbial selection in the rhizosphere. Only N fertilization resulted in consistent differences in bacterial orders across location, including orders containing genera involved in N dynamics in soil: Nitrosomonadales and Rhodocyclales. We also found that within-site spatial variability in soil properties influenced rhizosphere community structure, although differences were confined to minor taxa (< 0.1% of sequence reads). While our results provide insight into the effects of cultivar and N fertilization on the switchgrass rhizosphere bacterial community, they also indicate a need for future research addressing the influence of existing soil characteristics, including within-site spatial variability, on development of the rhizosphere microbiome in agricultural settings.

- **Chapter 3. Cultivar and Phosphorus Fertilization Effects on Switchgrass Biomass Yield, Phosphorus Removal, and Rhizosphere Microflora**

  Switchgrass (*Panicum virgatum* L.) is a native perennial grass identified as a promising biofuel crop for production on marginal agricultural lands. As such, research into switchgrass fertility and the switchgrass rhizosphere microbiome has been ongoing in an effort to increase sustainability in production. In this study, we examined the effects of cultivar and phosphorus (P) fertilization on biomass yield, phosphorus removal, and rhizosphere bacterial and fungal community structure in three switchgrass cultivars: 'Sunburst,' 'Shawnee' and 'Liberty' the first lowland bioenergy switchgrass adapted to USDA hardiness zones 4, 5, and 6. Biomass increased linearly in response to increasing P application on a low to medium soil test P clay loam soil. Applying 19.6 and 39.1 kg P ha-1, prior to establishment, provided average post-frost biomass yields of 10.1 and 10.3 Mg ha-1 yr-1, respectively, over three years. 'Shawnee' was more productive than 'Liberty' or 'Sunburst' (11.3, 10.2, and 8.6 Mg ha-1 yr-1, respectively). While cultivar was shown to influence both bacterial and fungal community structure in the rhizosphere, there were few consistent differences in taxa among cultivars. Phosphorus fertilization did not affect community structure among bacteria or fungi, despite a known switchgrass association with arbuscular mycorrhizal fungi for nutrient – particularly P – acquisition. The inability to detect fungal community differences as a function of P may be a result of known shortcomings in fungal sequencing, analyses, and taxonomy identification. Overall, our results indicate that while the rhizosphere effect does influence bacterial and fungal community structure, existing soil physiochemical parameters explain a greater proportion of variability in the rhizosphere community than do treatment effects.

- **Publications**

- Aller, D., R. Mazur, K. Moore, R. Hintz, D. Laird & R. Horton. 2017. Biochar Age and Crop Rotation Impacts on Soil Quality. Soil Sci. Soc. Am. J. (In press).
- Dokoohaki, H., F. Miguez, D.A. Laird, R. Horton & A. Basso. 2017. Assessing the biochar effects on selected physical properties of a sandy soil: An analytical approach. Commun. Soil Sci. Plant Anal. (In Press).
- Aller, D., S. Rathke, D. Laird, R. Cruse & J. Hatfield. 2017. Impacts of fresh and aged biochars on plant available water and water use efficiency. Geoderma, 307:114-121. http://dx.doi.org/10.1016/j.geoderma.2017.08.007.
- Archontoulis, S.V., I. Huber, F.E. Miguez, P.J. Thorburn & D.A. Laird. 2016. A model for mechanistic and system assessments of biochar effects on soils and crops and trade-offs. GCB Bioenergy. doi:10.1111/gcbb.12314.
- Fidel, R.B., D.A. Laird & T.B. Parkin. 2017. Impact of biochar organic and inorganic C on soil CO2 and N2O emissions. J. Environ. Quality, 46:505-513. doi:10.2134/jeq2016.09.0369. https://dl.sciencesocieties.org/publications/jeq/pdfs/46/3/505.

- Fidel, R.B. D.A. Laird & T.B. Parkin. 2017. Impact of six lignocellulosic biochars on C and N dynamics of two contrasting soils. GCB Bioenergy, 9:1279-1291. doi:10.1111/gcbb.12414.
- Laird, D.A., J.M. Novak, H.P. Collins, J.A. Ippolito, D.L. Karlen, R.D. Lentz, K.R. Sistani, K. Spokas & R.S. Van Pelt. 2017. Multi-year and multi-location soil quality and crop biomass yield responses to hardwood fast pyrolysis biochar. Geoderma, 289:46-53.
- Rogovska, N., D.A. Laird & D.L. Karlen. 2016. Corn and soil response to biochar application and stover harvest. Field Crops Res., 187:96-106. doi:10.1016/j.fcr.2015.12.013.

EXECUTIVE SUMMARY – FEEDSTOCK LOGISTICS

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

Co-Project Directors

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

Significant Accomplishments

- **Iowa State University**
  - **Drying Rate Models**. Four drying rate models were finalized to predict the moisture change in switchgrass based on environmental conditions and swath densities. These models were developed for predicting moisture change in day conditions and for night conditions at different maturity stages. During day time conditions in both maturity stages, solar radiations and vapor pressure deficit (VPD) were positively correlated with drying rate whereas, wind speed and swath density were negatively correlated. During night conditions in both maturity stages, VPD was positively correlated and swath density was negatively correlated with drying rate. Effect of wind speed was however positive in seed developed stage and negative in seed shattering and seed shattered stage of maturity. Moisture content predicted by models were in good agreement with the moisture change observed in the experimental field drying studies.

- **Biomass Drying Prediction Model**. An improved biomass drying prediction model has been developed. This model uses a random forest (RF) classification based algorithm, to predict moisture content (MC) of switchgrass (SW) and corn stover (CS). RF was able to predict the moisture content of switchgrass (SW) and corn stover (CS) with a coefficient of determination of 0.77 and 0.79, respectively. Hours after harvest, average solar radiation intensity, change in radiation intensity, rainfall, VPD were found to be the most important factors affecting the MC of CS. Drying CS in low density (LD) and medium density (MD) swaths facilitated quick drying even in moderate drying conditions and density were found to be higher in importance than other variables used for model development. Rainfall events ranging from 1.5 to 7.5 mm were experienced during the switchgrass drying period which delayed the crop drying by one day to several days depending on the weather conditions after rainfall. Several rewetting events were also observed due to dew at night and early morning which increased the MC in LD switchgrass and CS by 5 to 15%. The models developed in current study will help in decision making of switchgrass and CS collection after harvest based on forecasted weather conditions in lower Midwestern states.

- **Harvest Logistics Cost Analysis**. The results of the CenUSA harvest logistics cost analysis have been discussed with a number of US and international visitors, including industrial visitors from Brazil and China who are investigating the use of biomass for energy production.

- **Moisture Predicting Sensors**. 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.

- **Publications**. Three journal articles have been published in 2017, with one more journal article in review and a second journal article to be submitted for review.

  A book chapter to be published in CRC Biomass Preprocessing Book, has been submitted and reviewed and is expected to be published, 2017. A journal article has been submitted to *Agricultural and Forest Meteorology* journal for review.

  ✓ Khanchi, A. & S.J. Birrell. 2017. Drying models to estimate moisture change in switchgrass and corn stover based on weather conditions and swath density. Agric. For. Meteorol., 1(8): 237-238. https://doi.org/10.1016/j.agrformet.2017.01.019.

  ✓ Khanchi, A.& S.J. Birrell. 2017. Effect of rainfall and swath density on dry matter and composition change during drying of switchgrass and corn stover. Biosystems Engineering, 153:42-51.

- ✓ Khanchi, A. & S.J. Birrell. 2017. Modeling the influence of crop density and weather conditions on field drying characteristics of switchgrass and corn stover using random forest. Biosystems Engineering (re-submission).
- ✓ Khanchi, A., B. Sharma, A.K. Sharma, A. Kumar, J.S. Tumuluru & S.J. Birrell. 2017. Effects of Biomass Preprocessing Technologies on Gasification Performance and Economic Value of Syngas. Book Chapter submitted to CRC Biomass Preprocessing Book Chapter. (Submitted, to be published 2017).
- ✓ Sharma, B. S. Birrell & F.E. Miguez. 2017. Spatial modeling framework for bioethanol plant siting and biofuel production potential in the U.S. Appl. Energ. 191:75-86.
- ✓ Karakee, A. & S.J. Birrell. 2018. Optimization and cost analysis of crop residue harvest systems. (In preparation).

▪ **University of Wisconsin**

Significant Accomplishments

- **Switchgrass Drying Rate Model**. We completed a model of the switchgrass drying rate as a function of solar insolation, vapor pressure differential, conditioning level, raking, and swath density. This drying rate model was then used to develop a model to predict the harvest progression of switchgrass across the fall harvest season in the Upper Midwest. The model uses historical weather data to predict the rate at which harvest can be completed. This work resulted in the publication of two peer-reviewed journal articles:
  - ✓ Shinners, K.J. & J.C. Friede. 2017. Enhancing the drying rate of switchgrass. BioEnergy Res., 10(3): 603-612.
  - ✓ Shinners, K.J., B.K. Sabrowsky, C.L. Studer & R.L. Nicholson. 2017. Switchgrass harvest progression in the North-Central US. BioEnergy Res. 10(3): 613-625
- **Twine Density Cost**. The cost of twine for high-density large-square bales can exceed $3 per dry ton, which is almost 25 percent of the total cost of baling. Twine failure and broken bales anywhere in the logistics system adds considerably to the delivered costs due to the additional (inefficient) handling required to deal with broken bales. Work was completed developing relationships between twine tension and bale density for high-density bales. A manuscript was recently submitted based on this work:
  - ✓ McAfee, J.M., K.J. Shinners & J.C. Friede. 2017. Twine tension in high-density large-square biomass bales. Applied Eng. in Ag. (Submitted August 2017, in review.)

- **Auger Baler**. The experimental "auger" baler was evaluated when baling typical biomass crops. The baler was able to produce bales with density ranging from 15 to 20 lb./ft^3, considerably denser than conventional bales of similar crop material. Modifications were made to overcome performance issues related to feeding and crop flow, so baling can now take place at throughputs similar to conventional balers. Preliminary results of this work have been published in a conference proceeding and a peer-reviewed manuscript will be completed in the spring of 2018:

  ✓ Shinners, K.J. J.C. Friede, J.R. McAfee, D.E. Flick, N.C. Lacy & C.M. Nigon. 2017. Conventional and novel approaches to creating high-density biomass bales. Proceedings of the Inter. Conference on Agricultural Engineering. Hanover, GE. Nov. 10 - 11.

  ✓ Flick, D.E., K.J. Shinners, J.C. Friede & C. M. Nigon. 2018. Producing high-density biomass using an auger-baler concept. Transaction of the ASABE. (To be submitted in late-spring 2018).

- **High-Density Large Square Balers**. We investigated "high-density" large square balers to determine if these machines could produce bale densities which would reduce storage and transport costs by reducing required storage space and insuring weight-limited transport. Density in excess of 14 lb./ft^3 would provide weight limited transport in most cases. In only a few conditions was this goal reached and total baling energy requirements increased as a quadratic function of density. However, reduction in costs of aggregation, storage and transport more than offset the greater cost of harvesting high-density bales. A manuscript from this work is nearing completion:

  ✓ Shinners, K.J. & J.C. Friede. 2017. Energy requirements to produce high-density large-square biomass bales. Energies. (To be submitted November 2017).

- **Densification Characteristics**. Densification characteristics of common biomass crops was investigated using test fixture intended to re-compress large-square bales to "double density". Models of recompression forces and energy as a function of attained density were developed. Forces in the straps that resist the bale resilient forces were determined. The results of this will be developed into a peer-reviewed manuscript will be completed in the spring of 2018:

  ✓ McAfee, J.M., K.J. Shinners & J.C. Friede. 2018. Recompression of large-square biomass bales. Transaction of the ASABE. (To be submitted in spring 2018).

EXECUTIVE SUMMARY – SYSTEM PERFORMANCE METRICS, DATA COLLECTION, MODELING, ANALYSIS AND TOOLS

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

Co-Project Directors

- Cathy Kling, Iowa State University, ckling@iastate.edu, 515.294.5767.
- Jason Hill, hill0408@umn.edu, 612.624.2692.

Significant Accomplishments

- **Iowa State University**

  Objective 4 collaborators focused on completing the review process of a set of four simulation-based studies submitted to the Journal of the American Water Resources Association (JAWRA) SWAT Special Series. This set of studies describes the impact of introducing biofuel cropping systems in specific watersheds representative of the eastern or western Corn Belt regions, as well as for the entire Upper Mississippi and Ohio River systems (representative of the entire Corn Belt). An overview study provides an assessment of the policy implications of the results of the watershed analyses. All four studies are now forthcoming in JAWRA; it is anticipated that those studies will be published in the final 2017 issue or first 2018 issue of JAWRA.

- **University of Minnesota**

  This year, the Objective 4 team in Minnesota continued preparing and submitting manuscripts from the research results of previous years. This resulted in four more publications, with two more in review and at least one more in preparation.

  - Harding, K., T. Twine, A. VanLoocke & J. Hill. 2016. Impacts of second-generation biofuel feedstock production in the central U.S. on the hydrologic cycle and global warming mitigation potential. Geophys. Res. Lett. 43:10773-10781. doi:10.1002/2016GL069981.
  - Keeler, B., J. Gourevitch, S. Polasky, F. Isbell, C. Tessum, J. Hill & J. Marshall. 2016. The social costs of nitrogen. Sci. Adv., 2:1-9. doi:10.1126/sciadv.1600219. (Open Access).

- Sun, J., T. Twine, J. Hill, R. Noe, J. Shi &M. Li. 2017. Effects of land use change for crops on water and carbon budgets in the Midwest USA. Sustainability, 9:1-. doi:10.3390/su9020225. (Open Access).

- Tessum, C.W., J.D. Hill & J.D. Marshall. 2017. InMAP: A model for air pollution interventions. *PLOS ONE* 12(4): 1-26. doi:10.1371/journal.pone.0176131. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0176131. (Open Access).

FEEDSTOCK CONVERSION AND REFINING

Co-Project Director

- Robert C. Brown, Iowa State University, 515.294.7934.

Significant Accomplishments

We focused on completing journal publications.

- Aller, D., S. Bakshi & D.A. Laird. 2017. Modified method for proximate analysis of biochars. J. of Analytical & Applied Pyrolysis. 124:335-342. doi.org/10.1016/j.jaap.2017.01.012.

- Bakshi, S., D.M. Aller, D.A. Laird & R. Chintala. 2016. Comparison of the Physical and Chemical Properties of Laboratory- and Field-Aged Biochars. J. Env. Quality, 45:1627-1634. doi:10.2134/jeq2016.02.0062.

- Bakshi, S., C. Banik, S.J. Rathke & D. A. Laird. 2017. Arsenic sorption on zero-valent iron-biochar complexes. (In preparation).

- Banik, C., M. Lawrinenko, S. Bakshi & DA. Laird. 2017. Functional groups in relation to biochar surface charges. (In preparation).

- Dang, Q., Wenzhen, L. & M. Mba Wright. 2017. Techno-economic analysis of a hybrid biomass thermochemical and electrochemical conversion system. Energy Technol. (Accepted).

- Fidel, R. S. Archontoulis, B. Babcock, R.C. Brown, H. Dokoohaki, D. Hayes, D.A. Laird, F. Miguez, & M. Mba Wright. 2017. Commentary on Current economic obstacles to biochar use in agriculture and climate change mitigation regarding uncertainty, context-specificity and alternative value sources. Carbon Manage. (Accepted).

- Fidel, R., D.A. Laird, & K. Spokas. 2017. Sorption of ammonium and nitrate to biochars is electrostatic and pH-dependent. Sci. Rep. (Reviewers requested "major revisions" before publication).

- Fidel, R.B., D.A. Laird, M.L. Thompson & M. Lawrinenko. 2017. Characterization and quantification of biochar alkalinity. Chemosphere, 167:367-373. doi.org/10.1016/j.chemosphere.2016.09.151.

- Lawrinenko, M., D. Jing, C. Banik & D.A. Laird. 2017. Aluminum and iron biomass pretreatment impacts on biochar anion exchange capacity. Carbon, 118: 422-430. http://dx.doi.org/10.1016/j.carbon.2017.03.056.

- Lawrinenko, M., D.A. Laird, R.L. Johnson & D. Jing. 2016. Accelerated aging of biochars; impact on anion exchange capacity. Carbon, 10: 217-227. doi:10.1016/j.carbon.2016.02.096.

- Lawrinenko, M., J. (Hans) van Leeuwen & D.A. Laird. 2017. Sustainable pyrolytic production of zerovalent iron. ACS Sustainable Chem. Eng., 5: 767-773. doi:10.1021/acssuschemeng.6b02105.

- Lawrinenko, M., Z. Wang, R. Horton, D. Mendivelso-Perez, E. Smith, T. Webster, D.A. Laird & J. (Hans) van Leeuwen. 2017. Macroporous carbon supported zerovalent iron for remediation of trichloroethylene. ACS Sustainable Chem. Eng., 5: 1586-1593. doi:10.1021/acssuschemeng.6b02375.

- Li, W., Q. Dang, R. Smith, R.C. Brown & M. Mba Wright. 2017. Techno-Economic Analysis of the Stabilization of Bio-Oil Fractions for Insertion into Petroleum Refineries. ACS Sustainable Chem. Eng., 2: 1528-1537.

- Li, W., Q. Dang, D. Laird, R.C. Brown, & M. Mba Wright. 2017. The impacts of biomass properties on pyrolysis yields, economic and environmental performance of the pyrolysis-bioenergy-biochar platform to carbon negative energy. Bioresour. Technol. (Accepted).

- Qi, F. & M. Mba Wright. 2016. A novel optimization approach to estimating kinetic parameters of the enzymatic hydrolysis of corn stover. AIMS ENERGY, 1(4): 52-67.

- Qi, F., T.J. Heindel, M. Mba Wright. 2017. Numerical study of particle mixing in a lab-scale screw mixer using the discrete element method. Powder Technol., 308: 334-345.

EXECUTIVE SUMMARY – MARKETS AND DISTRIBUTION

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

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

Co-Project Directors

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

Significant Accomplishments

The primary goal of Objective 6 is to contribute new knowledge about how producers of dedicated biomass make decisions about participation and also about the contract mechanisms that might be effective as biomass processors work to procure feedstock from producers. In this final year, as a result of that research, we were invited to share our work in Washington, D.C. at a USDA C-FARE and Office of Chief Economist symposium, "American-Made Bioenergy from Field to Refinery: Feedstock Logistics."

The research and project support provided graduate student training in economics, and this year, a student earned his Ph.D., in part, as a result of a paper written through this support. The paper has been submitted for publication to *Energy Economics*, recognized as a premier field journal for work in the area of energy economics and finance. Additionally, this research will be summarized for publication in Iowa State University Center for Agricultural and Rural Development's *Ag Policy Review*, an in-print and online publication whose readership includes producers, policymakers, academics in the fields of agriculture and energy policy. Finally, our team's work in this area will be leveraged as Co-PD Jacobs begins work on a related competitive federal proposal to investigate sorghum as a feedstock for bioenergy.

EXECUTIVE SUMMARY – 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.

Co-Project Directors

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

Significant Accomplishments

We published a risk assessment model that measures the differences between two agricultural production systems forecasting the likelihood of worker injury. The published model provides a useful tool to produce logical results with limited agricultural injury data when comparing two agricultural productions systems. The ability to show the potential of where agricultural workers have the highest risk with newly developing systems like biofuel switchgrass production systems is valuable. A description of the model's approach and summary results for the public were made available on the E-extension web site Research Summary: Overview of Comparative Injury Risk Between Annual Corn and Perennial Switchgrass Production. 2017. http://articles.extension.org/pages/74211/research-summary:-overview-of-comparative-injury-risk-between-annual-corn-and-perennial-switchgrass.

EXECUTIVE SUMMARY – EDUCATION

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

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

Co-Project Directors

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

Significant Accomplishments

- **On-line Curriculum Course Modules.** We completed the design of a CenUSA Massive Open Online Course (MOOC) "Introduction to Perennial Grasses for Biofuels." The MOOC was offered to the public on a self-serve basis through The Ohio State University ATI Continuing Education program. Course feedback was evaluated to improve possible future course offerings. Existing modules were editing and brought online in the CenUSA Canvas-based learning management system at OSU ATI. New modules on plant breeding and warm-season grass pathology were also completed.

EXECUTIVE SUMMARY – EXTENSION AND OUTREACH

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

Co-Project Director

- Jill Euken, jeuken@iastate.edu, 515.294.6286.

Significant Accomplishments

- **Extension Staff Training/eXtension Team - Publications, Proposals, Presentations**
  - **BLADES Newsletter**
    - ✓ CenUSA Bioenergy Engineers Cut Switchgrass Drying Time by 50%. http://blades-newsletter.blogspot.com/2017/01/cenusa-bioenergy-engineers-cut.html.
    - ✓ Plant Breeders Increase Switchgrass Yield by 40%. http://blades-newsletter.blogspot.com/2017/01/plant-breeders-increase-switchgrass.html.
    - ✓ New Market Place Opportunities for Biobased Products. http://blades-newsletter.blogspot.com/2017/01/new-market-place-opportunities-for.html.
  - **eXtension Articles**
    - ✓ The CenUSA Legacy: Creating a Sustainable Biofuels and Bioproducts System for the Midwest, which provides impact details of the project in concise format. http://articles.extension.org/sites/default/files/CenUSA-Legacy-Flyer.pdf.
    - ✓ What Would it Take to Convince Farmers to Grow Switchgrass for Biomass? Richard Perrin & Susan Harlow. http://articles.extension.org/pages/74212.

- ✓ Research Summary: Overview of Comparative Injury Risk Between Annual Corn and Perennial Switchgrass Production. Saxon Ryan, Charles Schwab, and Mark Hanna. http://articles.extension.org/pages/74211.

- **Team Overview Articles**

  - ✓ CenUSA Feedstock Development. Mike Casler & Susan Harlow http://articles.extension.org/pages/74210.
  - ✓ CenUSA Feedstock Logistics: Innovative Systems for Harvest, Transportation, and Storage of Perennial Grass Biomass. Kevin Shinners & Susan Harlow. http://articles.extension.org/pages/74073.
  - ✓ CenUSA Feedstock Conversion and Refining. Ryan Smith & Susan Harlow. http://articles.extension.org/pages/74206.
  - ✓ CenUSA Extension and Outreach: Perennial Grass Bioenergy Research and Knowhow for Producers, Students and Stakeholders. Jill Euken, Amy Kohmetcher & Susan Harlow. http://articles.extension.org/pages/74209.
  - ✓ CenUSA Models Predict Large Water Quality Improvements from Perennials. Pamela Porter. http://articles.extension.org/pages/74213.

- **Outreach (Social Media)**

  - ✓ **CenUSA Vimeo Channel**. The 54 CenUSA videos archived on Vimeo had 900 plays or views of the videos on our Vimeo site between August 1, 2016 and July 31, 2017.
  - ✓ **CenUSA YouTube Channel**. The 54 CenUSA videos were viewed 5468 times between August 1, 2016 and July 31, 2017.
  - ✓ **CenUSA Website**. 4,750 page views by 2,009 viewers between August 2016 and July 31, 2017.
  - ✓ **eXtension Website**. 10,622 page views by 7,630 viewers between August 2016 and January 31, 2017.

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

The team participated in events between August 2016 and July 2017 that reached 361 producers and agriculture industry leaders.

- **Publications, Presentations, Proposals Submitted**

Switchgrass and Mixed Perennial Biomass Production on Two Marginally Productive Soils as Affected by Nitrogen Fertility and Harvest Management. 2017. Presented at ASA, CSSA, SSSA International Annual Meetings, Phoenix, AZ. 9 Nov. https://scisoc.confex.com/scisoc/2016am/webprogram/Paper99966.html.

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

  - **Youth Development**

    ✓ Conducted training for Vo-Ag and Science teachers in collaboration with Morningside College in Sioux City, IA for 15 Vo-Ag and STEM teachers on June 6, 14, 15 and 16. See Exhibit 1.

    ✓ Conducted teacher training events in conjunction with the *National Ag in the Classroom* conference June 20-23 (https://naitcconference.usu.edu). CenUSA was a sponsor for the conference and provided overviews of the CenUSA C6 BioFarm program at both a plenary session and a breakout session, reaching over 350 teachers.

- **Economics and Decision Tools**

  - **CenUSA Switchgrass Decision Tool**. http://www.extension.iastate.edu/AgDM/crops/html/a1-29.html) was downloaded and completed by 809 users during the course of the CenUSA project, exceeding our project goal by 309!

- **Publications, Presentations, Proposals Submitted**

  Perrin, R.K.. L.E. Fulginiti & M. Alhassan. 2017. Biomass from marginal cropland: willingness of North Central US farmers to produce switchgrass on their least productive fields. Biofpr., 11(2) doi:10.1002/bbb.1741.

- **Evaluation and Administration**

  - **Actual Accomplishments**

    ✓ Compiled reports from the CenUSA Extension team.

    ✓ Received approval for CenUSA C6 teacher renewal credit for professional development course to be offered in June 2017 (see: https://staffdev.aea4.k12.ia.us/4DCGI/SC003599761801INV&*).

    ✓ Selected for presentation at plenary session and breakout session at the National Agriculture in the Classroom Conference (http://naitcconference.usu.edu/index.cfm).

- ✓ C6 BioFarm: A Sustainability Game for Learning the Role of a Bio-Based Economy. Presented at National Extension Energy Summit (April 2017). https://ag.tennessee.edu/solar/nees2017/Pages/Agenda.aspx).
- ✓ Presented results from CenUSA and promoted use of CenUSA Decision Tool at Iowa Integrated Crop Advisor Conference. 1 Dec. 2016.
- ✓ Presented results from CenUSA and promoted use of CenUSA Decision Tool at SW Iowa Crop Advantage (112 participants). 17 Jan. 2017.
- ✓ Planned and conducted teacher training at Morningside College (June 2017) for 15 teachers and at the National Ag in the Classroom conference in Kansas City (July 2017) for 350 teachers.

EXECUTIVE SUMMARY – COMMERCIALIZATION

The Commercialization Objective was initiated in Year 4 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.

Co-Project Directors

- Tom Binder, Tom.Binder@adm.com, 217.451.4228.
- Fred Moesler, Renmatix, Fred.Moesler@renmatix.com 484.751.4018

Significant Accomplishments

- Provisional patent application submitted on “Methods of producing stable lignin phenolic oil.”
- Provisional patent application submitted on “Pyrolysis of lignin.”
- Demonstrated the use of microbial biocatalysts to produce vanillin from lignin-derived phenolic monomers. Specifically, conversion of 4-VG to vanillin was demonstrated.
- A variety of microbial species that were likely to naturally produce vanillin from 4-VG were identified in the scientific literature and characterized. These include *Pseudomonomas putida* KT2440, *Bacillus coagulans* DSM1 and *Lactobacillus coagulans* DSM 20174. Unfortunately, no production of vanillin from 4-VG was detected.

- The Cso2 enzyme from *Caulobacter segnis* was previously reported to enable the conversion of 4-VG to vanillin when expressed in Escherichia coli. Therefore, we cloned this enzyme into both *Saccharomyces cerevisiae* and *E. coli*, along with other genes intended to help with protein folding. Protein gels confirmed that the Cso2 gene product was expressed and soluble in the engineered E. coli strain.

- Despite verification of successful cloning of the Cso2 enzyme and supplementation of growth media with the iron chloride reported to increase enzyme activity, only very low levels of vanillin were detected. We have proposed that this low conversion is due to low solubility of 4-VG in aqueous fermentation media. However, the inclusion of emulsifiers did not improve vanillin production.

- **Publications**

    - Davis, K.M., M.R. Rover, R.C. Brown, X. Bai, Wen, Z. & L.R. Jarboe. 2016. Recovery and Utilization of Lignin as Monomers as Part of the Biorefinery Approach. Energies. 9(10): 808. doi:10.3390/en9100808.

    - Rover, M., P. Hall, R. Smith & R.C. Brown. 2016. Application of Low Temperature, Low Pressure Hydrogenation to Liquefy and Stabilize Lignin Streams, Oral Presentation, American Chemical Society National Meeting, San Diego, CA. 13 Mar.

    - Zhou, S., R.C. Brown & Bai. 2015. The use of calcium hydroxide pretreatment to overcome agglomeration of technical lignin during fast pyrolysis. Green Chemistry, Vol. 10.

- **Renmatix**

    At the 2016 annual meeting we reported that achieving high-value for lignin co-product from a biorefinery using the Renmatix Plantrose™ process to convert perennial grasses into sugars and lignin had the potential to make significant economic improvements to the biorefinery.

    The first opportunity evaluated and demonstrated in Year 6 for high-value lignin was as a partial replacement for phenol-formaldehyde adhesives for the production of OSB (oriented strand board) wood panels. Lignin from switchgrass was produced in Renmatix's Plantrose™ pilot plant, and was blended with a commercial, OSB resin at various partial replacement levels. The blends were tested for reactivity on maple veneer strips in our Automated Bonding Evaluation System and passed.

    Next the lignin was used to produce 3'x3' OSB panels at the University of Maine's Advanced Structures and Composites Center under industrially realistic OSB manufacturing conditions at up to 25% substitution rate in the panel face layers. The panels were tested against, and passed, US and Canadian commercial standards for internal bond strength, modulus of elasticity, modulus of rupture and thickness swell. The results of this work suggest that Plantrose™ biorefinery lignin could receive high values, possibly as much as $1,000/ton if used as a partial replacement for phenol-formaldehyde adhesives in OSB wood panel production, thereby significantly improving Plantrose™ biorefinery economics.

The second opportunity evaluated was the use of lignin in composite thermoplastic applications. Lignins from switchgrass were produced in Renmatix's Plantrose™ pilot plant. Each lignin was blended into polypropylene along with dispersing agents and commercial stabilizing agents using twin screw extrusion to homogenize the compositions that were prepared at various loading levels. Mold specimens with lignin and polypropylene were prepared and submitted for testing at Underwriters Laboratory (UL). In the event that lignin prepared from a Plantrose™ biorefinery can successfully be used in commercial applications in polypropylene thermoplastic applications, it may be possible to achieve value as high as $1,800-$3,000/ton, thereby significantly improving Plantrose™ biorefinery economics.

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

Quarterly Report May 1, 2017 – July 31, 2017

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. Mary Scott Hall (ISU Bioeconomy Institute) provides assistance with project financial matters.

- **CenUSA Bioenergy Advisory Board**

  Our Advisory Board was engaged in the project and provided feedback to the project director and leadership team.

- **Executive Team Meetings**

  The Co-Project directors representing each of the ten project objectives met monthly with Ken Moore and Anne Kinzel via online bimonthly 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 attended 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.

Germplasm to Harvest

Objective 1. Feedstock Development

1. Actual Accomplishments

- Collect all 2016 data from 13 locations in field-trial network.
- Conduct final data analyses.
- Conduct laboratory analyses of 'Liberty' samples in comparison to control varieties.

- Complete analysis of the electronic feeding monitoring.

2. **Planned Activities**

- All data have been collected and received at central locations.
- Several manuscripts are in various stages of preparation, including:
    - ✓ Summary of biomass yield improvements across 13 field-trial locations.
    - ✓ Nitrogen demand associated with breeding for increased biomass yield.
    - ✓ Biomass quality associated with breeding for increased biomass yield.
    - ✓ Multi-location survey of insect populations in switchgrass and big bluestem trials.
    - ✓ Conversion efficiency of 'Liberty' switchgrass.
    - ✓ Epidemiology of switchgrass rust.

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

See above.

Objective 2. Sustainable Feedstock Production Systems

- **Iowa State University**

Our efforts have been focused on writing and publishing during the last year. We have maintained the CenUSA system plots at the Armstrong Research Station, but as we no longer have CenUSA funding, we used funds from another project to support the plots and collect one last year of data. May-July 2017 includes work on the "in preparation paper" and maintaining the system plots.

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

Bakshi, S., S.J. Rathke, C. Banik & D.A. Laird. Impacts of biochar aging and soil type on soil nitrogen dynamics. (In preparation, tentative title).

- **Purdue University**

Nitrogen Management and Reserve Dynamics of *Miscanthus* genotypes. Nitrogen (N) reserves in vegetative tissues contribute N to regrowth of Miscanthus × giganteus shoots in spring, but our understanding of how N fertilization and plant genotype affect this process is incomplete. Our specific objectives were to:

- Determine how N fertilizer management impacts accumulation of dry matter (DM) and N among aboveground and below ground tissues and organs.
- Understand how changes in N management and tissue N concentration influence seasonal fluctuations in concentrations of buffer-soluble proteins and amino acids in putative storage organs including rhizomes and roots.
- Characterize genotypic variability and genotype x N interactions for N reserve accumulation and use among Miscanthus × giganteus genotypes.

Established plots of the IL Clone and Nagara-sib population were fertilized with 0-0, 0-150, 75-75, 150-0, and 150-150 kg N ha^{-1} where the first numeral denotes the N rate applied in 2011 (Year 1) and the second number denotes the N rate applied in 2012 (Year 2). Rhizomes, roots, stembases, and shoots were sampled at six-week intervals between March and August and then in November at dormancy. Concentrations of N, soluble protein and amino-N increased in all tissues with fertilizer N application (Fig 2). With the exception of rhizome amino-N, concentrations of these N pools in roots and rhizomes declined as plants resumed growth in spring and increased sharply between August and November as growth slowed (Fig. 3). Losses in shoot and stembase N mass between August and November were similar to total N accumulation in roots and rhizomes during this interval. Compared to the unfertilized control, specific N managements enhanced growth of above- and below ground tissues (Fig 1). The Illinois (IL) Clone generally had greater biomass yield of all organs than the Nagara-sib; the exception being shoot biomass in November when extensive leaf senescence reduced yield of the IL Clone. High biomass yields were obtained with 75 kg N ha^{-1} applied annually rather than semi-annual N applications of 150 kg N $^{-1}$ ha that depended on N recycling from roots/rhizomes as a supplemental N source.

Figure 1. The N treatments (all in kg N ha^{-1}) included: no N application either year (0N-0N), N application only in Year 1 (150N-0N) or Year 2 (0N-150N), or N application both years of the study (75N-75N; 150N-150N). C: means and LSDs for the main effects of harvest (plotted) and genotype (tabulated) on root mass. D: means and LSDs for the main effects of harvest (plotted) and genotype (tabulated) on rhizome mass. Tissue sampling commenced in March of Year 2. The LSDs are provided at *P*<0.05. In Panels C and D genotypic differences designated with (**) are significant at *P*<0.01.

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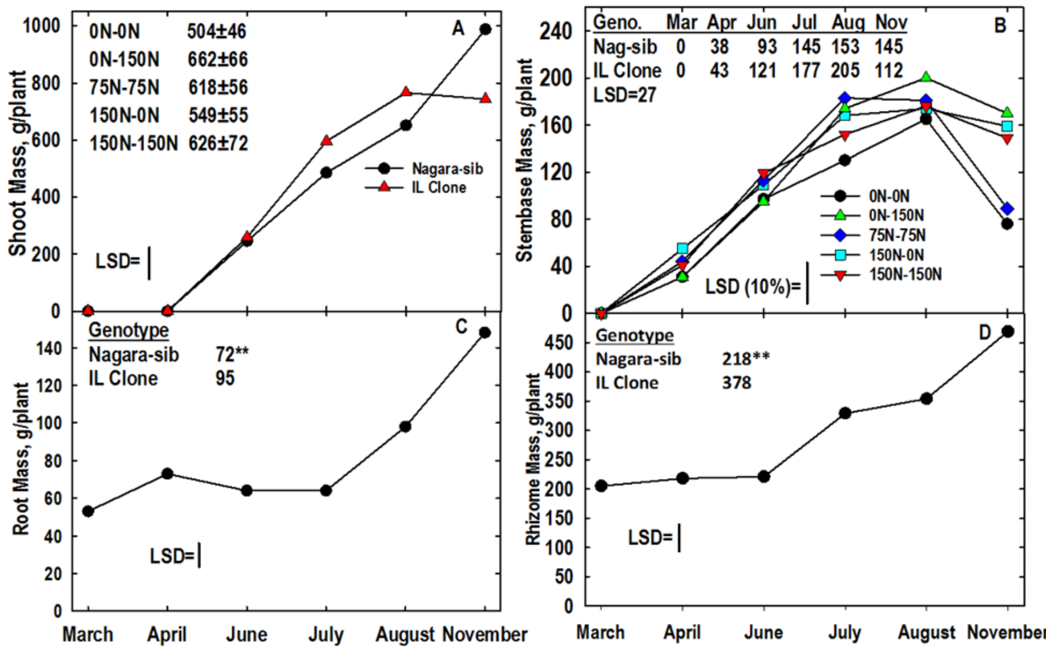

Fig. 1. Tissue dry matter yields of two *Miscanthus* genotypes (Nagara-sib, IL Clone) as influenced by nitrogen (N) management. A: means and least significant difference (LSD) for the genotype x harvest interaction on shoot biomass yield and the main effect means ± std. error of N management on shoot mass (tabulated). B: stembase means and LSDs for the N management x harvest interaction (plotted) and genotype x harvest interaction (tabulated) effects.

Figure 2. The N treatments (all in kg N ha^{-1}) included: no N application either year (0N-0N), N application only in Year 1 (150N-0N) or Year 2 (0N-150N), or N application both years of the study (75N-75N; 150N-150N). Tissue sampling commenced in March of Year 2. The LSDs are provided at $P<0.05$ unless otherwise noted. Genotypic differences designated with (* and **) are significant at $P<0.05$ and $P<0.01$, respectively.

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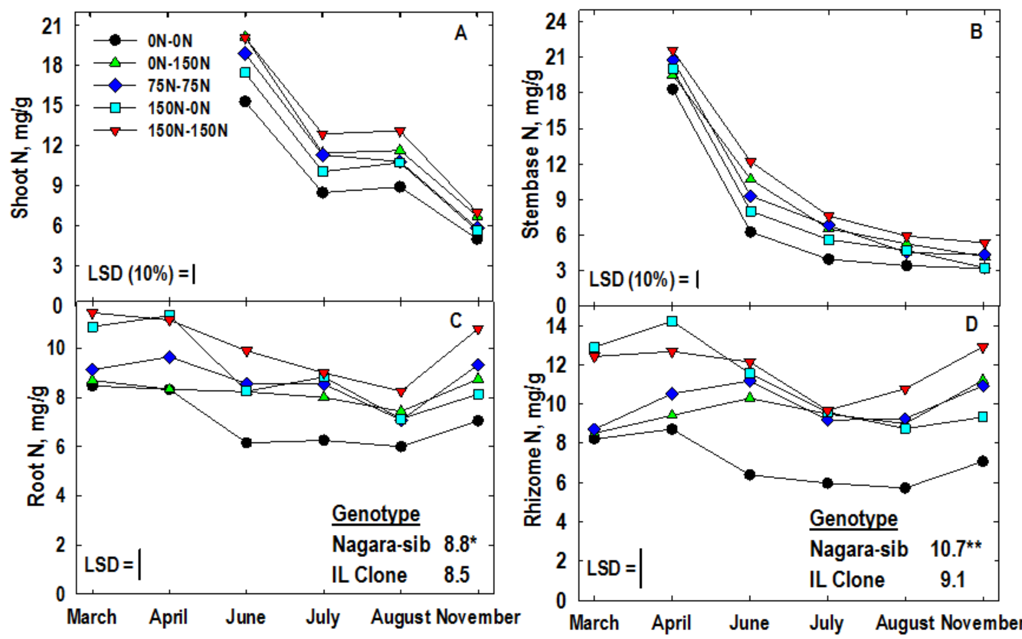

Fig. 2. Tissue nitrogen (N) concentrations of two *Miscanthus* genotypes (Nagara-sib, IL Clone) as influenced by N management. A: shoot N means and least significant differences (LSDs) for the N management x harvest interaction effect. B: N management x harvest interaction means for stembase N concentrations. C: root N means and LSDs for the N management x harvest interaction effect (plotted) and genotype main effect (tabulated). D: rhizome N means and LSDs for the N management x harvest interaction effect (plotted) and genotype main effect (tabulated).

Figure 3. Protein concentrations in roots (A) and rhizomes (B) of *Miscanthus* as influenced by nitrogen (N) management. Means and least significant differences (LSD, $P<0.05$) for the N management x harvest interaction are provided. The N treatments (all in kg N ha^{-1}) included: no N application either year (0N-0N), N application only in Year 1 (150N-0N) or Year 2 (0N-150N), or N application both years of the study (75N-75N; 150N-150N). Tissue sampling commenced in March of Year 2.

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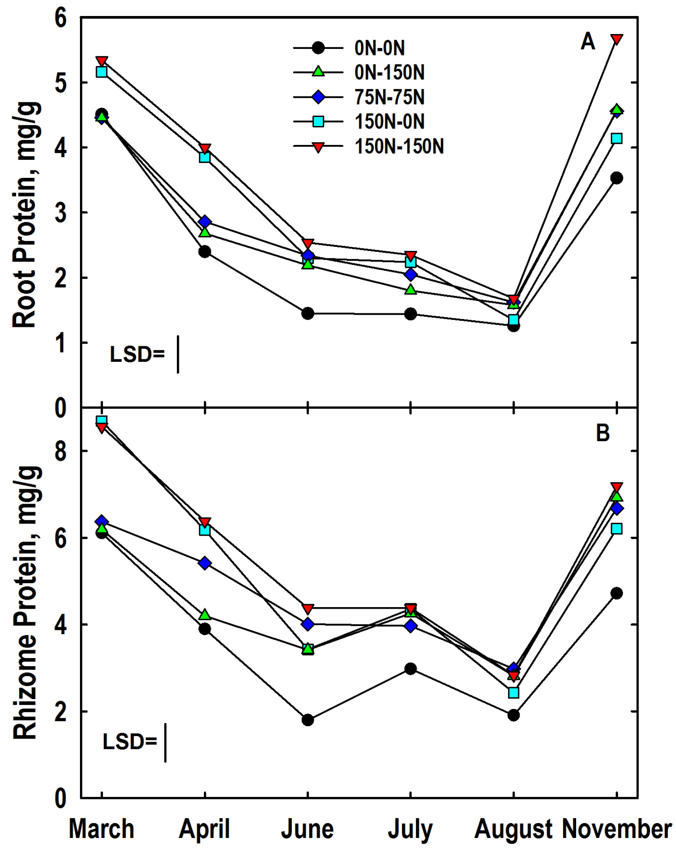

Fig. 3. Protein concentrations in roots (A) and rhizomes (B) of *Miscanthus* as influenced by nitrogen (N) management. Means and least significant differences (LSD, P<0.05) for the N management x harvest interaction are provided.

We also are analyzing eight years of compiled data focused on the impact of phosphorus (P) and potassium (K) nutrition on switchgrass biomass production. This large range in soil test level was created by differential fertilization of an alfalfa stand with high rates of P (up to 75 kg P/ha/yr) and K (up to 400 kg K/ha/yr) from 1997 to 2004. The alfalfa was rotated to switchgrass in 2007 and fertilized with 50 kg N/ha/yr. Soil test K concentrations range from 60 to over 300 mg/kg soil did not influence yield of ‘Shawnee’ switchgrass from 2008 to 2016 (Fig. 4). Likewise, soil test P concentrations ranging from 5 to 70 mg/kg soil had little impact on yield of ‘Shawnee’ switchgrass (Fig 5). Additional work is underway to explore the relationship between tissue P and K concentrations, soil P and K level, and biomass production.

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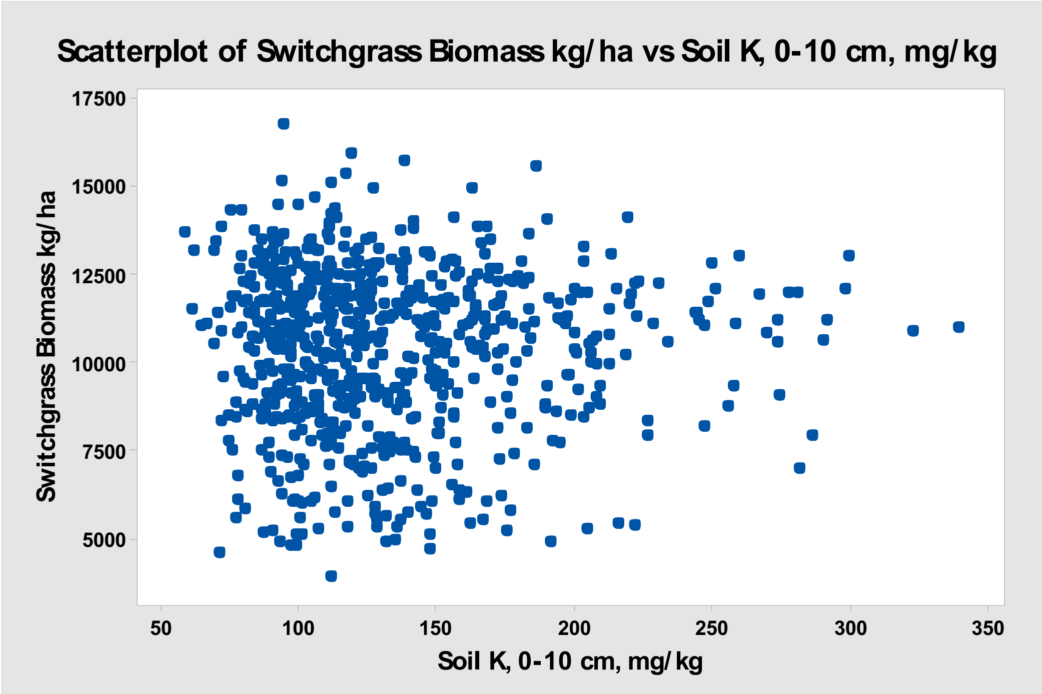

Fig. 4. Relationship between soil test potassium (K) concentration and biomass yield of Shawnee switchgrass.

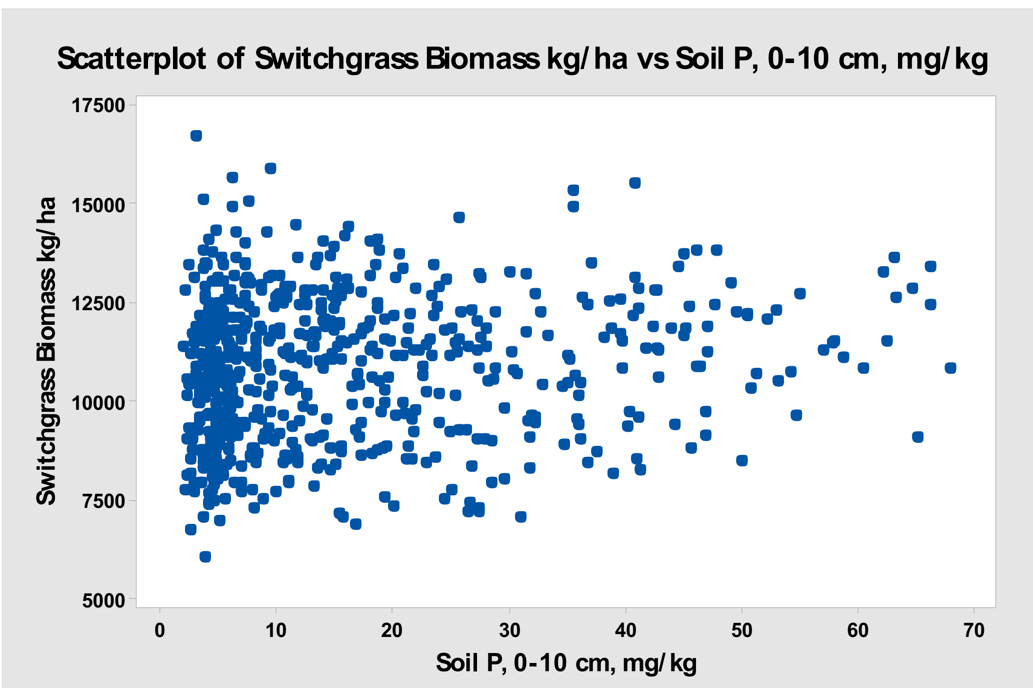

Fig. 5. Relationship between soil test phosphorus (P) concentration and

- **University of Illinois**

  We are currently conducting analyses of four years of data and writing manuscripts for publication in refereed journals. As we observed the effects of harvest timing on stand health, we decided to harvest one more year and plot maintenance was continued without fertilization. While we are working on a manuscript on biomass yield, we submitted two abstracts for oral-presentation to ASA, CSSA & SSSA International Annual Meetings on October 23, 2017.

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

    - ✓ Kim, H., M.S. Lee, A.C. Yannarell & D.K. Lee. 2017. Nitrogen, Phosphorus and Potassium Removal by Perennial Energy Grasses Grown on Wet Marginal Land. 2017 ASA, CSSA & SSSA International Annual Meetings. Tampa, FL. 23 Oct.

    - ✓ Cooney, D., M.S. Lee, M. Villamil & D.K. Lee. 2017. Nitrogen Cycling Microbial Community Affected by Perennial Energy Crops on a Riparian Buffer. 2017 ASA, CSSA & SSSA International Annual Meetings. Tampa, FL. 23 Oct.

- **University of Minnesota**

  - **Becker Location**

    All samples have been processed and analyzed.

  - **Lamberton Location**

    All samples have been processed and analyzed.

- **Other Activities**

  - Anne Sawyer completed her dissertation using data collected from CenUSA. She defended her dissertation on June 15, 2017 and officially graduated on July 31, 2017.

    - ✓ The first chapter, "Switchgrass and mixed perennial biomass production as affected by nitrogen fertility and harvest management" is based on the factor plots and examines near-anthesis and post-frost yield data and N uptake/removal from three switchgrass cultivars ('Liberty,' 'Shawnee' and 'Sunburst') and three perennial polycultures at Becker (2012-2015) and Lamberton (2013-2016). A manuscript has been prepared and will be submitted within the next month to *Agronomy Journal*.

    - ✓ Chapter 2, "Rhizobacterial community structure as a function of cultivar and nitrogen in switchgrass grown on two marginal soils" explores the community of rhizosphere bacteria in unfertilized and fertilized (112 kg N ha-1) 'Liberty,' 'Shawnee,' and

‘Sunburst’ from the near-anthesis factor plot harvest in 2014 using high-throughput sequencing of the 16S rRNA gene. A manuscript has been prepared and is undergoing internal review before submission.

- ✓ Chapter 3, “Cultivar and phosphorus fertilization effects on switchgrass biomass yield, phosphorus removal, and rhizosphere microflora”, is similar to Chapter 2 in using high-throughput sequencing of the 16S rRNA gene in bacteria, but also includes sequencing of the ITS region in fungi. Post-frost switchgrass biomass yield and P removal in ‘Liberty,’ ‘Shawnee’ and ‘Sunburst’ was evaluated at four P rates (0, 22, 45 and 67 kg P2O5 ha-1) over three years, and near-anthesis rhizosphere microflora community structure was evaluated in all cultivars at 0 and 67 kg P2O5 ha-1. As with Chapter 2, a manuscript has been prepared and is undergoing internal review before submission.

Objective 3. Feedstock Logistics

Iowa State University

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

1. **Planned Activities**

   Research activities planned included completion of all data analysis, and submission of journal articles.

2. **Actual Accomplishments**

   During this quarter, the emphasis has been on the completion of the analysis, writing and submission of journal articles.

   The biomass drying prediction models have been completed and a second journal article has been re-submitted for review. The results of the CenUSA harvest logistics cost analysis have been discussed with a number of US and international visitors including industrial visitors from Brazil and China who are investigating the use of biomass for energy production.

   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 will continue after the end of the project.

A journal article has been re-submitted to *Biosystems Engineering Journal* for review. A second journal article "Optimization and Cost Analysis of Crop-Residue Harvest Systems" (A. Karkee and S.J. Birrell) is in progress and will be submitted for publication.

3. Explanation of Variance

No variance in planned activities have been experienced.

4. Plans for Continuing Work Post CenUSA Bioenergy

Research activities planned after completion of the project include:

- Editing and submitting the journal article "Optimization and Cost Analysis of Crop-Residue Harvest Systems" (Karkee, A. & S.J. Birrell).
- The development and design of the electronics for real-time biomass moisture sensors will continue after the end of the project.

5.Publications, Presentations, and Proposals Submitted

Khanchi, A. & S.J. Birrell. 2017. Modeling the influence of crop density and weather conditions on field drying characteristics of switchgrass and corn stover using random forest. Biosystems Engineering (Re-submission).

University of Wisconsin

1. Planned Activities

Our efforts in this quarter were to:

- Re-design the experimental high-density baler to address crop flow issues.
- Continue to compress large square biomass bales to increase the dataset size.
- Continue work on twine tension for large square bales.
- Continue the outdoor storage study of large square bales covered with breathable film.
- Complete manuscripts for publication review.

2. Actual Accomplishments

- We completed the redesign of the experimental "auger" baler and conducted field evaluation in common biomass crops. Modifications were successful so baling can now take place at throughputs similar to conventional balers.
- Compression of large-square biomass bales to "double-density" has been conducted in common biomass crops. Relationships between achieved density and compressing force were developed.
- The lab work on twine failure force as a function of twine size and knot configuration is nearing completion.
- High-density bales placed into storage in the fall of 2016 were removed from storage in the summer of 2017. Data on moisture distribution, dry matter losses, and temperature history are being evaluated.
- Two manuscripts were revised after peer-review, then re-submitted and published. Another manuscript was completed and submitted for review.

3. Explanation of Variance

Work has progressed as planned.

4. Plans for Next Quarter

Complete manuscripts for publication review.

5. Publications/Presentations/Proposals Submitted

- Shinners, K.J. & J.C. Friede. 2017. Enhancing the drying rate of switchgrass. BioEnergy Res. 10(3): 603-612.
- Shinners, K.J., B.K. Sabrowsky, C.L. Studer & R.L. Nicholson. 2017. Switchgrass harvest progression in the North-Central US. BioEnergy Res. 10(3): 613-625.
- McAfee, J.M., K.J. Shinners & J.C. Friede. 2017. Twine tension in high-density large-square biomass bales. Applied Engineering in Agriculture. (Submitted and in review).
- Shinners, K.J. J.C. Friede, J.R. McAfee, D.E. Flick, N.C. Lacy & C.M. Nigon. 2017. Conventional and novel approaches to creating high-density biomass bales. Proceedings of the Inter. Conference on Agricultural Engineering. Hanover, GE. 10-11 Nov.

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

Iowa State University

1. Planned Activities

We remained focused on completing the review process of our set of four manuscripts submitted to the *Journal of the American Water Resources Association* (JAWRA) SWAT Special Series. Abstracts are again provided for the four manuscripts as an exhibit to this report.

2. Actual Accomplishments

We are pleased to report that all four manuscripts are now forthcoming in JAWRA and are now in the proof stage. We are hopeful that the set of four articles will be published in the final 2017 issue of JAWRA although the final publication may be delayed to the first issue of 2018.

3. Explanation of Variance

None.

4. Publications, Presentations/Proposals Submitted

- Kling, C.L., I. Chaubey, C. Raj, P.W. Gassman & Y. Panagopoulos. 2017. Policy implications from multi-scale watershed models of biofuel crop adoption across the corn Belt. J. Am. Water Resour. Assoc. (Forthcoming).
- Cibin, R, I. Chaubey, R.L. Muenich, K.A. Cherkauer, P. Gassman, C. Kling & Y. Panagopoulos. 2017. Ecosystem services evaluation of futuristic bioenergy-based land use change and their uncertainty from climate change and variability. J. Am. Water Resour. Assoc. (Forthcoming).
- Gassman, P.W., A. Valcu, C.L. Kling, Y. Panagopoulos, C. Raj, I. Chaubey, C.F. Wolter & K.E. Schilling. 2017. Assessment of bioenergy cropping scenarios for the Boone River watershed in north Central Iowa, United States. J. Am. Water Resour. Assoc. (Forthcoming).
- Panagopoulos, Y., P.W. Gassman, C.L. Kling, R. Cibin & I. Chaubey. 2017. Assessment of large-scale bioenergy cropping scenarios for the Upper Mississippi and Ohio-Tennessee River Basins. J. Am. Water Resour. Assoc. (Forthcoming).

University of Minnesota

1. **Planned Activities**

   Continued submission of manuscripts from output of previous quarters.

2. **Actual Accomplishments**

   This quarter, we resubmitted, after second revision, our manuscript on the air quality impacts of increased switchgrass production.

3. **Explanation of Variance**

   None

Post-Harvest

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

Activities for the quarter included preparation and submission of the following journal articles:

- Bbosa, D., R.C. Brown & M. Mba Wright. 2017. More Than Ethanol: A Techno-Economic Analysis of a Corn Stover-Ethanol Biorefinery Integrated with Hydrothermal Liquefaction to Convert Lignin into Biochemical. Biofuels, Bioprod. Biorefin. (Submitted).
- Qi, F.I. & M. Mba Wright. 2017. Particle scale modeling of heat transfer in granular flows in a double screw reactor. Powder Technol. (Submitted).
- Chumki, B., M. Lawrinenko, S. Bakshi & D.A. Laird. Functional groups in relation to biochar surface charges. (In preparation).
- Santanu, B., C. Banik, S.J. Rathke & D.A. Laird. Arsenic sorption on zero-valent iron-biochar complexes. (In preparation).

Objective 6. Markets and Distribution

1. **Planned Activities**

   Our team's anticipated activities for the 4th quarter were:

- **Task 1**. Develop a survey to identify the producer and land characteristics that may be used to infer optimal collection strategies for grasses from that used for stover.
- **Task 2**. Finalize the work on the economic feasibility of grasses, including a summary of our findings from the CenUSA project and suggestions for future work to advance knowledge of markets and efficient distribution systems.

2. **Actual Accomplishments**

- **Task 1**. We were unable to pursue this activity in the final quarter; it was not part of our initial project objectives.
- **Task 2**. We completed this, and as a result are preparing a publication on summary findings for the Iowa State University Center for Agricultural and Rural Development's *Agricultural Policy Review*.

3. **Publications / Presentations/Proposals Submitted**

Co-PDs Hayes and Jacobs along with recent PhD Chao Li submitted a paper for peer-review at the *Energy Economics,* "Price discrimination, procurement strategies, and market outcomes for cellulosic feedstock."

Objective 7. Health and Safety

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

- **Planned Activities**

Page proofs are expected to be review and the journal article completed.

- **Actual Accomplishments**

We addressed A second set of reviewers' comments from the *Journal of Agricultural Safety and Health* manuscript. The page proofs were reviewed before printing, noting that there were some serious errors identified in the page proofs. The article now appears in the American Society of Agricultural and Biological Engineers *Journal of Agricultural Safety and Health*.

- **Explanation of Variance**

None to report.

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

- ✓ Ryan, S. J., C. V. Schwab & G. A. Mosher. 2017. Agricultural worker injury comparative risk assessment methodology: Assessing corn and biofuel switchgrass production systems. ASABE J. Ag. Safety & Health. 23(3):219-235. doi:10.13031/jash.12245.

- ✓ Ryan, S. J., C. V. Schwab & H. M. Hanna. 2017. Research summary: overview of comparative injury risk between annual corn and perennial switchgrass production. eXtension.org website http://articles.extension.org/pages/74211/research-summary:-overview-of-comparative-injury-risk-between-annual-corn-and-perennial-switchgrass-.

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

  - **Planned Activities**

    Have one or two pilot samples taken and the analysis of the pilot dust exposure completed.

  - **Actual Accomplishments**

    No pilot samples were taken.

  - **Explanation of Variance**

    None to report.

Education and Outreach

Objective 8. Education

Subtask 1. Curriculum Development

1. **Planned Activities**

   - **Module 10. Plant Breeding**. Review draft on-line lesson and make edits as needed.
   - **Module 17. Plant Pathology for Warm-Season Grasses**. **R**eview draft online lessons and make edits as needed.

2. **Actual Accomplishments**

   - **Module 10. Plant Breeding**. Review and editing to online lesson completed.

- **Module 17. Plant Pathology for Warm-Season Grasses**. Review and editing to online lesson completed.

3. **Explanation of Variance**

   None.

Subtask 2A – Training Undergraduates via Internship Program

1. **Planned Activities**

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

2. **Actual Accomplishments**

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

3. **Explanation of Variance**:
   None.

Subtask 2B – Training Graduate Students via Intensive Program

No activities were undertaken as this was strictly a PY2 and a PY4 program activity.

Subtask 2C – Training Graduate Students via Monthly Research Webinar

This activity has been completed.

Publications / Presentations/Proposals Submitted

None.

Objective 9. Extension and Outreach

- **Extension Staff Training/eXtension Team**

  The **Extension Staff Training/eXtension Team** concentrates on creating and delivering professional development activities for Extension educators, agricultural and horticultural industry leaders and agricultural producers with special emphasis on materials development (videos, publications, web posts, etc.).

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

The **Producer Research Plots/Perennial Grass/Producer and Industry Education Team** covers the areas of production, harvest, storage, transportation; social and community impacts; producer and general public awareness of perennial crops and biochar agriculture; and Certified Crop Advisor training.

- **Economics and Decision Tools**

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**

The **Health and Safety Team** integrates its work with the Producer Research Plots/Perennial Grass team.

- **Broader Public Education/Youth Development/Master Gardener Program**

  - Youth Development introduces the topics of biofuels production, carbon and nutrient cycling, and biochar as a soil amendment through a series of experiential programs for youth.
  - Broader Public Education/Master Gardener 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**

The **Evaluation/Administration Team** coordinates the extension and outreach activities, develops and administers evaluation mechanisms for assessing learning and behavior change resulting from CenUSA extension and outreach activities, compiles evaluation results and prepares reports, coordinates team meetings, etc.

1. Actual Accomplishments

Nearly all of the activities of the CenUSA Extension Team wrapped up in December 2016. Below, please find descriptions of the three activities that were conducted during this quarter, concluding the Extension and Outreach activities for CenUSA:

- The final learning tool for CenUSA extension was developed and archived. The tool helps participants learn about pyrolysis. See: https://cfaeslessons.org.ohio-state.edu/Pyrolysis_7/.

- Conducted training for Vocational Ag and Science teachers in collaboration with Morningside College in Sioux City, IA on June 6, 14, 15 and 16. See attached report on the training.

- Conducted teacher training events in conjunction with the *National Ag in the Classroom Conference,* June 20-23, 2017 (https://naitcconference.usu.edu). CenUSA was a sponsor for the conference and provided overviews of the CenUSA C6 BioFarm program at both a plenary session and breakout session, reaching over 350 teachers.

2. **Explanation of Variance**

   None.

3. **Publications, Presentations, Proposals Submitted**

   None.

Objective 10. Commercialization

A provisional patent application was submitted on "Methods of producing stable lignin phenolic oil," which utilized mild pretreatment and hydrogenation to convert extracted lignin streams from biorefineries, including those from project partners ADM and Renmatix, into stable phenolic oil.

Sub Objective 10A. Archer-Daniels-Midland

No activities were undertaken as this was strictly a Year 1 to Year 5 activity. No forward planning is required.

Sub-Objective 2. Renmatix

1. **Planned Activities**

   Evaluate higher-value lignin applications to improve biorefinery economics.

2. **Actual Accomplishments**

At the 2016 annual meeting we reported that achieving high-value for lignin co-product from a biorefinery using the Renmatix Plantrose® process to convert perennial grasses into sugars and lignin had the potential to make significant economic improvements to the biorefinery. The first opportunity evaluated and demonstrated earlier in Year 6 for high-value lignin was as a partial replacement for phenol-formaldehyde adhesives for the production of SOB (oriented strand board) wood panels. During the last 2 quarters, another high-value lignin opportunity was identified and evaluated -- use of lignin in composite thermoplastic applications.

Experimental work started with preparation and evaluation of benchmark materials. Various lignins produced from Plantrose processed biomass sources (including switchgrass), and from Kraft lignin, were blended into polypropylene along with dispersing agents and commercial stabilizing agents using twin screw extrusion to homogenize the compositions that were prepared at various loading levels. Samples were molded and submitted for testing at Underwriters Laboratory (UL). The final report on the testing is expected to be received after this quarterly report has been submitted.

3. **Explanation of Variance**

   None.

4. **Publications / Presentations /Proposals Submitted**

   In early September 2017, Renmatix filed a provisional patent application related to the use of lignin from switchgrass in polymers. Renmatix may modify or expand such filing based on the results of the testing ongoing at Underwriters Laboratory.

Objective 10C. USDA-ARS, Lincoln, Nebraska - Alternative Uses for Native Perennial Warm-season Grasses

Nothing of significance to report this quarter.

Exhibit 2

Project Comments, Rob Mitchell, USDA-ARS, Lincoln, NE

The CenUSA Systems Analysis Field, located at the Eastern Nebraska Research and Extension Center (ENREC) near Ithaca, NE (41^o 08' 50" N, 96^o 27' 09" W) formed the foundation of the field scale research. Previous research at ARS-Lincoln determined the best regionally-adapted biomass feedstocks and those feedstocks were planted at the site. The selected site is marginally-productive for annual row crops, with about 1/3 of the field being poorly-drained (Fig. 1).

Switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), and low-diversity warm-season grass mixtures (big bluestem, indiangrass, and sideoats grama) are productive biomass feedstocks for much of the Great Plains and Midwest. These perennial grasses have excellent yield potential, grow well on marginally-productive cropland, and provide numerous environmental benefits. Three field replicates (2-acres each) were planted to 'Liberty' switchgrass, big bluestem, and the low-diversity mixture. Additionally, three 2-acre field replicates of continuous corn were planted to serve as a comparison. This site is poorly drained and marginally-productive for corn and soybean.

Perennial grasses were planted in April 2012 at 30 pure live seed (PLS) per square foot into soybean stubble using a Truax no-till drill. A post-plant, pre-emergent application of Quinclorac provided excellent control of grassy weeds, while an application of 2,4-D in early July controlled broadleaf weeds. Although a severe drought occurred after planting in 2012, excellent stands were established and harvestable yields were present after killing frost.

In 2013, N fertilizer treatments of 50 and 100 pounds of actual N per acre per year were initiated on the perennial grass fields. Corn plots received 125 pounds of actual N per acre per year. Perennial grass biomass was harvested after frost using a commercial rotary-head harvester and baled the same day with a mega-wide round baler. Perennial grass within each 1-acre subplot was harvested, baled, and bales cored for determining dry matter and composition. Corn grain yield was determined by harvesting with a field combine and adjusting yield to 15.5% moisture. On half of each corn replicate, stover was baled after harvest to determine stover yield.

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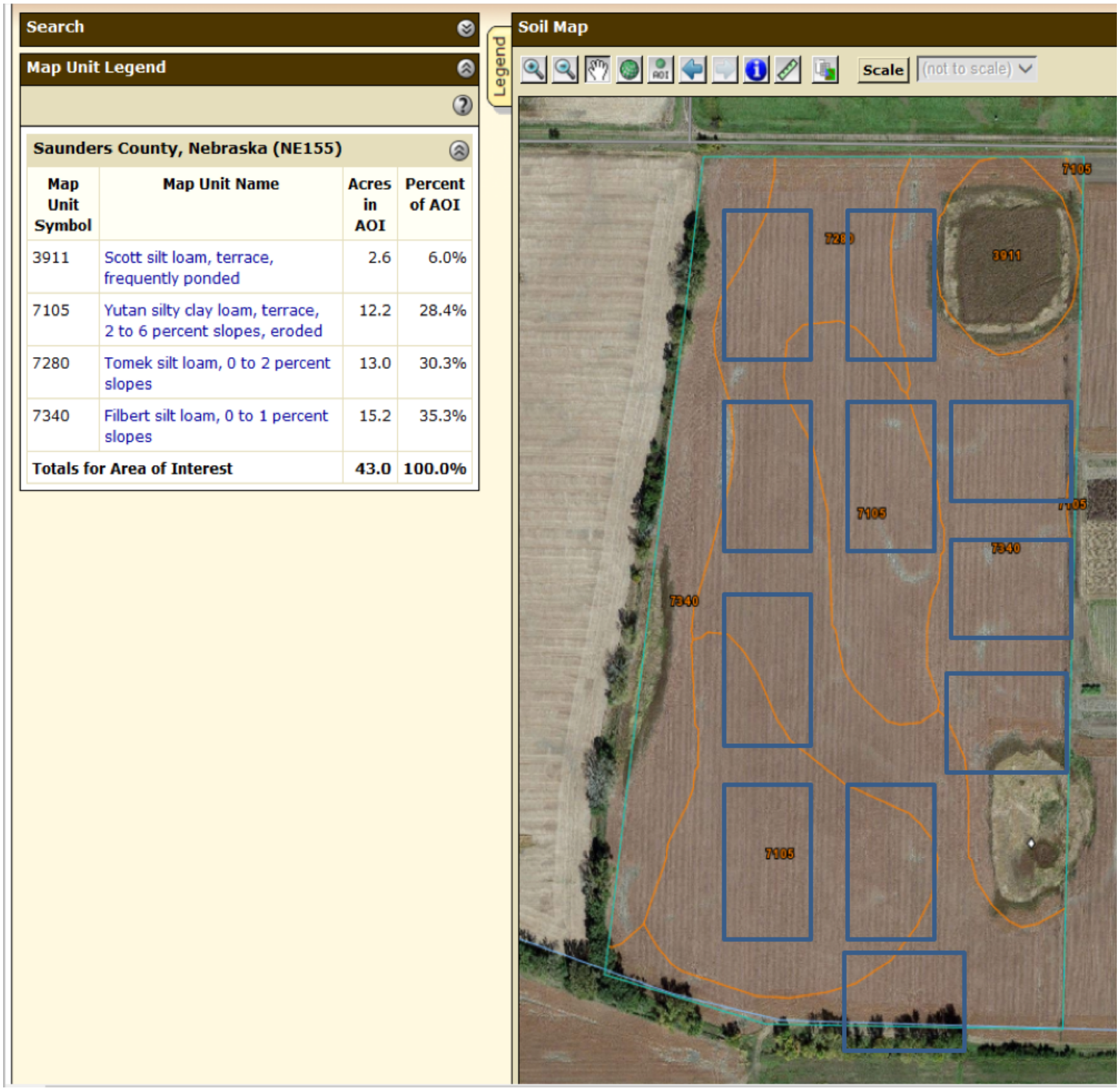

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
3911	Scott silt loam, terrace, frequently ponded	2.6	6.0%
7105	Yutan silty clay loam, terrace, 2 to 6 percent slopes, eroded	12.2	28.4%
7280	Tomek silt loam, 0 to 2 percent slopes	13.0	30.3%
7340	Filbert silt loam, 0 to 1 percent slopes	15.2	35.3%
Totals for Area of Interest		43.0	100.0%

Fig 1. CenUSA Systems Analysis Field near Ithaca, NE established in 2012 on a site that is marginally-productive for row crops, with about 1/3 of the area being poorly drained. Treatments include switchgrass, big bluestem, low-diversity mixture, and continuous corn

- **Field-scale Yield and Composition of Dedicated Feedstocks on Marginally-productive Cropland in Eastern Nebraska (In process)**

Our objective was to compare the field-scale production of ‘Liberty’ switchgrass, big bluestem, and a low-diversity mixture of big bluestem, indiangrass, and sideoats grama to continuous corn on a poorly drained marginally-productive field near Ithaca, Nebraska. There was no clear response to N rate in the perennial grasses, so dry matter yield (DM) was averaged across N rates. Perennial grass DM yields from 2013-2016 represent the total DM that was harvested, baled, and transported from each field to the storage facility. Perennial grass means include the planting year. Herbicide damage from glyphosate in 2014 reduced switchgrass yields in 2014 and 2015. Plant samples for compositional analysis have been processed and scanned, and NIRS predictions are underway.

Table 1. Field scale yields (U.S. tons/acre) for 'Liberty' switchgrass, big bluestem, a low diversity mixture, corn grain, and corn stover from rain fed fields near Ithaca, NE from 2012 through 2016. Yields represent 3 field replicates and are the mean of two fertilizer treatments (50 & 100 lb N/acre).

Feedstock	2012	2013	2014	2015	2016	Mean
'Liberty' Switchgrass (tons/acre)	3.4	5.1	4.5	4.6	5.7	4.7
Big bluestem (tons/acre)	1.2	4.1	4.7	4.3	5.4	3.9
LD Mixture (tons/acre)	1.9	5.0	5.7	5.7	6.1	4.9
Corn (bu/acre)	103.0	149.0	139.0	126.0	145.0	132.0
Stover (tons/acre)	1.4	1.9	1.8	1.7	1.6	1.7

- **Estimating Harvest Losses for Herbaceous Perennial Energy Crops on Marginally-Productive Cropland in Eastern Nebraska (In process)**

Little research has been conducted to estimate biomass losses during harvest in herbaceous perennial energy crops. Field-scale replicates of 'Liberty' switchgrass, big bluestem, and a low-diversity mixture (big bluestem, indiangrass, sideoats grama) were harvested with a self-propelled rotary head harvester after frost each year. Biomass was baled from each treatment area with a commercial round baler (JD 569 MegaWide Plus) immediately after harvest each year. Harvested residue remaining in the windrow after baling was sampled from six (6) locations in each treatment area using a 1'x8' quadrat placed across the windrow. The sampled area represented 67% of the width of each harvested swath. Mean transported yield for all feedstocks averaged 5 tons/acre/year with LDM being providing the greatest and big bluestem the least. Harvest loss varied across feedstocks with an average loss of 18.9%, 26.4%, and 15.1% of total transported yield for switchgrass, big bluestem, and LDM, respectively. Harvest loss in 2015 was two times greater than losses in 2014. Losses were greater for the higher N rate. At $80/ton, harvest losses per acre ranged from $69/acre for LDM to $99/ acre for big bluestem (Switchgrass – 0.85 tons/acre = $68/acre; big bluestem – 1.24 tons/acre = $99/acre; LD mixture – 0.86 tons/acre = $69/acre). It appears that current biomass harvesting capabilities are limited to between 5 & 6 tons/acre, beyond which biomass cannot be reliably captured with the baling equipment used (JD 569 MegaWide Plus, flare-to-flare width of 7.2’).

- **Growing season greenhouse gas emissions from perennial grasses and continuous corn on marginally-productive land (In process)**

Switchgrass, big bluestem, low diversity mixtures, and continuous corn fields were intensively sampled for greenhouse gas (GHG) emissions using static chambers in 2013, 2014, 2015, and 2016. Averaged across sampling dates in 2013 and 2014, N_2O daily emissions were 2.7, 3.4, & 5.1 times greater for corn than for SW, LDM, and BB, respectively. Additional data are being summarized.

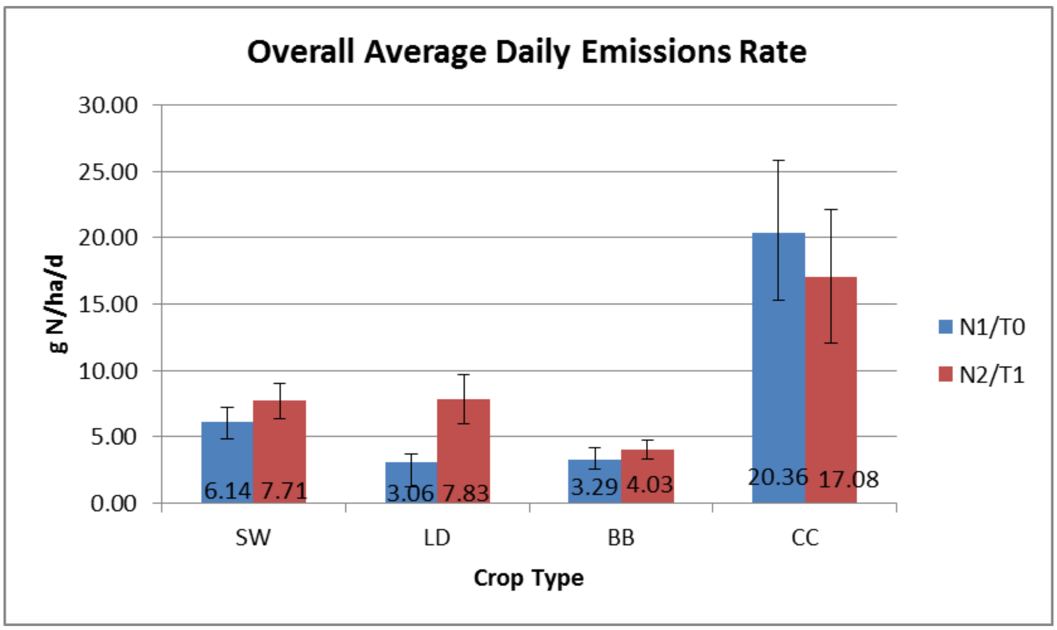

Fig. 2. Overall average emissions/day for each crop for all 2013 & 2014 sampling dates. Big bluestem had the lowest emission rates.

- **Effect of Harvest Date and Harvest Height on Herbaceous Perennial Feedstock Biomass and Potential Ethanol Yield (In process)**

Switchgrass, big bluestem, and warm-season grass mixtures are promising biomass feedstocks for much of the central and eastern USA. These feedstocks are high yielding, well-suited to marginally-productive cropland, and provide numerous environmental benefits. Bioenergy-specific cultivars and improved herbicides promote rapid establishment and harvestable yields after frost in the planting year. If moisture is adequate for establishment, fields are near full production in the year after planting with field-scale yield typically exceeding 10 Mg ha^{-1}.

Although recommendations are regionally-specific, these grasses are typically fertilized each spring and harvested once each year at anthesis or after a killing frost to a 10-cm stubble height. Following these recommendations, switchgrass stands have been productive for nearly 20 years. However, there is interest from conservation groups to leave some standing biomass in the field to provide over-wintering wildlife habitat and to catch snow to conserve moisture. Our objective was to determine how harvest date (at anthesis or after killing frost) and harvest height (5, 10, 15, 20, 25, and 30 cm above the soil surface) affect biomass production and potential cellulosic ethanol yield in switchgrass, big bluestem, and warm-season grass mixtures.

This study was conducted at the University of Nebraska ENREC near Ithaca, Nebraska, USA. The site has poorly drained soil and is marginally productive for corn (*Zea mays*) and soybean (*Glycine max*). Fields (0.9 ha each) of 'Liberty' switchgrass, big bluestem, and a mixture of big bluestem, indiangrass (*Sorghastrum nutans*) and sideoats grama (*Bouteloua curtipendula*) were planted in 2012. The three field replicates were split in half and fertilized annually with either 56 or 112 kg of N ha^{-1}. Harvest date (anthesis or after frost) and harvest height treatments (5, 10, 15, 20, 25, and 30 cm) were imposed in 2013 and 2014. Samples were collected from each harvest date and harvest height combination for each feedstock. Samples were weighed, dried at 55 C, ground to pass a 2-mm screen, and milled to pass a 1-mm screen. Samples were scanned using near infrared reflectance spectroscopy (NIRS) and potential ethanol was predicted. For all feedstocks, harvested biomass decreased linearly with increasing stubble height and harvesting at a 5-cm stubble height was not feasible at the field scale. In 2013, there was no difference in yield within a feedstock for biomass harvested at anthesis and those harvested after frost for big bluestem and switchgrass, but the mixture typically had greater yields when harvested after frost. In 2013 averaged across all feedstocks, for each 5-cm increase in stubble height, an average of 1.2 Mg ha^{-1} of biomass was left in the field. For switchgrass, potential ethanol yield in 2014 was similar across harvest dates, ranged from about 2,500 to 7,000 l ha^{-1}, and was driven by biomass yield. This study provides information for placing a monetary value on leaving standing biomass in the field for wildlife habitat and expands our understanding of the effects of management practices on biofuel production.

- **Predicting Switchgrass Mineral Concentration using NIRS (In process)**

Near-infrared reflectance spectroscopy (NIRS) is a rapid technique for quantifying plant compositional characteristics. Five field experiments containing switchgrass samples from multiple locations and genotypes were used to develop NIRS prediction equations for estimating mineral concentration as individual sets and a merged set. After NIRS scanning, the concentrations of K, P, Fe, N, Ca, Zn, Mg, S and Si were determined using ICP-AES. Scan and lab reference data were merged to develop NIRS equations to predict mineral composition for each sample set. Lab mean, standard error of prediction (SEP), R-squared values and SEP/lab mean percent were compared. Two sample sets appeared to be better suited for calibration equation development. One set represented the widest treatment variety and had mineral estimate SEP/lab mean ratios of Mg=0.16, S= 0.19, Si=0.19, N=0.05. The other set had the largest number of samples and had mineral estimate SEP/lab mean ratios of Fe=0.24, K=0.11, P=0.15, and Zn=0.16. A third set had mineral estimate SEP/lab mean ratios of 0.11 for Ca. A critical factor in equation development is the accuracy and precision of the reference lab data. Sample sets analyzed for mineral concentration using ICP-AES had a single standard analyzed multiple times in each set. When all sets of samples were merged for calibration equation development, SEP/lab mean ratios were larger for each mineral. Lab standard values varied from set to set which might explain why merging samples sets was not effective in reducing mineral estimate SEP/lab mean ratios. Initial results suggest using NIRS to estimate mineral concentration effectively ranks samples within plant populations. However, additional research is needed to use NIRS to accurately quantify mineral concentration in switchgrass across multiple environments and genotypes.

- **Pelleting Perennial Grass Feedstocks for Bioenergy (In process)**

  Using perennial grasses for bioenergy has the greatest probability for success if multiple commercialization opportunities are provided. ARS Lincoln partnered with Heldt Farms (harvest and baling) and Dehy Alfalfa Mills (pellet plant) to provide the commercial proof of concept for making pellets from switchgrass, big bluestem, and low diversity prairie mixtures in eastern Nebraska. Twelve (12) big round bales each of switchgrass, big bluestem, and a low diversity prairie mixture (36 bales total) were transported, successfully pelletized, and bagged in 50-lb bags at Dehy Alfalfa Mills near Bancroft, NE. The pelleting process was successful and resulted in pellets with bulk densities of 37.94 lbs ft^{-3} for switchgrass and big bluestem, and 38.26 lbs ft^{-3} for the low diversity mixture. We have quantified the chemical composition and conversion properties of the pellets (see below). We have approximately 2 tons of pellets for each feedstock on hand. The bags of pelleted material of known composition have been distributed to people requesting feedstock in lieu of shipping bales or ground material. Additionally, we have used the pellets as a natural mulch for establishing turfgrass, evaluated the pellets in an external residential furnace, used the pellets as a moisture absorbent material for high traffic areas during wet conditions, and used the pellets as ‘hail stones’ in a hail simulator.

- **Effect of Pelletizing Herbaceous Grasses on Chemical Composition and Conversion Properties (In process)**

Warm-season perennial grasses are promising candidates as bioenergy crops because of their high productivities and carbohydrate contents. However, storage and transport are challenging because of their low bulk density and poor flow properties. Pelletizing is a standard method for increasing bulk density of biomass. Field grown switchgrass, big bluestem, and a low diversity mixture were either milled or pelletized. Samples were analyzed for chemical composition using the dietary fiber method. Pelletized samples appeared to have lower overall structural carbohydrates and increased ethanol/water extractable materials. Samples were pretreated with low moisture ammonium hydroxide and evaluated for enzymatic sugar extraction. Pelletizing led to increased glucose yields for the big bluestem and low diversity mixture but not for the switchgrass. When pretreated with liquid hot-water, pelletizing was associated with increased glucose yields only for the low diversity mixture.

- **Perennial Grass Pellet Evaluation in a Central Boiler MAXIM M250 Residential Furnace**

Jim Inglis conducted a test fire of switchgrass, big bluestem, and low diversity mixture (LDM) pellets using a Central Boiler Maxim M250 exterior furnace. The pellets had large quantities of fines that needed to be screened before loading into the boiler. Based on total weight, quantity of fines ranged from 2.6% for the LDM to 21.1% for switchgrass. Compared to wood pellets and other grass pellets, there was more very fine dust. Excessive fines bind the auger and feed tube and can damage the feeding mechanism. During test firing of all types, large “clinkers” formed around the auger in 4.5-5 hours of burning under average system demand for residential heating. The formation of clinkers causes boiler combustion efficiency to drop and can cause the system to shut down due to auger plugging and ash build up on ventilation holes in the burn pot. There was minimal “fly ash” from the grass pellets, suggesting that buildup of ash on the heat exchangers would be less when compared to wood ash. This is probably the result of the ash not moving around in the burn pot area due fuel type developing clinkers rather than finer particulate ash. The grass pellets required longer time to burn than wood pellets. During high demand periods while burning grass pellets, the feeding rate had to be decreased to reduce the chance that the grass pellets would not be pushed up over the sides of the burn pot rather than out of the end.

Grass pellets seem to work best in low demand scenarios when feeding rate and required combustion air flow is at the lowest settings. Both higher feeding rates and airflow tend to result in higher temperatures in the burn pot ultimately creating larger clinkers that impede efficiency and ability to maintain burn without long term damage to the feeding mechanism. Grass pellets need to be monitored more closely when compared to other fuel types. For example, 550 lbs of wood pellets will burn in 4-5 days and the ash would not need to be cleaned from the burn pot. In contrast, I would not want to run grass pellets for more than 6 hours without cleaning clinkers from the auger and burn pot. This may be addressed by modifying the feeding mechanism and auger to do a better job of breaking up clinkers and pushing it out of the burn pot.

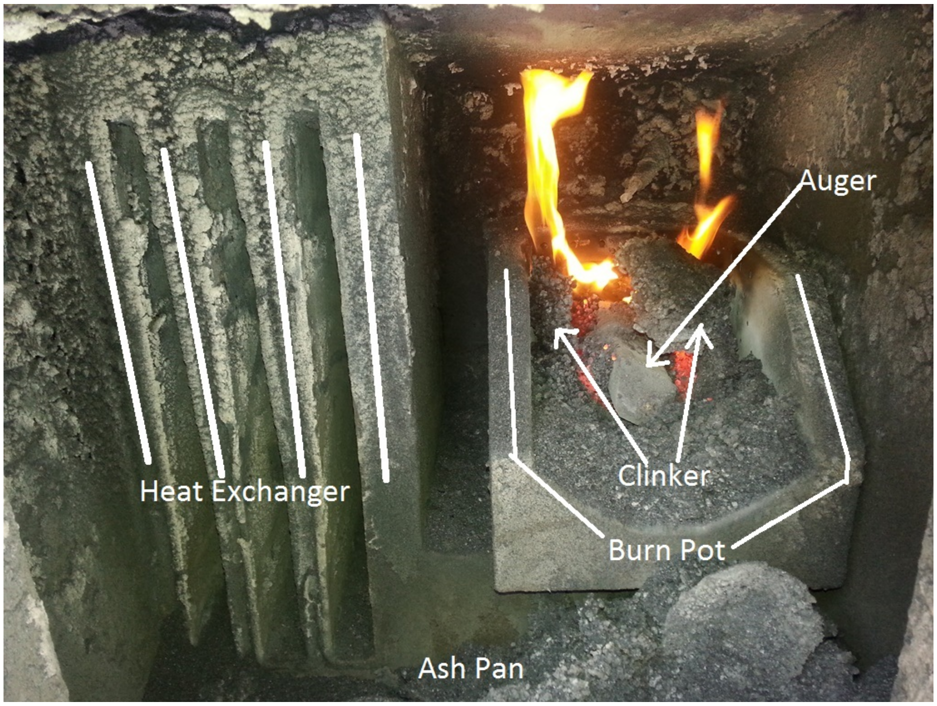

Fig. 3. The fire box of the Maxim M250 furnace burning grass pellets.

- **Using Perennial Warm-season Grass Biomass Feedstocks for Grazing (In process)**

Warm-season grasses like switchgrass, big bluestem, and indiangrass are productive for grazing and hay throughout much of the Corn Belt. One strategy for preparing for the emerging bioeconomy is to plant biomass feedstocks, then graze them while waiting for the emerging bioenergy industry. Our objective was to compare the best available cultivars of switchgrass, big bluestem, indiangrass, and warm-season mixtures (Mix 1 = big bluestem/indiangrass/sideoats; Mix 2 = big bluestem/indiangrass/switchgrass/sideoats/little bluestem) for livestock production in eastern Nebraska.

Fields were planted in 1-acre pastures in spring 2011 with three field replicates per grass. Pastures were fertilized each spring after the planting year with nitrogen at 60 lb N/acre. In 2012, pastures were grazed with two steers per acre for 69 d from June 7 to August 15. In 2013, pastures were grazed with 2 heifers per acre for 74 d from June 17 to August 29, 2013. All pastures had greater production in 2012 when steers grazed the pastures. Switchgrass had the lowest ADG and BWG throughout the study. Averaged across years, Mix 2, the most diverse mixture containing five species, had the greatest livestock performance. These preliminary data suggest that warm-season grasses could be planted for biomass feedstocks prior to the presence of a bioenergy market and grazed to return revenue while waiting for the completion of a bioenergy processing facility.

Table 2. Average daily gain (ADG) for switchgrass, indiangrass, big bluestem, and different warm-season grass mixtures grazed in 2012, 2013, and 2014 near Mead, NE. Pastures were grazed by steers in 2012 and heifers in 2013 and 2014.

	2012	2013	2014	Mean
		ADG (lbs/hd/d)		
Switchgrass	1.9	0.9	0.4	1.0
Indiangrass	2.3	1.3	0.8	1.5
Big bluestem	2.3	1.3	1.0	1.5
Mix 1	2.1	1.3	1.0	1.5
Mix 2	2.5	1.4	0.9	1.6

Table 3. Body weight gain (BWG) for switchgrass, indiangrass, big bluestem, and different warm-season grass mixtures grazed in 2012, 2013, and 2014 near Mead, NE. Pastures were grazed by steers in 2012 and heifers in 2013 and 2014.

	2012	2013	2014	Mean
		BWG (lbs/acre)		
Switchgrass	256	126	52	145
Indiangrass	320	196	124	213
Big bluestem	318	186	148	217
Mix 1	294	193	149	212
Mix 2	346	202	141	230

- **Using Perennial Grasses for Biomass and Grazing in an Integrated Crop-livestock System**

Fields were planted and established as a 50-acre farm to demonstrate potential grazing and bioenergy dual purpose use in eastern Nebraska. The study was leveraged to be included as a location in the South Dakota State University (SDSU) integrated crop livestock grazing

USDA Coordinated Agricultural Project CAP. In 2015 and 2016, bromegrass and switchgrass were harvested for hay. Grazing began in spring 2017. The study uses 'Newell' smooth bromegrass pastures for grazing in spring and autumn, 'Liberty' switchgrass for flash grazing in late spring then harvest for bioenergy after frost, 'Shawnee' switchgrass for summer grazing, corn for grain and stover for grazing and bioenergy in late autumn, and triticale for early spring grazing and potential bioenergy production. The 'Newell' smooth bromegrass was grazed for 21 days in 2017 and produced an average daily gain of 2.44 lb/hd/d. The first grazing of 'Liberty' switchgrass began on June 13, 2017 and grazing lasted for 7 days. 'Shawnee' switchgrass grazing began on June 20, 2017 and will continue until forage is limiting and smooth bromegrass regrowth can be grazed or corn has been harvested and stalks are available for grazing.

- **Using Visual Obstruction (VOM) and Elongated Leaf Height Measurements to Predict Standing Crop Biomass on Bioenergy Production Fields (In process)**

  Switchgrass, big bluestem, and warm-season grass mixtures are being evaluated as biofuel feedstocks for the United States. Efficiently and accurately estimating biomass feedstock supplies in the field will be necessary for biorefineries to prepare for biomass scheduling. The objective of this study was to determine how well indirect methods predict biomass feedstock supplies for different feedstocks. Indirect measurements were conducted in eastern Nebraska from 2012 to 2015 in 0.9-ha fields of switchgrass, big bluestem, and low diversity mixtures. A modified Robel pole was used to determine visual obstruction and elongated leaf height. Prediction models demonstrate that visual obstruction and elongated leaf height are correlated with yield, but the ability to predict biomass varied across feedstocks. Data are being analyzed and summarized to make recommendations.

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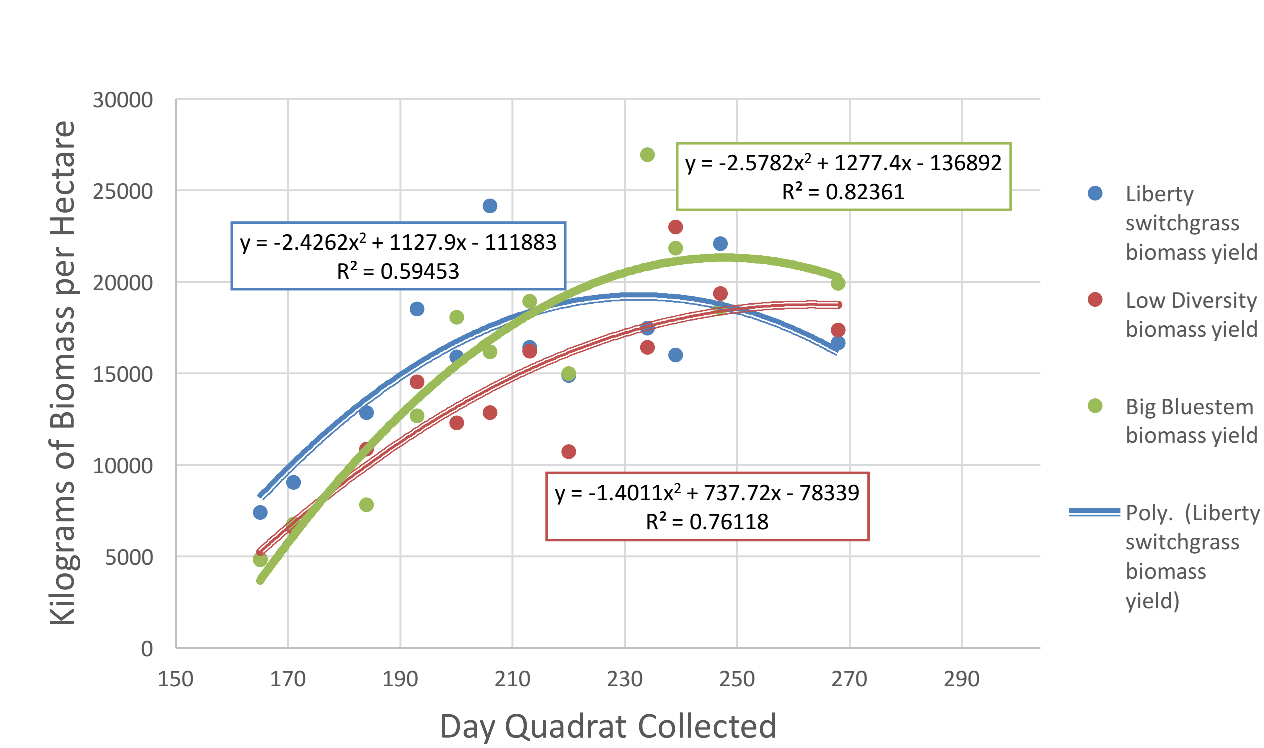

Fig. 4. Relationship between visual obstruction and aboveground biomass for switchgrass, big bluestem, and low diversity mixtures near Mead, NE.

- **Quantifying costs and monetizing benefits of bioenergy crops (In process)**

Quantifying the costs associated with establishing and managing bioenergy feedstocks is straight forward and well established. For example, in a 5-year study on field-scale sites established and managed in Nebraska, South Dakota, and North Dakota, farmer inputs were tracked and average establishment and management costs were determined. At the end of 5-years, average switchgrass costs were variable and fields that were economically feasible produced a harvestable yield in the planting year and land costs accounted for about half of the cost of production (Perrin et al. 2008). Additionally, the energy balance was positive for the switchgrass system (Schmer et al. 2008).

Based on these and other establishment and management inputs (Mitchell et al. 2012a), Jacobs et al. (2015) developed a decision support tool for estimating establishment and management costs and comparing potential switchgrass return to corn, soybean, and Conservation Reserve Program (CRP) grasslands. This tool can be tailored to specific areas within farmer fields and used to estimate the feasibility of growing switchgrass on all or a portion of a field. Monetizing the benefits of perennial energy crops like switchgrass is a more difficult task. Meehan et al. (2013) evaluated the feasibility and monetized the benefits of switching 16,727 ha in 100-m buffer strips along drainages from continuous corn to perennial grass in a focal area in southern Wisconsin. They estimated that converting from continuous corn to perennial grasses on these 16,727 ha focal areas decreased annual income by 75%, increased annual net energy produced by 33%, reduced annual P loading by 29%, increased C sequestration by 30%, reduced N_2O emission by 84%, and increased pollinator abundance by 11%. The benefits of monetizing ecosystem services varied, but monetizing ecosystem services based on the social costs of pollution far exceeded the opportunity costs and stacking the monetized benefits results in significant monetary returns. Studies such as Meehan et al. (2013) demonstrate the critical data need for quantifying ecosystem services from field comparisons between crop and Bioenergy production systems.

These direct comparisons have been a critical component of the NIFA-AFRI-CAP grants (www.cenusa.iastate.edu) and will provide valuable inputs for modeling efforts (Porter et al. 2015). For example, research in eastern Nebraska has demonstrated that each year more than 1 Mg of C/ha is sequestered in switchgrass fields managed for Bioenergy (Follett et al. 2012; Stewart et al. 2015; Kibet et al. 2015). There are several barriers that discourage deploying perennial grasses for bioenergy including; 1) the lack of an existing bioenergy market, 2) the conflict between the ecologically and economically best use of land; 3) the lack of long-term guarantees needed to make perennials feasible since at least 5 years are needed to make money; 4) the lack of an even playing field with commodity crops; and 5) a lack of understanding of how the risks will be managed and distributed. Grazing and hay are the only currently-available large-scale markets for perennial grasses, but others have promise. Based on more than 25 years of bioenergy research in Nebraska, growing perennial grasses such as switchgrass for bioenergy are non-invasive (Mitchell et al. 2015), rapidly established (Mitchell et al. 2012a,b), productive (Mitchell et al. 2016), profitable for the farmer (Perrin et al. 2008; Jacobs et al. 2015), and protective of the environment (Follett et al. 2012; Stewart et al. 2015; Kibet et al. 2015). However, it is difficult to change the culture of agriculture unless there is a distinct economic incentive for growing biomass while fitting into the time constraints of the current production system. Government and society need to support bioenergy deployment by providing incentives for ecosystem services, supporting biomass use from CRP and cover crops, and valuing ecosystem services.

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- **Harvest Date and N Fertilizer Implications of Growing Switchgrass for Bioenergy on Marginal Land (In process)**

  Switchgrass (*Panicum virgatum* L.) is a promising bioenergy feedstock. Appropriate use of nitrogen (N) fertilizer is essential for developing profitable and sustainable switchgrass biomass production systems, especially on marginally productive cropland.

  This study was conducted to determine the long-term environmental and economic efficiency of applying N fertilizer to switchgrass grown for biomass energy on marginally-productive cropland. The experimental design included three field replicates each of three annually-applied N fertilizer rates (0, 60, 120 kg N/ha) and two harvest dates (anthesis and post-frost). Reported biomass yields were collected over 14 field production years (2000-2013). Nitrogen use efficiency (NUE), a common agronomic metric in crop production, and N economic efficiency (NEE), a new measure of the value of N fertilizer application to the producer, were determined from DM yield. Switchgrass biomass increased as N fertilizer rate increased. Higher biomass yield with higher N fertilizer rates did not result in greater NUE or NEE. For both harvest dates, NUE and NEE were greater for the 60 kg of N/ha rate than for the 120 kg of N/ha rate. For the August harvests, applying 60 kg of N/ha resulted in a 42% higher NUE and NEE than the 120 kg of N/ha rate. For the post frost harvests, applying 60 kg of N/ha resulted in a 55% higher NUE and NEE than the 120 kg of N/ha rate. These results provide strong support for applying 60 kg of N/ha rather than 120 kg of N/ha, even though the long-term yield average was greater for the 120 kg of N/ha rate. Based on 14 years of field data, applying 60 kg of N/ha and harvesting after frost is the most economically and environmentally sustainable management practice due to its higher NUE and higher NEE compared to other management practices. Evaluating crop response on the basis of NEE is a promising approach to indicate the on-farm value of fertilizer management programs for perennial grasses.

- **Factor Analysis Research: Biomass Yield of Annual and Perennial Feedstocks on Marginally-productive Cropland in Eastern Nebraska**

  - Yield data for select switchgrass, big bluestem, and mixtures from 2012-2016 is being summarized.

  - Yield data for winter wheat, biomass sorghum, oats, and teff from 2012-2016 is being summarized.

- Samples collected in 2012, 2013, 2014, 2015, & 2016 have been processed and are being scanned and predicted using NIRS.

- **Refereed Publications with Abstracts**

- **Vogel, K.P., R. Mitchell, M. Casler & G. Sarath. 2014. Registration of 'Liberty' switchgrass. J. Plant Registrations, 8:242-247.**

  'Liberty' (Reg. No. CV-271, PI 669371) switchgrass (*Panicum virgatum* L.) is a lowland-type cultivar that is adapted to USDA plant hardiness zones (HZ) 4, 5, and 6 in the U.S. Great Plains and Midwest, east of 100° W. longitude. It was developed for use as a perennial biomass energy crop and is the first high yielding biomass-type lowland cultivar adapted to this region. It can produce greater biomass yields than upland- or forage type switchgrass cultivars developed previously for use in the region, and it has equivalent winter survival. 'Liberty' has significantly greater winter survival in its adaptation region than previously released lowland switchgrass cultivars such as 'Kanlow' and 'Alamo' that frequently have substantial winter damage and stand loss north of 40° N latitude in the U.S. Great Plains and Midwest.

- **Porter, P., R.B. Mitchell & K.J. Moore. 2015. Reducing hypoxia in the Gulf of Mexico: Reimagining a more resilient agricultural landscape in the Mississippi River watershed. J. Soil Water Conserv., 70(3):63A-68A. http://www.jswconline.org/content/70/3/63A.refs. (Open Access).**

  Perennial grass-based biofuels and bioproducts provide opportunity to integrate perennial grasses back into agricultural systems, at a landscape scale and achieve significant water and ecosystem service benefits. They could be targeted strategically, offering a tool for landowners to stabilize areas of their farm that are environmentally sensitive, fields that are adjacent to waterways, or that are steeper, wetter, more erosive, or that may be marginally profitable for row crops. Planting perennial prairie grasses or prairie grass strips could be an effective strategy for nutrient removal and enhanced environmental performance while still farming a majority of the field. In addition, perennial grasses could serve a dual purpose for grazing cattle. In a time of constrained federal and state budgets, a key attraction of perennial grass-based biofuels and bioproducts may be its "working lands" approach to conservation. Building new market demand could allow perennial grasses, once native to the central United States to be reestablished on lands that are better suited to perennial production. In short, perennial grasses for bioenergy is a market-driven agricultural system that provides conservation benefits as an outcome, rather than direct payment to landowners for conservation as an add-on.

- **Mitchell, R.B. & K.P. Vogel. 2015. Grass invasion into switchgrass managed for biomass energy. Bioenergy Res., 9:50-56. doi 10.1007/s12155-015-9656-4. 2015.**

  Switchgrass (*Panicum virgatum*) is a C4 perennial grass and is the model herbaceous perennial bioenergy feedstock. Although it is indigenous to North American grasslands east of the Rocky Mountains and has been planted for forage and conservation purposes for more than 75 years, there is concern that switchgrass grown as a biofuel crop could become invasive. Our objective is to report on the invasion of C4 and C3 grasses into the stands of two switchgrass cultivars following 10 years of management for biomass energy under different N and harvest management regimes in eastern Nebraska. Switchgrass stands were invaded by big bluestem (*Andropogon gerardii*), smooth bromegrass (*Bromus inermis*), and other grasses during the 10 years. The greatest invasion by grasses occurred in plots to which 0 N had been applied and with harvests at anthesis. In general, less grass encroachment occurred in plots receiving at least 60 kg of N ha−1 or in plots harvested after frost. There were differences among cultivars with Cave-in-Rock being more resistant to invasion than Trailblazer. There was no observable evidence of switchgrass from this study invading into border areas or adjacent fields after 10 years of management for biomass energy. Results indicate that switchgrass is more likely to be invaded by other grasses than to encroach into native prairies or perennial grasslands seeded on marginally productive cropland in the western Corn Belt of the USA.

- **Moore, K.J., S. Birrell, R.C. Brown, M.D. Casler, J.E. Euken, H.M. Hanna, D.J. Hayes, J.D. Hill, K.L. Jacobs, C.L. Kling, D. Laird, R.B. Mitchell, P.T. Murphy, D.R. Raman, C.V. Schwab, K.J. Shinners, K.P. Vogel & J.J. Volenec. 2014. Midwest vision for sustainable fuel production. Biofuels, 5:687-702. 2015.**

  CenUSA Bioenergy, a USDA-NIFA-AFRI coordinated agricultural project has multiple research projects focused on the North Central region of the US. CenUSA's vision is to develop a regional system for producing fuels and other products from perennial grass crops grown on marginally productive land or land that is otherwise unsuitable for annual cropping. CenUSA has made contributions to nine primary systems needed to make this vision a reality: feedstock improvement; feedstock production on marginal land; feedstock logistics; modeling system performance; feedstock conversion into biofuels and other products; marketing; health and safety; education; and outreach. The final section, Future Perspectives, sets forth a roadmap of additional research, technology development and education required to realize commercialization.

- **Mitchell, R., M. Schmer, B. Anderson, V. Jin, K. Balkcom, J. Kiniry, A. Coffin, A. & P. White. 2016. Dedicated energy crops and crop residues for bioenergy feedstocks in the Central and Eastern USA. BioEnergy Res., 9:384-398. doi:**

10.1007/s12155-016-9734-2. http://link.springer.com/article/10.1007/s12155-016-9734-2. (Open Access).

Dedicated energy crops and crop residues will meet herbaceous feedstock demands for the new bioeconomy in the Central and Eastern USA. Perennial warm-season grasses and corn stover are well-suited to the eastern half of the USA and provide opportunities for expanding agricultural operations in the region. A suite of warm-season grasses and associated management practices have been developed by researchers from the Agricultural Research Service of the US Department of Agriculture (USDA) and collaborators associated with USDA Regional Biomass Research Centers. Second generation biofuel feedstocks provide an opportunity to increase the production of transportation fuels from recently fixed plant carbon rather than from fossil fuels. Although there is no "one-size-fits-all" bioenergy feedstock, crop residues like corn (Zea mays L.) stover are the most readily available bioenergy feedstocks. However, on marginally productive cropland, perennial grasses provide a feedstock supply while enhancing ecosystem services. Twenty-five years of research has demonstrated that perennial grasses like switchgrass (*Panicum virgatum* L.) are profitable and environmentally sustainable on marginally productive cropland in the western Corn Belt and Southeastern USA.

- **Vogel, K.P., R. Medill, S.D. Masterson, R.B. Mitchell & G. Sarath. 2017. Mineral element analyses of switchgrass biomass: comparison of the accuracy and precision of laboratories. Agronomy J., 109:735-738. doi:10.2134/agronj2016.08.0475.**

  Mineral concentration of plant biomass can affect its use in thermal conversion to energy. The objective of this study was to compare the precision and accuracy of university and private laboratories that conduct mineral analyses of plant biomass on a fee basis. Accuracy and precision of the laboratories was tested by having all laboratories conduct mineral analyses on subsamples of the same set of standard switchgrass (*Panicum virgatum* L.) samples and a certified standard. Laboratories differed significantly in both accuracy and precision even though several used the same analysis method indicating that the differences among laboratories were due to within laboratory procedures and quality control. Laboratories should be using sample standards to monitor both precision and accuracy of their mineral analyses. It would be advisable for researchers submitting samples to service laboratories to replicate the unknown samples to determine precision and to include replicated standards among the submitted samples to determine accuracy.

- **Blanco-Canqui, H., R. Mitchell, V. Jin, M. Schmer & K. Eskridge. 2017. Perennial warm-season grasses for producing biofuel and enhancing soil properties: An alternative to corn residue removal. GCB Bioenergy. doi:10.1111/gcbb.12436. http://dx.doi.org/10.1111/gcbb.12436. (Open Access).**

Removal of corn residues at high rates for biofuel and other off-farm uses may negatively impact soil and the environment in the long term. Biomass removal from perennial warm-season grasses (WSGs) grown in marginally productive lands could be an alternative to corn residue removal as biofuel feedstocks while controlling water and wind erosion, sequestering carbon (C), cycling water and nutrients, and enhancing other soil ecosystem services. We compared wind and water erosion potential, soil compaction, soil hydraulic properties, soil organic C (SOC), and soil fertility between biomass removal from WSGs and corn residue removal from rain fed no-till continuous corn on a marginally productive site on a silty clay loam in eastern Nebraska after 2 and 3 years of management. The field-scale treatments were as follows: (i) switchgrass, (ii) big bluestem, and (iii) low-diversity grass mixture [big bluestem, indiangrass, and sideoats grama], and (iv) 50% corn residue removal with three replications. Across years, corn residue removal increased wind-erodible fraction from 41% to 86% and reduced wet aggregate stability from 1.70 to 1.15 mm compared with WSGs in the upper 7.5 cm soil depth. Corn residue removal also reduced water retention by 15% between 33 and 300 kPa potentials and plant-available water by 25% in the upper 7.5 cm soil depth. However, corn residue removal did not affect final water infiltration, SOC concentration, soil fertility, and other properties. Overall, corn residue removal increases erosion potential and reduces water retention shortly after removal, suggesting that biomass removal from perennial WSGs is a desirable alternative to corn residue removal for biofuel production and maintenance of soil ecosystem services.

- **Sindelar, A.J., M.R. Schmer, R.W. Gesch, F. Forcella, C.A. Eberle, M.D. Thom & D.W. Archer. 2015. Winter oilseed production in the U.S. Corn belt: Opportunities and limitations. GCB Bioenergy, 9: 508-524. http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12297/full. (Open Access).**

Interest from the US commercial aviation industry and commitments established by the US Navy and Air Force to use renewable fuels has spurred interest in identifying and developing crops for renewable aviation fuel. Concern regarding greenhouse gas emissions associated with land-use change and shifting land grown for food to feedstock production for fuel has encouraged the concept of intensifying current prominent cropping systems through various double cropping strategies. Camelina (Camelina sativa L.) and field pennycress (*Thlaspi arvense L.*) are two winter oilseed crops that could potentially be integrated into the corn (*Zea mays L.*)–soybean [(Glycine max (L.) Merr.] cropping system, which is the prominent cropping system in the US Corn Belt. In addition to providing a feedstock for renewable aviation fuel production, integrating these crops into corn–soybean cropping systems could also potentially provide a range of ecosystem services. Some of these include soil protection from wind and water erosion, soil organic C (SOC) sequestration, water quality improvement through nitrate reduction, and a food source for pollinators. However, integration of these crops into corn–soybean cropping systems also carries possible limitations, such as potential yield reductions of the subsequent soybean crop. This review identifies and discusses some of the key benefits and constraints of integrating camelina or field pennycress into corn–soybean cropping systems and identifies generalized areas for potential adoption in the US Corn Belt.

- **Non-refereed Publications with Abstracts**

  - **Mitchell, R.B., K.P. Vogel & M.R. Schmer. 2013. Switchgrass (*Panicum virgatum*) for biofuel production. Sustainable Ag Energy Community of Practice, eXtension (revised). http://articles.extension.org/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production. (Extension Circular).**

    Switchgrass (*Panicum virgatum*) is a native warm-season grass that is a leading biomass crop in the US. More than 70-years of experience with switchgrass as a hay and forage crop suggests switchgrass will be productive and sustainable on rain-fed marginal land east of the 100th Meridian. Long-term plot trials and farm-scale studies in the Great Plains and plot trials in the Great Plains, Midwest, South, and Southeast indicate switchgrass is productive, protective of the environment, and profitable for the farmer. Weed control is essential during establishment, but with good management is typically not required again. Although stands can be maintained indefinitely, stands are expected to last at least 10 years, after which time the stand will be renovated and new, higher-yielding material will be seeded on the site. Fertility requirements are well understood in most regions, with about 12 to 14 pounds of N per acre required for each ton of expected yield if the crop is allowed to completely senesce before the annual harvest. Historically, breeding and genetics research has been conducted at a limited number of locations by USDA and university scientists, but the potential bioenergy market has promoted testing by public and private entities throughout the US. Switchgrass is well-suited to marginal cropland and is an energetically and economically feasible and sustainable biomass energy crop with currently-available technology.

  - **Mitchell, R.B., J.J. Volenec & P. Porter. 2013. Test plots show how perennial grasses can be grown for biofuels, eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. http://www.extension.org/pages/68155/test-plots-show-how-perennial-grasses-can-be-grown-for-biofuels#.VRQjJvzF-QU. (Extension Circular).**

    Researchers, farmers, and industry representatives across the country are interested in testing the performance of energy crops. Setting up a test plot in your region can be useful in showing producers the potential for growing bioenergy feedstocks on their farms. The test plot can demonstrate best management practices and yield potential as well as how to establish perennial grasses quickly and economically. Additionally, it can demonstrate differences between the forage and bioenergy strains of various perennial grasses. We provide suggestions for establishing and managing your own energy crop demonstration plot.

- **Mitchell, R.B. Establishing and managing perennial grasses for bioenergy. 2013. Proc. 25th Annual Integrated Crop Management Conference, Iowa State University, pp. 49-51. (Proceeding).**

  Switchgrass (*Panicum virgatum*) is native to every U.S. state east of the Rocky Mountains, is the most advanced herbaceous perennial bioenergy feedstock, and best management practices (BMPs) have been developed for bioenergy production in most agro-ecoregions. Additionally, big bluestem (Andropogon gerardii), indiangrass (Sorghastrum nutans), and sideoats grama (Bouteloua curtipendula) are promising bioenergy feedstocks, either grown as single-species stands or in low-diversity mixtures. Native warm-season grasses have a reputation for being difficult to establish. Historically, these grasses often required 2 or 3 years to establish an acceptable stand. However, advancements in herbicides, cultivar development, and planting equipment have improved establishment dramatically. Today, it is feasible to harvest 50% of the cultivar's yield potential after frost in the seeding year. By the end of the first full growing season after seeding, it is feasible to produce and harvest 75% to 100% of the cultivar's yield potential. If precipitation is adequate, warm-season grasses are readily established when quality seed of adapted cultivars are used in conjunction with the proper planting date, seeding rate, seeding method, and weed control.

- **Mitchell, R.B. & M.R. Schmer. Switchgrass for biomass energy. 2014. Proc. Nebraska Crop Production Clinic, University of Nebraska, pp. 13-16. (Proceeding).**

  Switchgrass (*Panicum virgatum*) is a native warm-season grass and is the model herbaceous perennial biomass energy feedstock for the USA. More than 75-years of experience confirm that switchgrass will be productive and sustainable on rain-fed marginally-productive cropland east of the 100th meridian. The development of best management practices for biomass energy production have accelerated establishment and increased production efficiency. With adequate precipitation, switchgrass is readily established when quality seed of adapted cultivars is used in conjunction with the proper planting date, seeding rate, seeding method, and weed control. Advancements in herbicides, cultivar development, and planting equipment make it feasible for stands to reach 75% to 100% of the cultivar's yield potential 15 to 18 months after planting. Long-term studies indicate switchgrass stands can be maintained indefinitely, but stands are expected to be renovated to higher yielding material after about 10 years. Switchgrass requires about 10 pounds of N per acre for each ton of expected yield if the crop is harvested once annually after dormancy. New biomass-specific cultivars like 'Liberty' produce up to 8 tons of biomass per acre and are well-suited to marginally-productive cropland in the Great Plains and Midwest.

- **Mitchell, R.B., K.P. Vogel & M. Schmer. 2013. Growing switchgrass for biofuels, Fact Sheet No. 3, CenUSA Bioenergy, Iowa State Univ., Ames, IA. http://articles.extension.org/sites/default/files/Factsheet3.GrowingSwitchgrassforBiofuels.pdf . (Extension Circular).**

  Contrary to popular belief, switchgrass is not a new or novel crop but has more than 75 years of research and farming experience. Currently available plant materials and production practices can reliably produce five tons per acre in the central Great Plains and Midwest. New cultivars and management practices will significantly increase yields similar to the yield increases achieved in corn in the last 30 years. The availability of adequate acres of agricultural land and the profit potential provided to farmers for growing switchgrass in a region will determine the success of growing switchgrass for biomass energy. Production practices and plant materials are available to achieve sustainable and profitable biomass production, for both farmers and bio-refineries, to help meet the energy requirements of the nation and reduce our dependence on foreign oil.

- **Mitchell, R.B. & S. Harlow. 2013. Switchgrass stand establishment: key factors for success. eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. (http://www.extension.org/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success#.VRQhzPzF-QU). (Extension Circular).**

  Switchgrass (*Panicum virgatum* L.) is not difficult to establish if precipitation is timely and four key management practices are followed. First, purchase certified seed with excellent seed lot quality. Second, develop a good firm seedbed. Third, plant the seed at the proper time, depth, and rate. Finally, control weeds during the planting year. While money spent on good-quality seed and weed control will likely result in a higher per acre cost for establishment, the reward is rapid establishment of a productive stand with lower costs per ton of biomass over the life of the stand. Successful stand establishment is critical to the long-term economic viability of switchgrass stands. Farmers in regions with good soils and favorable precipitation should be able to harvest switchgrass after frost in the planting year. Using bioenergy-specific cultivars such as 'Liberty' should produce 3-4 tons per acre in the planting year and 6-8 tons per acre in subsequent years.

- **Mitchell, R.B., B. Anderson & D. Redfearn. 2014. Switchgrass for forage and bioenergy. Proc. 2014 Nebraska Grazing Conference, Univ. of Nebraska, 48-53.**

Switchgrass is a native warm-season grass that has been used for hay, forage, and conservation purposes for decades and switchgrass research in Nebraska has been ongoing since 1936. Recently, switchgrass has been identified as a model perennial grass for bioenergy in the Great Plains and Midwest. Since 1990, research in Nebraska on marginally productive cropland has demonstrated that best management practices will maintain productive, profitable, and sustainable switchgrass stands for more than 15 years on marginally productive cropland in the eastern half of Nebraska. Additionally, switchgrass can provide quality forage for grazing after cool-season pastures have been utilized. Switchgrass must be properly managed to maintain productive stands and quality forage. Poor management will cause productivity and stand persistence to decline, and forage quality will be poor. With proper management, switchgrass can provide both forage and biomass to mitigate risk and diversify potential use.

- **Mitchell, R.B. & S. Harlow. 2014. Control weeds in switchgrass (*Panicum virgatum* L.) grown for biomass, eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. (http://www.extension.org/pages/70396/control-weeds-in-switchgrass-panicum-virgatum-l-grown-for-biomass#.VRQfW_zF-QU). (Extension Circular).**

  It's critical to control weeds before and during establishment of switchgrass stands grown for biomass, because weeds are the most frequent reason a stand fails. You should have few problems with weeds in established stands. Control weeds in the planting year with mowing and applying pre- and post-emergent herbicides, if permitted in your state.

- **Mitchell, R.B. & S. Brown. 2015. Guidelines to growing perennial grasses for biofuel and bioproducts. eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. http://articles.extension.org/sites/default/files/Cenusa_Guide_to_Perennials.pdf. (Extension Circular).**

  Switchgrass, big bluestem, and warm-season grass mixtures provide numerous benefits. Existing field equipment, herbicides, and cultivar improvement promote rapid establishment in the planting year. These grasses typically produce a harvestable yield after frost in the planting year and are near full production in the year after planting if moisture is adequate. Typical baled yield at the field scale after establishment exceeds 5 tons per acre in areas east of the arid section of the country. These grasses can be productive for 10 years or longer with good management. Guidelines are provided on best management practices for establishing and managing perennial grasses for multiple uses.

- **Jacobs, K., R. Mitchell & C. Hart. 2015.** To grow or not to grow: A tool for comparing returns to switchgrass for bioenergy with annual crops and CRP**, eXtension Fact Sheet,**

CenUSA Bioenergy, Iowa State Univ., Ames, IA. (http://cenusa.iastate.edu/switchgrass-production-tool. (Extension Circular).

The decision to grow perennial grasses for bioenergy has long-term land use implications. Perennial grasses like switchgrass must be harvested annually for 5 to 10 years to be economically feasible. Typically, the decision comes down to which production system has the greatest economic benefit. Producers need a tool to compare the potential economic return of switchgrass in relation to other crop production systems. This decision tool is intended to be a guide for producers considering switchgrass for biomass. The production estimates, returns, and costs provided are based on the best available information for switchgrass production. When evaluating switchgrass as a production alternative, producers should consider their specific field characteristics and productive capabilities and adjust, as necessary, the default values supplied.

- **CenUSA Fact Sheets**
  - **Guidelines to Growing Perennial Grasses for Biofuel and Bioproducts.** http://articles.extension.org/sites/default/files/Cenusa_Guide_to_Perennials.pdf.
  - **Guidelines to Growing Perennial Grasses for Biofuel and Bioproducts.** https://cenusa.iastate.edu/files/guidelines_to_growing_perennial_grasses_copy.pdf.
  - **Switchgrass (*Panicum virgatum* L.) Stand Establishment: Key Factors for Success.** http://www.extension.org/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success.
  - **Control Weeds in Switchgrass (*Panicum virgatum* L.) Grown for Biomass.** http://articles.extension.org/pages/70396/control-weeds-in-switchgrass-panicum-virgatum-l-grown-for-biomass.
  - **Switchgrass Stand Establishment: Key Factors for Success.** http://articles.extension.org/sites/default/files/FactSheet4.SwitchgrassStandEstablishment.pdf.
  - **Switchgrass (*Panicum virgatum*) for Biofuel Production.** http://articles.extension.org/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production.
  - **Test Plots Show How Perennial Grasses Can Be Grown for Biofuels.** http://www.extension.org/pages/68155/test-plots-show-how-perennial-grasses-can-be-grown-for-biofuels.

- **Growing Switchgrass for Biofuels.** http://articles.extension.org/sites/default/files/Factsheet3.GrowingSwitchgrassforBiofuels.pdf.

- **CenUSA Videos**

  - **Harvesting Native Grass for Biofuel Production.** Rob Mitchell (USDA-ARS) discusses the potential of switchgrass in biofuel production while demonstrating harvesting equipment usage. https://www.youtube.com/watch?v=ybDGWJa6pzc. [2:57]

  - **Switchgrass Establishment, Weed Control, and Seed Quality.** Rob Mitchell (USDA-ARS) discusses switchgrass establishment, weed control, and seed quality at the March 20, 2012, CenUSA-Extension Switchgrass Establishment Field Day in Mead, Nebraska. https://www.youtube.com/watch?v=7xVFMqBvCvQ. [30:53]

  - **No-Till Drill Calibration Training.** Rob Mitchell (USDA-ARS) discusses how to calibrate the Truax No-Till Drill Seeder at the CenUSA Switchgrass Establishment Field Day (Mar. 20, 2012) held in Mead, Nebraska. https://www.youtube.com/watch?v=7TPLfWLkd_U. [20:05]

  - **Switchgrass Planting Practices for Stand Establishment**. Rob Mitchell (USDA-ARS) walks you through the keys to successful switchgrass establishment. https://www.youtube.com/watch?v=vwBQ3aYpfmM. [5:17]

  - **Harvesting Native Grass for Biofuel Production**. Rob Mitchell (USDA-ARS) discusses the potential of switchgrass in biofuel production while demonstrating harvesting equipment usage. https://www.youtube.com/watch?v=ybDGWJa6pzc. [2:57]

  - **Commercialization Update: Opportunities for Perennial Biofeedstocks**. Rob Mitchell (USDA-ARS) discusses commercialization opportunities for switchgrass and other perennial biofeedstocks. https://www.youtube.com/watch?v=jtrGuZ-DDAs. [2:18]

- **Outreach Activities**

  - Switchgrass establishment, weed control, herbicides, and seed quality, Switchgrass Establishment Field Day, University of Nebraska, Univ. of Nebraska ARDC. 2012, Mar. 20. Ithaca, NE.

  - Grassland drill calibration, Switchgrass Establishment Field Day, University of Nebraska, Univ. of Nebraska ARDC. 2012. Mar. 20. Ithaca, NE.

- Switchgrass agronomics, economics, and logistics, Switchgrass I, Switchgrass Genomics Executive Committee and the Samuel Roberts Noble Foundation. 2012. Mar 27. Ardmore, OK.
- Grasslands for bioenergy, Nebraska Range Short Course, Univ. of Nebraska and Chadron State College. 2012. June 20. Chadron, NE.
- Switchgrass for bioenergy, Univ. of Nebraska Crop Management Diagnostic Clinic. 2012: Aug. 30. Ithaca, NE.
- Establishing and managing perennial grasses for bioenergy, Integrated Crop Management Conference. 2012. Ames, IA. 29 Nov.
- Perennial grass storage and agronomics, Roadmap to Commercialize Thermochemical Biofuels and Bioproducts Processing in the Midwest Workshop. 2012. Ames, IA. 11 Dec.
- The pros and cons of using native perennial grasses for biofuel feedstocks, Invasive Potential of Biofuel Crops Symposium, North Central Weed Science Society Meeting. 2012. St. Louis, MO. 13 Dec.
- The feasibility of switchgrass for bioenergy, and Establishment and management of switchgrass for bioenergy, Northwest Certified Crop Advisors Workshop. 2013. St. Joseph, MO. 23 Jan.
- Establishing and managing perennial grasses for bioenergy, Heartland Regional Water Workshop. 2013. Feb22. Nebraska City, NE.
- Sustainable production of switchgrass for bioenergy in the Great Plains and Midwest, 9th Energy Biosciences Institute Bioenergy Feedstocks Symposium. 2013. University of Illinois, Champaign, IL. 22 Aug.
- Perennial Grasses: A Productive, Profitable, and Protective Strategy for Marginally Productive Cropland, Advanced Biofuels Conference & Expo. 2013. Omaha, NE. 12 Sep.
- Establishing and managing perennial grasses for bioenergy, 25th Annual Integrated Crop Management Conference. 2013. Ames, IA. 4 Dec.
- Switchgrass for biomass energy, Nebraska Crop Production Clinics, 5 dates and locations throughout Nebraska. 2014. Univ. of Nebraska. 9-23 Jan.
- Bioenergy research update, Abengoa Advanced Biofuels Project Meeting, 2014. Grand Island, NE. 22 Jan.

- Perennial grasses for bioenergy demonstrations, Vermeer Manufacturing Global Pavilion. 2014. Pella, IA. 31 Mar.
- Example Application of the Feedstock Readiness Level Tool: Perennial Grasses in the Great Plains & Midwest, USDA/DOE Biomass Research and Development Initiative Technical Advisory Committee, invited by the office of the Secretary of Agriculture. 2014. Washington, D.C. 5 Jun.
- Grasslands for bioenergy, Nebraska Range Short Course, Univ. of Nebraska and Chadron State College. 2014. Chadron, NE. 18 Jun.
- Marginal lands in the Great Plains and Midwest, Incorporating Bioenergy in Sustainable Landscape Designs Workshop Two: Agricultural Landscapes. 2014. Argonne National Lab, Argonne, IL. 24-26 Jun.
- Perennial Grass Field Day. We hosted the American Seed Trade Association on a field day addressing all aspects of perennial grasses for bioenergy and forage. The field day was attended by 60 seed professionals. 2014. Jul. 24. Univ. of Nebraska, Ithaca, NE.
- Switchgrass for forage and biomass, Nebraska Grazing Conference 2014. Univ. of Nebraska, Kearney, NE. 13 Aug.
- Establishing and managing perennial grasses for bioenergy, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Beaver Crossing, NE. 19 Aug.
- Planting and harvesting perennial grasses, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Beaver Crossing, NE. 19 Aug.
- Establishing and managing perennial grasses for bioenergy, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Humboldt, NE. 20 Aug.
- Planting and harvesting perennial grasses, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Humboldt, NE. 20 Aug.
- Forage and bioenergy research update, Nebraska Plant Materials Committee. 2014. Lincoln, NE. 21 Aug.
- Perennial grass for bioenergy, Vermeer Forage and Biomass Dealer Meeting, Vermeer Mfg. 2014. Pella, IA. 4 Sep.
- New switchgrass developed specifically for bioenergy use, Brownfield Ag News radio (more than 350 station affiliates). 2014. 29 Aug.

- Potential of 'Liberty' switchgrass, USDA Weekly Radio Features. 2014. 5 Sep.
- New switchgrass variety may serve a dual purpose, USDA Weekly Radio Features. 2014. 5 Sep.
- Switchgrass Field Day, Pure Nebraska, a TV news program on KOLN/KGIN TV and CBS affiliates, first aired 2014. 9 Sep.
- Native perennial grasses for bioenergy, Association of Fish & Wildlife Agencies Biofuel Working Group, North American Wildlife and Natural Resources Conference. 2015. Omaha, NE. 13 Mar.
- Recent advancements in switchgrass and other perennial grasses for bioenergy, ABFC Advanced Bioeconomy Feedstocks (ABFC2015) Conference. 2015. New Orleans, LA. 9-10 Jun.
- Feedstock Readiness Level Tool Update, ABFC Advanced Bioeconomy Feedstocks (ABFC2015) Conference. 2015. New Orleans, LA. 9-10 Jun.
- 'Liberty' switchgrass, interview with Grant Gerlock, NET Radio, featured on the 10 June, 2015 NPR report, "EPA, farmers divided over proposed ethanol standards" as well as the printed story on the prospects of using perennial grasses for ethanol (http://insideenergy.org/2015/05/28/next-generation-fuels-stuck-in-neutral/). 2015. Mead, NE.
- Establishing perennial grasses for displays at the Nebraska State Fair and Husker Harvest Days. May 2015.
- Environmental benefits of perennial grasses, Eureka! 2016, Univ. of Nebraska Extension Conference, 2016. Lincoln. NE. 16 Mar.
- Evolution and focus of the USDA Central-East Regional Biomass Research Center, GAO Bioenergy Review, USDA-ARS-NLAE. 2016. Ames, IA. 13 Apr.
- Invited Conference Welcome & Introduction: Back to the future: a perspective from the central USA, World Bioenergy Congress & Expo. 2016. Rome, Italy. 16 Mar.
- Invited Presentation: Herbaceous perennial feedstocks for marginally-productive landscapes in the central USA, World Bioenergy Congress & Expo. 2016. Rome, Italy. 13 Jun.

- Invited Presentation: Commercialization opportunities for herbaceous perennial feedstocks, Northeast Woody/Warm-Season Biomass Consortium. 2016. State College, PA. 26-27 Jul.
- Invited Presentation: Central-East Regional Biomass Research Center, Inaugural DOE National Laboratory/USDA Research Collaboration Meeting on Bioenergy and Biobased Products, NREL. 2016. Golden, CO. 23-24 Aug.
- Invited Presentation & Workshop Participant: How to quantify the costs and monetize the benefits of bioenergy crops. Bioenergy Solutions to Gulf Hypoxia Workshop, Argonne National Lab. 2016. Washington, DC. 30-31 Aug.
- Guest lecture: Bioenergy research in the central USA, CPSC 415, Bioenergy Crops. 2016. Urbana, IL. 13 Oct.
- Invited Presentation: Grassland research updates, Center for Grassland Studies Citizens Advisory Council Meeting. 2016. Lincoln, NE. 21 Oct.
- Switchgrass stand establishment, cultivar development and acreage needs for a viable biofuel industry, CenUSA Bioenergy webcast. Purdue University Extension. 2017. Jul. https://vimeo.com/223392567.

- **Students Mentored**

Drs. Jin, Schmer, and Mitchell mentored the following undergraduate student interns for 10 weeks each summer as part of the USDA-NIFA-CAP funded CenUSA project, 2012-present.

- Kirsten Paff, Purdue University, 13 June - 3 August 2012.
- Chris Anderson, University of Idaho, 13 June - 3 August 2012.
- David Carlson, University of Minnesota, 11 June - 3 August 2013.
- Haley Chatelaine, Benedictine College, 2 June - 30 July 2014.
- Joel Bauer, Iowa State University, 2 June - 30 July 2014.
- Jason Hambrick, University of Missouri, 2 June - 30 July 2014.
- Julie Juarez, University of California-Berkeley, 2 June - 30 July 2014.
- Tracy Campbell, University of Missouri, 1 June - 30 July 2015.
- Rachael Dennis, University of Miami, 1 June - 30 July 2015.

- Phil Jelcic, University of Illinois, 1 June - 30 July 2015.
- Alex Ryan, Clemson University, 1 June - 30 July 2015.
- Sory Soumare, Des Moines Area Community College, 1 June – 30 July 2015.
- Kelvin Wong, University of Minnesota, 1 June - 30 July 2015.
- Kevin Wu, University of Houston, 1 June - 3 August 2016.
- Michael Calfe, Clemson University, 1 June - 3 August 2016.
- Emma Palermo, Syracuse University, 1 June - 3 August 2016.

- **Additional Collaborations**

ARS-Lincoln provided seed, establishment guidelines, and management guidelines for most of the systems analysis plots, factor analysis plots, and on-farm demonstration sites established for CenUSA. ARS-Lincoln planted on-farm demonstration sites near Beaver Crossing and Humboldt, Nebraska, a demonstration site at Vermeer Manufacturing near Pella, IA, and a wetland site in eastern North Dakota. ARS-Lincoln provided feedstock to a number of collaborators including ADM, Renmatix, and Kimberly-Clark for evaluation through proprietary processes. Semi-loads of large round bales of switchgrass were provided to Iowa State University for feedlot-scale beef cattle feeding trials. Feedstock samples were processed and evaluated for a number of collaborators to determine treatment effects on compositional characteristics using NIRS analysis.

C6 Biofarm Curriculum Workshop (Sioux city, Iowa)

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AgEds & SusAg at Iowa State University
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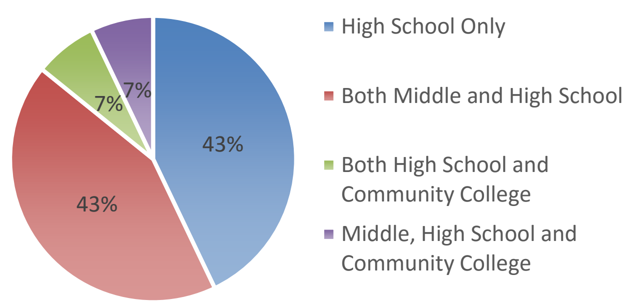
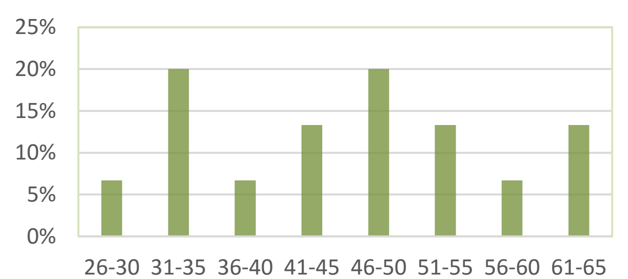
Exhibit 1

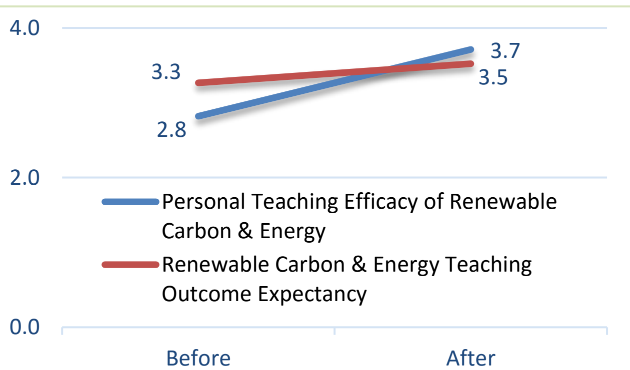
CenUSA Extension/Outreach and ISU Extension hosted a 4-day workshop on the C6 BioFarm Curriculum at Morningside College in Sioux City, IA in June, 2017. C6 BioFarm is a game suite and curriculum designed to help middle and high school students learn about renewable carbon and energy. This workshop was designed to increase teachers' knowledge of renewable carbon and energy, and learn how to integrate C6 Biofarm into their classroom teaching. This workshop used team-based learning activities, lab experiments, and field trips to promote the learning experience. Fifteen teachers successfully completed the workshop (n=15). Among the fifteen participants, there was a good diversity of teaching levels, disciplines, and ages. Participant surveys showed that the workshop signifcantly improved participants teaching efficacy in renewable carbon topics. Teachers increased their knowledge in twelve relevent topics, and the majority of the teachers indicated they plan to integrate BioFarm Curriculum into their classroom teaching.



Participants' Teaching Levels



Participants Age Group



Participants Teaching Efficacy Change

Knowledge Increases

Knowledge topics that were signficatly increased after the workshop (*p*<.005)	Perceieved value	Increased proportion
How to reduce personal carbon footprint	4.20	32.6%
Impacts of different agricultural practices	4.13	32.6%
Bio-renewable energy STEM careers	4.13	33.3%
Economic, social, and environmental impacts of food, fuel, fiber production	4.13	60.6%
Role of carbon in the energy cycle	4.07	48.8%
Impacts of climate change	4.07	31.9%
Production of bio-renewable products	4.00	52.4%
Perennial grasses for water quality and biomass feedstocks	4.00	65.8%
Fossil vs. renewable carbon sources	3.93	34.7%
Biomass conversion technologies	3.93	103.7%
Differentiation of starch-based and cellulosic ethanol	3.93	66.7%
Environmental impacts of biomass	3.93	62.1%

Integration and Implementation of C6 BioFarm Curriculum into Classroom Teaching

	Teachers's comments
1	"I will use almost all of lessons 1-4 in my Natural Resources and in Agriculture II courses. Lessons 5-6 will likely be spread out into almost all my courses. I will likely condense most of the units."
2	"I am going to try and implement as many of these experiments as I can."
3	"I plan on implementing a large number of the hands-on activities into various classes that I teach."
4	"I will probably take about 50% of the material to utilize in my existing classes."
5	"I will probably use at least one third or more of these ideas and adapt the technology to my student audience."
6	"I think I will try to implement at least a small piece of each of the lessons."
7	"I will try and incorporate the teaching styles as information gathered into my courses."
8	"I will incorporate many of the activities into my courses."

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

Exhibit 2

Project Comments, Rob Mitchell, USDA-ARS, Lincoln, NE

The CenUSA Systems Analysis Field, located at the Eastern Nebraska Research and Extension Center (ENREC) near Ithaca, NE (41^{o} 08’ 50” N, 96^{o} 27’ 09” W) formed the foundation of the field scale research. Previous research at ARS-Lincoln determined the best regionally-adapted biomass feedstocks and those feedstocks were planted at the site. The selected site is marginally-productive for annual row crops, with about 1/3 of the field being poorly-drained (Fig. 1).

Switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), and low-diversity warm-season grass mixtures (big bluestem, indiangrass, and sideoats grama) are productive biomass feedstocks for much of the Great Plains and Midwest. These perennial grasses have excellent yield potential, grow well on marginally-productive cropland, and provide numerous environmental benefits. Three field replicates (2-acres each) were planted to ‘Liberty’ switchgrass, big bluestem, and the low-diversity mixture. Additionally, three 2-acre field replicates of continuous corn were planted to serve as a comparison. This site is poorly drained and marginally-productive for corn and soybean.

Perennial grasses were planted in April 2012 at 30 pure live seed (PLS) per square foot into soybean stubble using a Truax no-till drill. A post-plant, pre-emergent application of Quinclorac provided excellent control of grassy weeds, while an application of 2,4-D in early July controlled broadleaf weeds. Although a severe drought occurred after planting in 2012, excellent stands were established and harvestable yields were present after killing frost.

In 2013, N fertilizer treatments of 50 and 100 pounds of actual N per acre per year were initiated on the perennial grass fields. Corn plots received 125 pounds of actual N per acre per year. Perennial grass biomass was harvested after frost using a commercial rotary-head harvester and baled the same day with a mega-wide round baler. Perennial grass within each 1-acre subplot was harvested, baled, and bales cored for determining dry matter and composition. Corn grain yield was determined by harvesting with a field combine and adjusting yield to 15.5% moisture. On half of each corn replicate, stover was baled after harvest to determine stover yield.

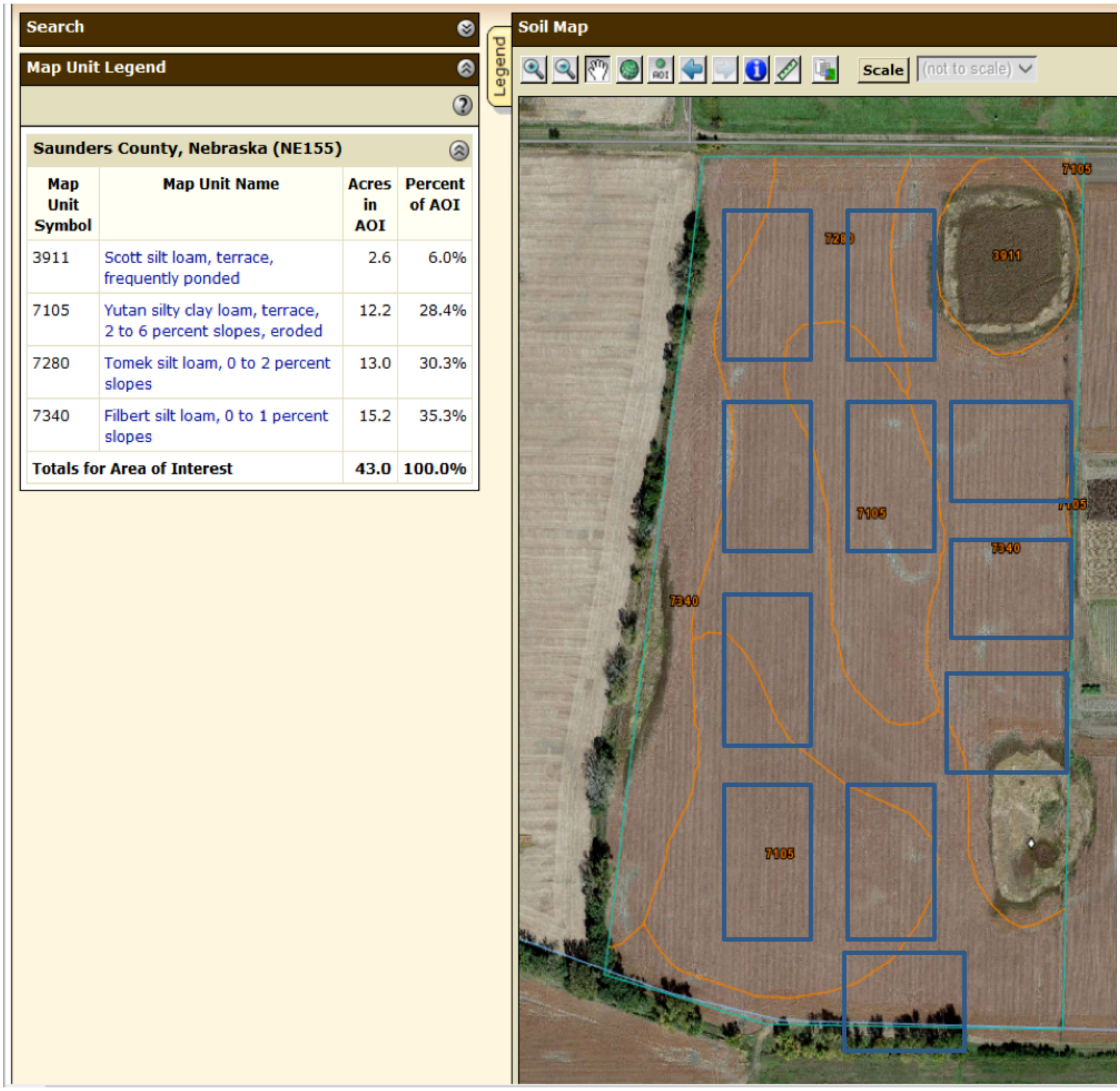


Fig 1. CenUSA Systems Analysis Field near Ithaca, NE established in 2012 on a site that is marginally-productive for row crops, with about 1/3 of the area being poorly drained. Treatments include switchgrass, big bluestem, low-diversity mixture, and continuous corn

- **Field-scale Yield and Composition of Dedicated Feedstocks on Marginally-productive Cropland in Eastern Nebraska (In process)**

  Our objective was to compare the field-scale production of ‘Liberty’ switchgrass, big bluestem, and a low-diversity mixture of big bluestem, indiangrass, and sideoats grama to continuous corn on a poorly drained marginally-productive field near Ithaca, Nebraska. There was no clear response to N rate in the perennial grasses, so dry matter yield (DM) was averaged across N rates. Perennial grass DM yields from 2013-2016 represent the total DM that was harvested, baled, and transported from each field to the storage facility. Perennial grass means include the planting year. Herbicide damage from glyphosate in 2014 reduced switchgrass yields in 2014 and 2015. Plant samples for compositional analysis have been processed and scanned, and NIRS predictions are underway.

Table 1. Field scale yields (U.S. tons/acre) for 'Liberty' switchgrass, big bluestem, a low diversity mixture, corn grain, and corn stover from rain fed fields near Ithaca, NE from 2012 through 2016. Yields represent 3 field replicates and are the mean of two fertilizer treatments (50 & 100 lb N/acre).

Feedstock	2012	2013	2014	2015	2016	Mean
'Liberty' Switchgrass (tons/acre)	3.4	5.1	4.5	4.6	5.7	4.7
Big bluestem (tons/acre)	1.2	4.1	4.7	4.3	5.4	3.9
LD Mixture (tons/acre)	1.9	5.0	5.7	5.7	6.1	4.9
Corn (bu/acre)	103.0	149.0	139.0	126.0	145.0	132.0
Stover (tons/acre)	1.4	1.9	1.8	1.7	1.6	1.7

- **Estimating Harvest Losses for Herbaceous Perennial Energy Crops on Marginally-Productive Cropland in Eastern Nebraska (In process)**

Little research has been conducted to estimate biomass losses during harvest in herbaceous perennial energy crops. Field-scale replicates of 'Liberty' switchgrass, big bluestem, and a low-diversity mixture (big bluestem, indiangrass, sideoats grama) were harvested with a self-propelled rotary head harvester after frost each year. Biomass was baled from each treatment area with a commercial round baler (JD 569 MegaWide Plus) immediately after harvest each year. Harvested residue remaining in the windrow after baling was sampled from six (6) locations in each treatment area using a 1'x8' quadrat placed across the windrow. The sampled area represented 67% of the width of each harvested swath. Mean transported yield for all feedstocks averaged 5 tons/acre/year with LDM being providing the greatest and big bluestem the least. Harvest loss varied across feedstocks with an average loss of 18.9%, 26.4%, and 15.1% of total transported yield for switchgrass, big bluestem, and LDM, respectively. Harvest loss in 2015 was two times greater than losses in 2014. Losses were greater for the higher N rate. At $80/ton, harvest losses per acre ranged from $69/acre for LDM to $99/ acre for big bluestem (Switchgrass – 0.85 tons/acre = $68/acre; big bluestem – 1.24 tons/acre = $99/acre; LD mixture – 0.86 tons/acre = $69/acre). It appears that current biomass harvesting capabilities are limited to between 5 & 6 tons/acre, beyond which biomass cannot be reliably captured with the baling equipment used (JD 569 MegaWide Plus, flare-to-flare width of 7.2').

- **Growing season greenhouse gas emissions from perennial grasses and continuous corn on marginally-productive land (In process)**

Switchgrass, big bluestem, low diversity mixtures, and continuous corn fields were intensively sampled for greenhouse gas (GHG) emissions using static chambers in 2013, 2014, 2015, and 2016. Averaged across sampling dates in 2013 and 2014, N_2O daily emissions were 2.7, 3.4, & 5.1 times greater for corn than for SW, LDM, and BB, respectively. Additional data are being summarized.

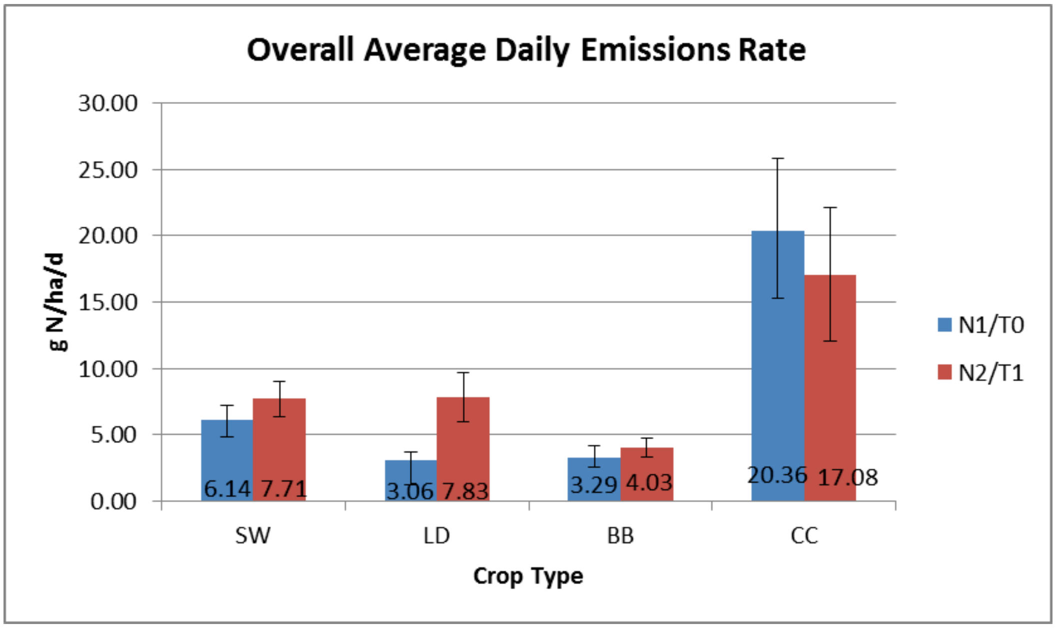


Fig. 2. Overall average emissions/day for each crop for all 2013 & 2014 sampling dates. Big bluestem had the lowest emission rates.

- **Effect of Harvest Date and Harvest Height on Herbaceous Perennial Feedstock Biomass and Potential Ethanol Yield (In process)**

Switchgrass, big bluestem, and warm-season grass mixtures are promising biomass feedstocks for much of the central and eastern USA. These feedstocks are high yielding, well-suited to marginally-productive cropland, and provide numerous environmental benefits. Bioenergy-specific cultivars and improved herbicides promote rapid establishment and harvestable yields after frost in the planting year. If moisture is adequate for establishment, fields are near full production in the year after planting with field-scale yield typically exceeding 10 Mg ha^{-1}.

Although recommendations are regionally-specific, these grasses are typically fertilized each spring and harvested once each year at anthesis or after a killing frost to a 10-cm stubble height. Following these recommendations, switchgrass stands have been productive for nearly 20 years. However, there is interest from conservation groups to leave some standing biomass in the field to provide over-wintering wildlife habitat and to catch snow to conserve moisture. Our objective was to determine how harvest date (at anthesis or after killing frost) and harvest height (5, 10, 15, 20, 25, and 30 cm above the soil surface) affect biomass production and potential cellulosic ethanol yield in switchgrass, big bluestem, and warm-season grass mixtures.

This study was conducted at the University of Nebraska ENREC near Ithaca, Nebraska, USA. The site has poorly drained soil and is marginally productive for corn (*Zea mays*) and soybean (*Glycine max*). Fields (0.9 ha each) of 'Liberty' switchgrass, big bluestem, and a mixture of big bluestem, indiangrass (*Sorghastrum nutans*) and sideoats grama (*Bouteloua curtipendula*) were planted in 2012. The three field replicates were split in half and fertilized annually with either 56 or 112 kg of N ha^{-1}. Harvest date (anthesis or after frost) and harvest height treatments (5, 10, 15, 20, 25, and 30 cm) were imposed in 2013 and 2014. Samples were collected from each harvest date and harvest height combination for each feedstock. Samples were weighed, dried at 55 C, ground to pass a 2-mm screen, and milled to pass a 1-mm screen. Samples were scanned using near infrared reflectance spectroscopy (NIRS) and potential ethanol was predicted. For all feedstocks, harvested biomass decreased linearly with increasing stubble height and harvesting at a 5-cm stubble height was not feasible at the field scale. In 2013, there was no difference in yield within a feedstock for biomass harvested at anthesis and those harvested after frost for big bluestem and switchgrass, but the mixture typically had greater yields when harvested after frost. In 2013 averaged across all feedstocks, for each 5-cm increase in stubble height, an average of 1.2 Mg ha^{-1} of biomass was left in the field. For switchgrass, potential ethanol yield in 2014 was similar across harvest dates, ranged from about 2,500 to 7,000 l ha^{-1}, and was driven by biomass yield. This study provides information for placing a monetary value on leaving standing biomass in the field for wildlife habitat and expands our understanding of the effects of management practices on biofuel production.

- **Predicting Switchgrass Mineral Concentration using NIRS (In process)**

  Near-infrared reflectance spectroscopy (NIRS) is a rapid technique for quantifying plant compositional characteristics. Five field experiments containing switchgrass samples from multiple locations and genotypes were used to develop NIRS prediction equations for estimating mineral concentration as individual sets and a merged set. After NIRS scanning, the concentrations of K, P, Fe, N, Ca, Zn, Mg, S and Si were determined using ICP-AES. Scan and lab reference data were merged to develop NIRS equations to predict mineral composition for each sample set. Lab mean, standard error of prediction (SEP), R-squared values and SEP/lab mean percent were compared. Two sample sets appeared to be better suited for calibration equation development. One set represented the widest treatment variety and had mineral estimate SEP/lab mean ratios of Mg=0.16, S= 0.19, Si=0.19, N=0.05. The other set had the largest number of samples and had mineral estimate SEP/lab mean ratios of Fe=0.24, K=0.11, P=0.15, and Zn=0.16. A third set had mineral estimate SEP/lab mean ratios of 0.11 for Ca. A critical factor in equation development is the accuracy and precision of the reference lab data. Sample sets analyzed for mineral concentration using ICP-AES had a single standard analyzed multiple times in each set. When all sets of samples were merged for calibration equation development, SEP/lab mean ratios were larger for each mineral. Lab standard values varied from set to set which might explain why merging samples sets was not effective in reducing mineral estimate SEP/lab mean ratios. Initial results suggest using NIRS to estimate mineral concentration effectively ranks samples within plant populations. However, additional research is needed to use NIRS to accurately quantify mineral concentration in switchgrass across multiple environments and genotypes.

- **Pelleting Perennial Grass Feedstocks for Bioenergy (In process)**

  Using perennial grasses for bioenergy has the greatest probability for success if multiple commercialization opportunities are provided. ARS Lincoln partnered with Heldt Farms (harvest and baling) and Dehy Alfalfa Mills (pellet plant) to provide the commercial proof of concept for making pellets from switchgrass, big bluestem, and low diversity prairie mixtures in eastern Nebraska. Twelve (12) big round bales each of switchgrass, big bluestem, and a low diversity prairie mixture (36 bales total) were transported, successfully pelletized, and bagged in 50-lb bags at Dehy Alfalfa Mills near Bancroft, NE. The pelleting process was successful and resulted in pellets with bulk densities of 37.94 lbs ft^{-3} for switchgrass and big bluestem, and 38.26 lbs ft^{-3} for the low diversity mixture. We have quantified the chemical composition and conversion properties of the pellets (see below). We have approximately 2 tons of pellets for each feedstock on hand. The bags of pelleted material of known composition have been distributed to people requesting feedstock in lieu of shipping bales or ground material. Additionally, we have used the pellets as a natural mulch for establishing turfgrass, evaluated the pellets in an external residential furnace, used the pellets as a moisture absorbent material for high traffic areas during wet conditions, and used the pellets as ‘hail stones’ in a hail simulator.

- **Effect of Pelletizing Herbaceous Grasses on Chemical Composition and Conversion Properties (In process)**

  Warm-season perennial grasses are promising candidates as bioenergy crops because of their high productivities and carbohydrate contents. However, storage and transport are challenging because of their low bulk density and poor flow properties. Pelletizing is a standard method for increasing bulk density of biomass. Field grown switchgrass, big bluestem, and a low diversity mixture were either milled or pelletized. Samples were analyzed for chemical composition using the dietary fiber method. Pelletized samples appeared to have lower overall structural carbohydrates and increased ethanol/water extractable materials. Samples were pretreated with low moisture ammonium hydroxide and evaluated for enzymatic sugar extraction. Pelletizing led to increased glucose yields for the big bluestem and low diversity mixture but not for the switchgrass. When pretreated with liquid hot-water, pelletizing was associated with increased glucose yields only for the low diversity mixture.

- **Perennial Grass Pellet Evaluation in a Central Boiler MAXIM M250 Residential Furnace**

  Jim Inglis conducted a test fire of switchgrass, big bluestem, and low diversity mixture (LDM) pellets using a Central Boiler Maxim M250 exterior furnace. The pellets had large quantities of fines that needed to be screened before loading into the boiler. Based on total weight, quantity of fines ranged from 2.6% for the LDM to 21.1% for switchgrass. Compared to wood pellets and other grass pellets, there was more very fine dust. Excessive fines bind the auger and feed tube and can damage the feeding mechanism. During test firing of all types, large "clinkers" formed around the auger in 4.5-5 hours of burning under average system demand for residential heating. The formation of clinkers causes boiler combustion efficiency to drop and can cause the system to shut down due to auger plugging and ash build up on ventilation holes in the burn pot. There was minimal "fly ash" from the grass pellets, suggesting that buildup of ash on the heat exchangers would be less when compared to wood ash. This is probably the result of the ash not moving around in the burn pot area due fuel type developing clinkers rather than finer particulate ash. The grass pellets required longer time to burn than wood pellets. During high demand periods while burning grass pellets, the feeding rate had to be decreased to reduce the chance that the grass pellets would not be pushed up over the sides of the burn pot rather than out of the end.

  Grass pellets seem to work best in low demand scenarios when feeding rate and required combustion air flow is at the lowest settings. Both higher feeding rates and airflow tend to result in higher temperatures in the burn pot ultimately creating larger clinkers that impede efficiency and ability to maintain burn without long term damage to the feeding mechanism. Grass pellets need to be monitored more closely when compared to other fuel types. For example, 550 lbs of wood pellets will burn in 4-5 days and the ash would not need to be cleaned from the burn pot. In contrast, I would not want to run grass pellets for more than 6 hours without cleaning clinkers from the auger and burn pot. This may be addressed by modifying the feeding mechanism and auger to do a better job of breaking up clinkers and pushing it out of the burn pot.

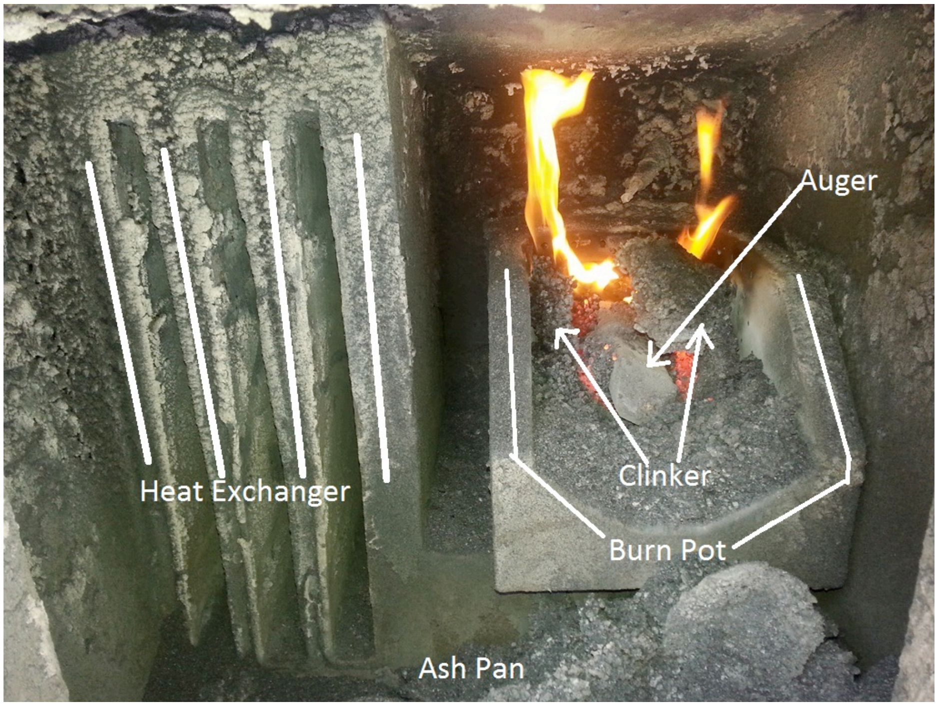


Fig. 3. The fire box of the Maxim M250 furnace burning grass pellets.

- **Using Perennial Warm-season Grass Biomass Feedstocks for Grazing (In process)**

Warm-season grasses like switchgrass, big bluestem, and indiangrass are productive for grazing and hay throughout much of the Corn Belt. One strategy for preparing for the emerging bioeconomy is to plant biomass feedstocks, then graze them while waiting for the emerging bioenergy industry. Our objective was to compare the best available cultivars of switchgrass, big bluestem, indiangrass, and warm-season mixtures (Mix 1 = big bluestem/indiangrass/sideoats; Mix 2 = big bluestem/indiangrass/switchgrass/sideoats/little bluestem) for livestock production in eastern Nebraska.

Fields were planted in 1-acre pastures in spring 2011 with three field replicates per grass. Pastures were fertilized each spring after the planting year with nitrogen at 60 lb N/acre. In 2012, pastures were grazed with two steers per acre for 69 d from June 7 to August 15. In 2013, pastures were grazed with 2 heifers per acre for 74 d from June 17 to August 29, 2013. All pastures had greater production in 2012 when steers grazed the pastures. Switchgrass had the lowest ADG and BWG throughout the study. Averaged across years, Mix 2, the most diverse mixture containing five species, had the greatest livestock performance. These preliminary data suggest that warm-season grasses could be planted for biomass feedstocks prior to the presence of a bioenergy market and grazed to return revenue while waiting for the completion of a bioenergy processing facility.

Table 2. Average daily gain (ADG) for switchgrass,

indiangrass, big bluestem, and different warm-season grass mixtures grazed in 2012, 2013, and 2014 near Mead, NE. Pastures were grazed by steers in 2012 and heifers in 2013 and 2014.				
	2012	2013	2014	Mean
		ADG (lbs/hd/d)		
Switchgrass	1.9	0.9	0.4	1.0
Indiangrass	2.3	1.3	0.8	1.5
Big bluestem	2.3	1.3	1.0	1.5
Mix 1	2.1	1.3	1.0	1.5
Mix 2	2.5	1.4	0.9	1.6

Table 3. Body weight gain (BWG) for switchgrass, indiangrass, big bluestem, and different warm-season grass mixtures grazed in 2012, 2013, and 2014 near Mead, NE. Pastures were grazed by steers in 2012 and heifers in 2013 and 2014.

	2012	2013	2014	Mean
		BWG (lbs/acre)		
Switchgrass	256	126	52	145
Indiangrass	320	196	124	213
Big bluestem	318	186	148	217
Mix 1	294	193	149	212
Mix 2	346	202	141	230

- **Using Perennial Grasses for Biomass and Grazing in an Integrated Crop-livestock System**

Fields were planted and established as a 50-acre farm to demonstrate potential grazing and bioenergy dual purpose use in eastern Nebraska. The study was leveraged to be included as a location in the South Dakota State University (SDSU) integrated crop livestock grazing USDA Coordinated Agricultural Project CAP. In 2015 and 2016, bromegrass and switchgrass were harvested for hay. Grazing began in spring 2017. The study uses 'Newell' smooth bromegrass pastures for grazing in spring and autumn, 'Liberty' switchgrass for flash grazing in late spring then harvest for bioenergy after frost, 'Shawnee' switchgrass for summer grazing, corn for grain and stover for grazing and bioenergy in late autumn, and triticale for early spring grazing and potential bioenergy production. The 'Newell' smooth bromegrass was grazed for 21 days in 2017 and produced an average daily gain of 2.44 lb/hd/d. The first grazing of 'Liberty' switchgrass began on June 13, 2017 and grazing lasted for 7 days. 'Shawnee' switchgrass grazing began on June 20, 2017 and will continue until forage is limiting and smooth bromegrass regrowth can be grazed or corn has been harvested and stalks are available for grazing.

- **Using Visual Obstruction (VOM) and Elongated Leaf Height Measurements to Predict Standing Crop Biomass on Bioenergy Production Fields (In process)**

  Switchgrass, big bluestem, and warm-season grass mixtures are being evaluated as biofuel feedstocks for the United States. Efficiently and accurately estimating biomass feedstock supplies in the field will be necessary for biorefineries to prepare for biomass scheduling. The objective of this study was to determine how well indirect methods predict biomass feedstock supplies for different feedstocks. Indirect measurements were conducted in eastern Nebraska from 2012 to 2015 in 0.9-ha fields of switchgrass, big bluestem, and low diversity mixtures. A modified Robel pole was used to determine visual obstruction and elongated leaf height. Prediction models demonstrate that visual obstruction and elongated leaf height are correlated with yield, but the ability to predict biomass varied across feedstocks. Data are being analyzed and summarized to make recommendations.

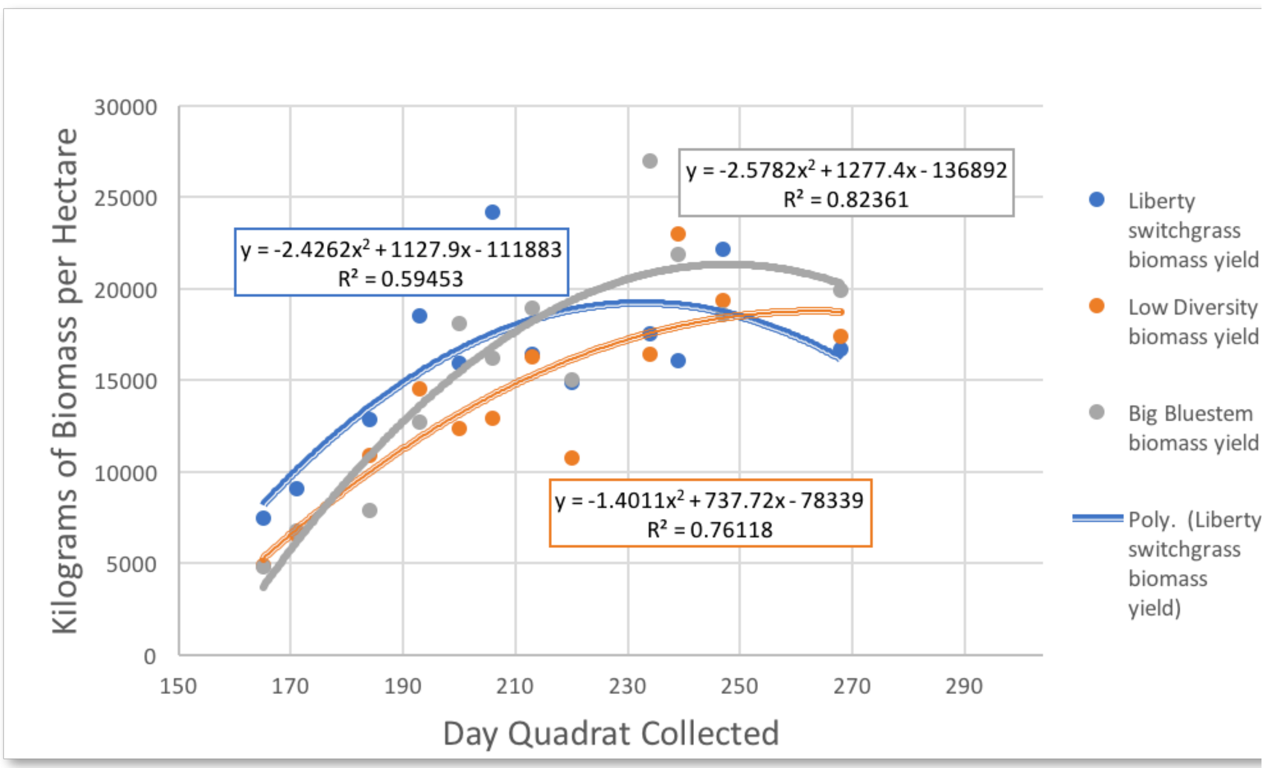


Fig. 4. Relationship between visual obstruction and aboveground biomass for switchgrass, big bluestem, and low diversity mixtures near Mead, NE.

- **Quantifying costs and monetizing benefits of bioenergy crops (In process)**

Quantifying the costs associated with establishing and managing bioenergy feedstocks is straight forward and well established. For example, in a 5-year study on field-scale sites established and managed in Nebraska, South Dakota, and North Dakota, farmer inputs were tracked and average establishment and management costs were determined. At the end of 5-years, average switchgrass costs were variable and fields that were economically feasible produced a harvestable yield in the planting year and land costs accounted for about half of the cost of production (Perrin et al. 2008). Additionally, the energy balance was positive for the switchgrass system (Schmer et al. 2008).

Based on these and other establishment and management inputs (Mitchell et al. 2012a), Jacobs et al. (2015) developed a decision support tool for estimating establishment and management costs and comparing potential switchgrass return to corn, soybean, and Conservation Reserve Program (CRP) grasslands. This tool can be tailored to specific areas within farmer fields and used to estimate the feasibility of growing switchgrass on all or a portion of a field. Monetizing the benefits of perennial energy crops like switchgrass is a more difficult task. Meehan et al. (2013) evaluated the feasibility and monetized the benefits of switching 16,727 ha in 100-m buffer strips along drainages from continuous corn to perennial grass in a focal area in southern Wisconsin. They estimated that converting from continuous corn to perennial grasses on these 16,727 ha focal areas decreased annual income by 75%, increased annual net energy produced by 33%, reduced annual P loading by 29%, increased C sequestration by 30%, reduced N_2O emission by 84%, and increased pollinator abundance by 11%. The benefits of monetizing ecosystem services varied, but monetizing ecosystem services based on the social costs of pollution far exceeded the opportunity costs and stacking the monetized benefits results in significant monetary returns. Studies such as Meehan et al. (2013) demonstrate the critical data need for quantifying ecosystem services from field comparisons between crop and Bioenergy production systems.

These direct comparisons have been a critical component of the NIFA-AFRI-CAP grants (www.cenusa.iastate.edu) and will provide valuable inputs for modeling efforts (Porter et al. 2015). For example, research in eastern Nebraska has demonstrated that each year more than 1 Mg of C/ha is sequestered in switchgrass fields managed for Bioenergy (Follett et al. 2012; Stewart et al. 2015; Kibet et al. 2015). There are several barriers that discourage deploying perennial grasses for bioenergy including; 1) the lack of an existing bioenergy market, 2) the conflict between the ecologically and economically best use of land; 3) the lack of long-term guarantees needed to make perennials feasible since at least 5 years are needed to make money; 4) the lack of an even playing field with commodity crops; and 5) a lack of understanding of how the risks will be managed and distributed. Grazing and hay are the only currently-available large-scale markets for perennial grasses, but others have promise. Based on more than 25 years of bioenergy research in Nebraska, growing perennial grasses such as switchgrass for bioenergy are non-invasive (Mitchell et al. 2015), rapidly established (Mitchell et al. 2012a,b), productive (Mitchell et al. 2016), profitable for the farmer (Perrin et al. 2008; Jacobs et al. 2015), and protective of the environment (Follett et al. 2012; Stewart et al. 2015; Kibet et al. 2015). However, it is difficult to change the culture of agriculture unless there is a distinct economic incentive for growing biomass while fitting into the time constraints of the current production system. Government and society need to support bioenergy deployment by providing incentives for ecosystem services, supporting biomass use from CRP and cover crops, and valuing ecosystem services.

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- **Harvest Date and N Fertilizer Implications of Growing Switchgrass for Bioenergy on Marginal Land (In process)**

Switchgrass (*Panicum virgatum* L.) is a promising bioenergy feedstock. Appropriate use of nitrogen (N) fertilizer is essential for developing profitable and sustainable switchgrass biomass production systems, especially on marginally productive cropland.

This study was conducted to determine the long-term environmental and economic efficiency of applying N fertilizer to switchgrass grown for biomass energy on marginally-productive cropland. The experimental design included three field replicates each of three annually-applied N fertilizer rates (0, 60, 120 kg N/ha) and two harvest dates (anthesis and post-frost). Reported biomass yields were collected over 14 field production years (2000-2013). Nitrogen use efficiency (NUE), a common agronomic metric in crop production, and N economic efficiency (NEE), a new measure of the value of N fertilizer application to the producer, were determined from DM yield. Switchgrass biomass increased as N fertilizer rate increased. Higher biomass yield with higher N fertilizer rates did not result in greater NUE or NEE. For both harvest dates, NUE and NEE were greater for the 60 kg of N/ha rate than for the 120 kg of N/ha rate. For the August harvests, applying 60 kg of N/ha resulted in a 42% higher NUE and NEE than the 120 kg of N/ha rate. For the post frost harvests, applying 60 kg of N/ha resulted in a 55% higher NUE and NEE than the 120 kg of N/ha rate. These results provide strong support for applying 60 kg of N/ha rather than 120 kg of N/ha, even though the long-term yield average was greater for the 120 kg of N/ha rate. Based on 14 years of field data, applying 60 kg of N/ha and harvesting after frost is the most economically and environmentally sustainable management practice due to its higher NUE and higher NEE compared to other management practices. Evaluating crop response on the basis of NEE is a promising approach to indicate the on-farm value of fertilizer management programs for perennial grasses.

- **Factor Analysis Research: Biomass Yield of Annual and Perennial Feedstocks on Marginally-productive Cropland in Eastern Nebraska**

  - Yield data for select switchgrass, big bluestem, and mixtures from 2012-2016 is being summarized.

  - Yield data for winter wheat, biomass sorghum, oats, and teff from 2012-2016 is being summarized.

  - Samples collected in 2012, 2013, 2014, 2015, & 2016 have been processed and are being scanned and predicted using NIRS.

- **Refereed Publications with Abstracts**

  - **Vogel, K.P., R. Mitchell, M. Casler & G. Sarath. 2014. Registration of 'Liberty' switchgrass. J. Plant Registrations, 8:242-247.**

    'Liberty' (Reg. No. CV-271, PI 669371) switchgrass (*Panicum virgatum* L.) is a lowland-type cultivar that is adapted to USDA plant hardiness zones (HZ) 4, 5, and 6 in the U.S. Great Plains and Midwest, east of 100° W. longitude. It was developed for use as a perennial biomass energy crop and is the first high yielding biomass-type lowland cultivar adapted to this region. It can produce greater biomass yields than upland- or forage type switchgrass cultivars developed previously for use in the region, and it has equivalent winter survival. 'Liberty' has significantly greater winter survival in its adaptation region than previously released lowland switchgrass cultivars such as 'Kanlow' and 'Alamo' that frequently have substantial winter damage and stand loss north of 40° N latitude in the U.S. Great Plains and Midwest.

  - **Porter, P., R.B. Mitchell & K.J. Moore. 2015. Reducing hypoxia in the Gulf of Mexico: Reimagining a more resilient agricultural landscape in the Mississippi River watershed. J. Soil Water Conserv., 70(3):63A-68A. http://www.jswconline.org/content/70/3/63A.refs. (Open Access).**

    Perennial grass-based biofuels and bioproducts provide opportunity to integrate perennial grasses back into agricultural systems, at a landscape scale and achieve significant water and ecosystem service benefits. They could be targeted strategically, offering a tool for landowners to stabilize areas of their farm that are environmentally sensitive, fields that are adjacent to waterways, or that are steeper, wetter, more erosive, or that may be marginally profitable for row crops. Planting perennial prairie grasses or prairie grass strips could be an effective strategy for nutrient removal and enhanced environmental performance while still farming a majority of the field. In addition, perennial grasses could serve a dual purpose for grazing cattle. In a time of constrained federal and state budgets, a key attraction of perennial grass-based biofuels and bioproducts may be its "working lands" approach to conservation. Building new market demand could allow perennial grasses, once native to the central United States to be reestablished on lands that are better suited to perennial production. In short, perennial grasses for bioenergy is a market-driven agricultural system that provides conservation benefits as an outcome, rather than direct payment to landowners for conservation as an add-on.

- **Mitchell, R.B. & K.P. Vogel. 2015. Grass invasion into switchgrass managed for biomass energy. Bioenergy Res., 9:50-56. doi 10.1007/s12155-015-9656-4. 2015.**

  Switchgrass (Panicum virgatum) is a C4 perennial grass and is the model herbaceous perennial bioenergy feedstock. Although it is indigenous to North American grasslands east of the Rocky Mountains and has been planted for forage and conservation purposes for more than 75 years, there is concern that switchgrass grown as a biofuel crop could become invasive. Our objective is to report on the invasion of C4 and C3 grasses into the stands of two switchgrass cultivars following 10 years of management for biomass energy under different N and harvest management regimes in eastern Nebraska. Switchgrass stands were invaded by big bluestem (*Andropogon gerardii*), smooth bromegrass (*Bromus inermis*), and other grasses during the 10 years. The greatest invasion by grasses occurred in plots to which 0 N had been applied and with harvests at anthesis. In general, less grass encroachment occurred in plots receiving at least 60 kg of N ha^{-1} or in plots harvested after frost. There were differences among cultivars with Cave-in-Rock being more resistant to invasion than Trailblazer. There was no observable evidence of switchgrass from this study invading into border areas or adjacent fields after 10 years of management for biomass energy. Results indicate that switchgrass is more likely to be invaded by other grasses than to encroach into native prairies or perennial grasslands seeded on marginally productive cropland in the western Corn Belt of the USA.

- **Moore, K.J., S. Birrell, R.C. Brown, M.D. Casler, J.E. Euken, H.M. Hanna, D.J. Hayes, J.D. Hill, K.L. Jacobs, C.L. Kling, D. Laird, R.B. Mitchell, P.T. Murphy, D.R. Raman, C.V. Schwab, K.J. Shinners, K.P. Vogel & J.J. Volenec. 2014. Midwest vision for sustainable fuel production. Biofuels, 5:687-702. 2015.**

  CenUSA Bioenergy, a USDA-NIFA-AFRI coordinated agricultural project has multiple research projects focused on the North Central region of the US. CenUSA's vision is to develop a regional system for producing fuels and other products from perennial grass crops grown on marginally productive land or land that is otherwise unsuitable for annual cropping. CenUSA has made contributions to nine primary systems needed to make this vision a reality: feedstock improvement; feedstock production on marginal land;

feedstock logistics; modeling system performance; feedstock conversion into biofuels and other products; marketing; health and safety; education; and outreach. The final section, Future Perspectives, sets forth a roadmap of additional research, technology development and education required to realize commercialization.

- **Mitchell, R., M. Schmer, B. Anderson, V. Jin, K. Balkcom, J. Kiniry, A. Coffin, A. & P. White. 2016. Dedicated energy crops and crop residues for bioenergy feedstocks in the Central and Eastern USA. BioEnergy Res., 9:384-398. doi: 10.1007/s12155-016-9734-2. http://link.springer.com/article/10.1007/s12155-016-9734-2. (Open Access).**

  Dedicated energy crops and crop residues will meet herbaceous feedstock demands for the new bioeconomy in the Central and Eastern USA. Perennial warm-season grasses and corn stover are well-suited to the eastern half of the USA and provide opportunities for expanding agricultural operations in the region. A suite of warm-season grasses and associated management practices have been developed by researchers from the Agricultural Research Service of the US Department of Agriculture (USDA) and collaborators associated with USDA Regional Biomass Research Centers. Second generation biofuel feedstocks provide an opportunity to increase the production of transportation fuels from recently fixed plant carbon rather than from fossil fuels. Although there is no "one-size-fits-all" bioenergy feedstock, crop residues like corn (Zea mays L.) stover are the most readily available bioenergy feedstocks. However, on marginally productive cropland, perennial grasses provide a feedstock supply while enhancing ecosystem services. Twenty-five years of research has demonstrated that perennial grasses like switchgrass (Panicum virgatum L.) are profitable and environmentally sustainable on marginally productive cropland in the western Corn Belt and Southeastern USA.

- **Vogel, K.P., R. Medill, S.D. Masterson, R.B. Mitchell & G. Sarath. 2017. Mineral element analyses of switchgrass biomass: comparison of the accuracy and precision of laboratories. Agronomy J., 109:735-738. doi:10.2134/agronj2016.08.0475.**

  Mineral concentration of plant biomass can affect its use in thermal conversion to energy. The objective of this study was to compare the precision and accuracy of university and private laboratories that conduct mineral analyses of plant biomass on a fee basis. Accuracy and precision of the laboratories was tested by having all laboratories conduct mineral analyses on subsamples of the same set of standard switchgrass (*Panicum virgatum* L.) samples and a certified standard. Laboratories differed significantly in both accuracy and precision even though several used the same analysis method indicating that the differences among laboratories were due to within laboratory procedures and quality control. Laboratories should be using sample standards to monitor both precision and accuracy of their mineral analyses. It would be advisable for researchers submitting samples to service laboratories to replicate the unknown samples to determine precision and to include replicated standards among the submitted samples to determine accuracy.

- **Blanco-Canqui, H., R. Mitchell, V. Jin, M. Schmer & K. Eskridge. 2017. Perennial warm-season grasses for producing biofuel and enhancing soil properties: An alternative to corn residue removal. GCB Bioenergy. doi:10.1111/gcbb.12436. http://dx.doi.org/10.1111/gcbb.12436. (Open Access).**

  Removal of corn residues at high rates for biofuel and other off-farm uses may negatively impact soil and the environment in the long term. Biomass removal from perennial warm-season grasses (WSGs) grown in marginally productive lands could be an alternative to corn residue removal as biofuel feedstocks while controlling water and wind erosion, sequestering carbon (C), cycling water and nutrients, and enhancing other soil ecosystem services. We compared wind and water erosion potential, soil compaction, soil hydraulic properties, soil organic C (SOC), and soil fertility between biomass removal from WSGs and corn residue removal from rain fed no-till continuous corn on a marginally productive site on a silty clay loam in eastern Nebraska after 2 and 3 years of management. The field-scale treatments were as follows: (i) switchgrass, (ii) big bluestem, and (iii) low-diversity grass mixture [big bluestem, indiangrass, and sideoats grama], and (iv) 50% corn residue removal with three replications. Across years, corn residue removal increased wind-erodible fraction from 41% to 86% and reduced wet aggregate stability from 1.70 to 1.15 mm compared with WSGs in the upper 7.5 cm soil depth. Corn residue removal also reduced water retention by 15% between 33 and 300 kPa potentials and plant-available water by 25% in the upper 7.5 cm soil depth. However, corn residue removal did not affect final water infiltration, SOC concentration, soil fertility, and other properties. Overall, corn residue removal increases erosion potential and reduces water retention shortly after removal, suggesting that biomass removal from perennial WSGs is a desirable alternative to corn residue removal for biofuel production and maintenance of soil ecosystem services.

- **Sindelar, A.J., M.R. Schmer, R.W. Gesch, F. Forcella, C.A. Eberle, M.D. Thom & D.W. Archer. 2015. Winter oilseed production in the U.S. Corn belt: Opportunities and limitations. GCB Bioenergy, 9: 508-524. http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12297/full. (Open Access).**

  Interest from the US commercial aviation industry and commitments established by the US Navy and Air Force to use renewable fuels has spurred interest in identifying and developing crops for renewable aviation fuel. Concern regarding greenhouse gas emissions associated with land-use change and shifting land grown for food to feedstock production for fuel has encouraged the concept of intensifying current prominent cropping systems through various double cropping strategies. Camelina (Camelina sativa L.) and field pennycress (*Thlaspi arvense L.*) are two winter oilseed crops that could potentially be integrated into the corn (*Zea mays L.*)–soybean [(Glycine max (L.) Merr.] cropping system, which is the prominent cropping system in the US Corn Belt. In addition to providing a feedstock for renewable aviation fuel production, integrating these crops into corn–soybean cropping systems could also potentially provide a range of ecosystem services. Some of these include soil protection from wind and water erosion, soil organic C (SOC) sequestration, water quality improvement through nitrate reduction, and a food source for pollinators. However, integration of these crops into corn–soybean cropping systems also carries possible limitations, such as potential yield reductions of the subsequent soybean crop. This review identifies and discusses some of the key benefits and constraints of integrating camelina or field pennycress into corn–soybean cropping systems and identifies generalized areas for potential adoption in the US Corn Belt.

- **Non-refereed Publications with Abstracts**

  - **Mitchell, R.B., K.P. Vogel & M.R. Schmer. 2013. Switchgrass (Panicum virgatum) for biofuel production. Sustainable Ag Energy Community of Practice, eXtension (revised). http://articles.extension.org/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production. (Extension Circular).**

    Switchgrass (Panicum virgatum) is a native warm-season grass that is a leading biomass crop in the US. More than 70-years of experience with switchgrass as a hay and forage crop suggests switchgrass will be productive and sustainable on rain-fed marginal land east of the 100th Meridian. Long-term plot trials and farm-scale studies in the Great Plains and plot trials in the Great Plains, Midwest, South, and Southeast indicate switchgrass is productive, protective of the environment, and profitable for the farmer. Weed control is essential during establishment, but with good management is typically not required again. Although stands can be maintained indefinitely, stands are expected to last at least 10 years, after which time the stand will be renovated and new, higher-yielding material will be seeded on the site. Fertility requirements are well understood in most regions, with about 12 to 14 pounds of N per acre required for each ton of expected yield if the crop is allowed to completely senesce before the annual harvest. Historically, breeding and genetics research has been conducted at a limited number of locations by USDA and university scientists, but the potential bioenergy market has promoted testing by public and private entities throughout the US. Switchgrass is well-suited to marginal cropland and is an energetically and economically feasible and sustainable biomass energy crop with currently-available technology.

  - **Mitchell, R.B., J.J. Volenec & P. Porter. 2013. Test plots show how perennial grasses can be grown for biofuels, eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. http://www.extension.org/pages/68155/test-plots-show-how-perennial-grasses-can-be-grown-for-biofuels#.VRQjJvzF-QU. (Extension Circular).**

Researchers, farmers, and industry representatives across the country are interested in testing the performance of energy crops. Setting up a test plot in your region can be useful in showing producers the potential for growing bioenergy feedstocks on their farms. The test plot can demonstrate best management practices and yield potential as well as how to establish perennial grasses quickly and economically. Additionally, it can demonstrate differences between the forage and bioenergy strains of various perennial grasses. We provide suggestions for establishing and managing your own energy crop demonstration plot.

- **Mitchell, R.B. Establishing and managing perennial grasses for bioenergy. 2013. Proc. 25th Annual Integrated Crop Management Conference, Iowa State University, pp. 49-51. (Proceeding).**

  Switchgrass (Panicum virgatum) is native to every U.S. state east of the Rocky Mountains, is the most advanced herbaceous perennial bioenergy feedstock, and best management practices (BMPs) have been developed for bioenergy production in most agro-ecoregions. Additionally, big bluestem (Andropogon gerardii), indiangrass (Sorghastrum nutans), and sideoats grama (Bouteloua curtipendula) are promising bioenergy feedstocks, either grown as single-species stands or in low-diversity mixtures. Native warm-season grasses have a reputation for being difficult to establish. Historically, these grasses often required 2 or 3 years to establish an acceptable stand. However, advancements in herbicides, cultivar development, and planting equipment have improved establishment dramatically. Today, it is feasible to harvest 50% of the cultivar's yield potential after frost in the seeding year. By the end of the first full growing season after seeding, it is feasible to produce and harvest 75% to 100% of the cultivar's yield potential. If precipitation is adequate, warm-season grasses are readily established when quality seed of adapted cultivars are used in conjunction with the proper planting date, seeding rate, seeding method, and weed control.

- **Mitchell, R.B. & M.R. Schmer. Switchgrass for biomass energy. 2014. Proc. Nebraska Crop Production Clinic, University of Nebraska, pp. 13-16. (Proceeding).**

  Switchgrass (Panicum virgatum) is a native warm-season grass and is the model herbaceous perennial biomass energy feedstock for the USA. More than 75-years of experience confirm that switchgrass will be productive and sustainable on rain-fed marginally-productive cropland east of the 100th meridian. The development of best management practices for biomass energy production have accelerated establishment and increased production efficiency. With adequate precipitation, switchgrass is readily established when quality seed of adapted cultivars is used in conjunction with the proper planting date, seeding rate, seeding method, and weed control. Advancements in herbicides, cultivar development, and planting equipment make it feasible for stands to reach 75% to 100% of the cultivar's yield potential 15 to 18 months after planting. Long-term studies indicate switchgrass stands can be maintained indefinitely, but stands are expected to be renovated to higher yielding material after about 10 years. Switchgrass requires about 10 pounds of N per acre for each ton of expected yield if the crop is harvested once annually after dormancy. New biomass-specific cultivars like 'Liberty' produce up to 8 tons of biomass per acre and are well-suited to marginally-productive cropland in the Great Plains and Midwest.

- **Mitchell, R.B., K.P. Vogel & M. Schmer. 2013. Growing switchgrass for biofuels, Fact Sheet No. 3, CenUSA Bioenergy, Iowa State Univ., Ames, IA. http://articles.extension.org/sites/default/files/Factsheet3.GrowingSwitchgrassforBiofuels.pdf . (Extension Circular).**

  Contrary to popular belief, switchgrass is not a new or novel crop but has more than 75 years of research and farming experience. Currently available plant materials and production practices can reliably produce five tons per acre in the central Great Plains and Midwest. New cultivars and management practices will significantly increase yields similar to the yield increases achieved in corn in the last 30 years. The availability of adequate acres of agricultural land and the profit potential provided to farmers for growing switchgrass in a region will determine the success of growing switchgrass for biomass energy. Production practices and plant materials are available to achieve sustainable and profitable biomass production, for both farmers and bio-refineries, to help meet the energy requirements of the nation and reduce our dependence on foreign oil.

- **Mitchell, R.B. & S. Harlow. 2013. Switchgrass stand establishment: key factors for success. eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. (http://www.extension.org/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success#.VRQhzPzF-QU). (Extension Circular).**

  Switchgrass (Panicum virgatum L.) is not difficult to establish if precipitation is timely and four key management practices are followed. First, purchase certified seed with excellent seed lot quality. Second, develop a good firm seedbed. Third, plant the seed at the proper time, depth, and rate. Finally, control weeds during the planting year. While money spent on good-quality seed and weed control will likely result in a higher per acre cost for establishment, the reward is rapid establishment of a productive stand with lower costs per ton of biomass over the life of the stand. Successful stand establishment is critical to the long-term economic viability of switchgrass stands. Farmers in regions with good soils and favorable precipitation should be able to harvest switchgrass after frost in the planting year. Using bioenergy-specific cultivars such as 'Liberty' should produce 3-4 tons per acre in the planting year and 6-8 tons per acre in subsequent years.

- **Mitchell, R.B., B. Anderson & D. Redfearn. 2014. Switchgrass for forage and bioenergy. Proc. 2014 Nebraska Grazing Conference, Univ. of Nebraska, 48-53.**

Switchgrass is a native warm-season grass that has been used for hay, forage, and conservation purposes for decades and switchgrass research in Nebraska has been ongoing since 1936. Recently, switchgrass has been identified as a model perennial grass for bioenergy in the Great Plains and Midwest. Since 1990, research in Nebraska on marginally productive cropland has demonstrated that best management practices will maintain productive, profitable, and sustainable switchgrass stands for more than 15 years on marginally productive cropland in the eastern half of Nebraska. Additionally, switchgrass can provide quality forage for grazing after cool-season pastures have been utilized. Switchgrass must be properly managed to maintain productive stands and quality forage. Poor management will cause productivity and stand persistence to decline, and forage quality will be poor. With proper management, switchgrass can provide both forage and biomass to mitigate risk and diversify potential use.

- **Mitchell, R.B. & S. Harlow. 2014. Control weeds in switchgrass (Panicum virgatum L.) grown for biomass, eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. (http://www.extension.org/pages/70396/control-weeds-in-switchgrass-panicum-virgatum-l-grown-for-biomass#.VRQfW_zF-QU). (Extension Circular).**

  It's critical to control weeds before and during establishment of switchgrass stands grown for biomass, because weeds are the most frequent reason a stand fails. You should have few problems with weeds in established stands. Control weeds in the planting year with mowing and applying pre- and post-emergent herbicides, if permitted in your state.

- **Mitchell, R.B. & S. Brown. 2015. Guidelines to growing perennial grasses for biofuel and bioproducts. eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. http://articles.extension.org/sites/default/files/Cenusa_Guide_to_Perennials.pdf. (Extension Circular).**

  Switchgrass, big bluestem, and warm-season grass mixtures provide numerous benefits. Existing field equipment, herbicides, and cultivar improvement promote rapid establishment in the planting year. These grasses typically produce a harvestable yield after frost in the planting year and are near full production in the year after planting if moisture is adequate. Typical baled yield at the field scale after establishment exceeds 5 tons per acre in areas east of the arid section of the country. These grasses can be productive for 10 years or longer with good management. Guidelines are provided on best management practices for establishing and managing perennial grasses for multiple uses.

- **Jacobs, K., R. Mitchell & C. Hart. 2015. To grow or not to grow: A tool for comparing returns to switchgrass for bioenergy with annual crops and CRP, eXtension Fact Sheet, CenUSA Bioenergy, Iowa State Univ., Ames, IA. (http://cenusa.iastate.edu/switchgrass-production-tool. (Extension Circular).**

The decision to grow perennial grasses for bioenergy has long-term land use implications. Perennial grasses like switchgrass must be harvested annually for 5 to 10 years to be economically feasible. Typically, the decision comes down to which production system has the greatest economic benefit. Producers need a tool to compare the potential economic return of switchgrass in relation to other crop production systems. This decision tool is intended to be a guide for producers considering switchgrass for biomass. The production estimates, returns, and costs provided are based on the best available information for switchgrass production. When evaluating switchgrass as a production alternative, producers should consider their specific field characteristics and productive capabilities and adjust, as necessary, the default values supplied.

- **CenUSA Fact Sheets**

  - **Guidelines to Growing Perennial Grasses for Biofuel and Bioproducts.** http://articles.extension.org/sites/default/files/Cenusa_Guide_to_Perennials.pdf.

  - **Guidelines to Growing Perennial Grasses for Biofuel and Bioproducts.** https://cenusa.iastate.edu/files/guidelines_to_growing_perennial_grasses_copy.pdf.

  - **Switchgrass (Panicum virgatum L) Stand Establishment: Key Factors for Success.** http://www.extension.org/pages/68050/switchgrass-panicum-virgatum-l-stand-establishment:-key-factors-for-success.

  - **Control Weeds in Switchgrass (Panicum virgatum L.) Grown for Biomass.** http://articles.extension.org/pages/70396/control-weeds-in-switchgrass-panicum-virgatum-l-grown-for-biomass.

  - **Switchgrass Stand Establishment: Key Factors for Success.** http://articles.extension.org/sites/default/files/FactSheet4.SwitchgrassStandEstablishment.pdf.

  - **Switchgrass (Panicum virgatum) for Biofuel Production.** http://articles.extension.org/pages/26635/switchgrass-panicum-virgatum-for-biofuel-production.

  - **Test Plots Show How Perennial Grasses Can Be Grown for Biofuels.** http://www.extension.org/pages/68155/test-plots-show-how-perennial-grasses-can-be-grown-for-biofuels.

  - **Growing Switchgrass for Biofuels.** http://articles.extension.org/sites/default/files/Factsheet3.GrowingSwitchgrassforBiofuels.pdf.

- **CenUSA Videos**

- **Harvesting Native Grass for Biofuel Production.** Rob Mitchell (USDA-ARS) discusses the potential of switchgrass in biofuel production while demonstrating harvesting equipment usage. https://www.youtube.com/watch?v=ybDGWJa6pzc. [2:57]

- **Switchgrass Establishment, Weed Control, and Seed Quality.** Rob Mitchell (USDA-ARS) discusses switchgrass establishment, weed control, and seed quality at the March 20, 2012, CenUSA-Extension Switchgrass Establishment Field Day in Mead, Nebraska. https://www.youtube.com/watch?v=7xVFMqBvCvQ. [30:53]

- **No-Till Drill Calibration Training.** Rob Mitchell (USDA-ARS) discusses how to calibrate the Truax No-Till Drill Seeder at the CenUSA Switchgrass Establishment Field Day (Mar. 20, 2012) held in Mead, Nebraska. https://www.youtube.com/watch?v=7TPLfWLkd_U. [20:05]

- **Switchgrass Planting Practices for Stand Establishment**. Rob Mitchell (USDA-ARS) walks you through the keys to successful switchgrass establishment. https://www.youtube.com/watch?v=vwBQ3aYpfmM. [5:17]

- **Harvesting Native Grass for Biofuel Production**. Rob Mitchell (USDA-ARS) discusses the potential of switchgrass in biofuel production while demonstrating harvesting equipment usage. https://www.youtube.com/watch?v=ybDGWJa6pzc. [2:57]

- **Commercialization Update: Opportunities for Perennial Biofeedstocks**. Rob Mitchell (USDA-ARS) discusses commercialization opportunities for switchgrass and other perennial biofeedstocks. https://www.youtube.com/watch?v=jtrGuZ-DDAs. [2:18]

- **Outreach Activities**

  - Switchgrass establishment, weed control, herbicides, and seed quality, Switchgrass Establishment Field Day, University of Nebraska, Univ. of Nebraska ARDC. 2012, Mar. 20. Ithaca, NE.

  - Grassland drill calibration, Switchgrass Establishment Field Day, University of Nebraska, Univ. of Nebraska ARDC. 2012. Mar. 20. Ithaca, NE.

  - Switchgrass agronomics, economics, and logistics, Switchgrass I, Switchgrass Genomics Executive Committee and the Samuel Roberts Noble Foundation. 2012. Mar 27. Ardmore, OK.

  - Grasslands for bioenergy, Nebraska Range Short Course, Univ. of Nebraska and Chadron State College. 2012. June 20. Chadron, NE.

  - Switchgrass for bioenergy, Univ. of Nebraska Crop Management Diagnostic Clinic. 2012: Aug. 30. Ithaca, NE.

- Establishing and managing perennial grasses for bioenergy, Integrated Crop Management Conference. 2012. Ames, IA. 29 Nov.

- Perennial grass storage and agronomics, Roadmap to Commercialize Thermochemical Biofuels and Bioproducts Processing in the Midwest Workshop. 2012. Ames, IA. 11 Dec.

- The pros and cons of using native perennial grasses for biofuel feedstocks, Invasive Potential of Biofuel Crops Symposium, North Central Weed Science Society Meeting. 2012. St. Louis, MO. 13 Dec.

- The feasibility of switchgrass for bioenergy, and Establishment and management of switchgrass for bioenergy, Northwest Certified Crop Advisors Workshop. 2013. St. Joseph, MO. 23 Jan.

- Establishing and managing perennial grasses for bioenergy, Heartland Regional Water Workshop. 2013. Feb22. Nebraska City, NE.

- Sustainable production of switchgrass for bioenergy in the Great Plains and Midwest, 9th Energy Biosciences Institute Bioenergy Feedstocks Symposium. 2013. University of Illinois, Champaign, IL. 22 Aug.

- Perennial Grasses: A Productive, Profitable, and Protective Strategy for Marginally Productive Cropland, Advanced Biofuels Conference & Expo. 2013. Omaha, NE. 12 Sep.

- Establishing and managing perennial grasses for bioenergy, 25th Annual Integrated Crop Management Conference. 2013. Ames, IA. 4 Dec.

- Switchgrass for biomass energy, Nebraska Crop Production Clinics, 5 dates and locations throughout Nebraska. 2014. Univ. of Nebraska. 9-23 Jan.

- Bioenergy research update, Abengoa Advanced Biofuels Project Meeting, 2014. Grand Island, NE. 22 Jan.

- Perennial grasses for bioenergy demonstrations, Vermeer Manufacturing Global Pavilion. 2014. Pella, IA. 31 Mar.

- Example Application of the Feedstock Readiness Level Tool: Perennial Grasses in the Great Plains & Midwest, USDA/DOE Biomass Research and Development Initiative Technical Advisory Committee, invited by the office of the Secretary of Agriculture. 2014. Washington, D.C. 5 Jun.

- Grasslands for bioenergy, Nebraska Range Short Course, Univ. of Nebraska and Chadron State College. 2014. Chadron, NE. 18 Jun.

- Marginal lands in the Great Plains and Midwest, Incorporating Bioenergy in Sustainable Landscape Designs Workshop Two: Agricultural Landscapes. 2014. Argonne National Lab, Argonne, IL. 24-26 Jun.

- Perennial Grass Field Day. We hosted the American Seed Trade Association on a field day addressing all aspects of perennial grasses for bioenergy and forage. The field day was attended by 60 seed professionals. 2014. Jul. 24. Univ. of Nebraska, Ithaca, NE.

- Switchgrass for forage and biomass, Nebraska Grazing Conference 2014. Univ. of Nebraska, Kearney, NE. 13 Aug.

- Establishing and managing perennial grasses for bioenergy, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Beaver Crossing, NE. 19 Aug.

- Planting and harvesting perennial grasses, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Beaver Crossing, NE. 19 Aug.

- Establishing and managing perennial grasses for bioenergy, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Humboldt, NE. 20 Aug.

- Planting and harvesting perennial grasses, Switchgrass Bioenergy Field Day, Univ. of Nebraska. 2014. Humboldt, NE. 20 Aug.

- Forage and bioenergy research update, Nebraska Plant Materials Committee. 2014. Lincoln, NE. 21 Aug.

- Perennial grass for bioenergy, Vermeer Forage and Biomass Dealer Meeting, Vermeer Mfg. 2014. Pella, IA. 4 Sep.

- New switchgrass developed specifically for bioenergy use, Brownfield Ag News radio (more than 350 station affiliates). 2014. 29 Aug.

- Potential of 'Liberty' switchgrass, USDA Weekly Radio Features. 2014. 5 Sep.

- New switchgrass variety may serve a dual purpose, USDA Weekly Radio Features. 2014. 5 Sep.

- Switchgrass Field Day, Pure Nebraska, a TV news program on KOLN/KGIN TV and CBS affiliates, first aired 2014. 9 Sep.

- Native perennial grasses for bioenergy, Association of Fish & Wildlife Agencies Biofuel Working Group, North American Wildlife and Natural Resources Conference. 2015. Omaha, NE. 13 Mar.

- Recent advancements in switchgrass and other perennial grasses for bioenergy, ABFC **Advanced Bioeconomy Feedstocks (ABFC2015) Conference**. 2015. **New Orleans, LA. 9-10 Jun.**

- Feedstock Readiness Level Tool Update, ABFC **Advanced Bioeconomy Feedstocks (ABFC2015) Conference**. 2015. **New Orleans, LA. 9-10 Jun.**

- 'Liberty' switchgrass, interview with Grant Gerlock, NET Radio, featured on the 10 June, 2015 NPR report, "EPA, farmers divided over proposed ethanol standards" as well as the printed story on the prospects of using perennial grasses for ethanol (http://insideenergy.org/2015/05/28/next-generation-fuels-stuck-in-neutral/). 2015. Mead, NE.

- Establishing perennial grasses for displays at the Nebraska State Fair and Husker Harvest Days. May 2015.

- Environmental benefits of perennial grasses, Eureka! 2016, Univ. of Nebraska Extension Conference, 2016. Lincoln. NE. 16 Mar.

- Evolution and focus of the USDA Central-East Regional Biomass Research Center, GAO Bioenergy Review, USDA-ARS-NLAE. 2016. Ames, IA. 13 Apr.

- Invited Conference Welcome & Introduction: Back to the future: a perspective from the central USA, World Bioenergy Congress & Expo. 2016. Rome, Italy. 16 Mar.

- Invited Presentation: Herbaceous perennial feedstocks for marginally-productive landscapes in the central USA, World Bioenergy Congress & Expo. 2016. Rome, Italy. 13 Jun.

- Invited Presentation: Commercialization opportunities for herbaceous perennial feedstocks, Northeast Woody/Warm-Season Biomass Consortium. 2016. State College, PA. 26-27 Jul.

- Invited Presentation: Central-East Regional Biomass Research Center, Inaugural DOE National Laboratory/USDA Research Collaboration Meeting on Bioenergy and Biobased Products, NREL. 2016. Golden, CO. 23-24 Aug.

- Invited Presentation & Workshop Participant: How to quantify the costs and monetize the benefits of bioenergy crops. Bioenergy Solutions to Gulf Hypoxia Workshop, Argonne National Lab. 2016. Washington, DC. 30-31 Aug.

- Guest lecture: Bioenergy research in the central USA, CPSC 415, Bioenergy Crops. 2016. Urbana, IL. 13 Oct.

- Invited Presentation: Grassland research updates, Center for Grassland Studies Citizens Advisory Council Meeting. 2016. Lincoln, NE. 21 Oct.
- Switchgrass stand establishment, cultivar development and acreage needs for a viable biofuel industry, CenUSA Bioenergy webcast. Purdue University Extension. 2017. Jul. https://vimeo.com/223392567.

- **Students Mentored**

Drs. Jin, Schmer, and Mitchell mentored the following undergraduate student interns for 10 weeks each summer as part of the USDA-NIFA-CAP funded CenUSA project, 2012-present.

- Kirsten Paff, Purdue University, 13 June - 3 August 2012.
- Chris Anderson, University of Idaho, 13 June - 3 August 2012.
- David Carlson, University of Minnesota, 11 June - 3 August 2013.
- Haley Chatelaine, Benedictine College, 2 June - 30 July 2014.
- Joel Bauer, Iowa State University, 2 June - 30 July 2014.
- Jason Hambrick, University of Missouri, 2 June - 30 July 2014.
- Julie Juarez, University of California-Berkeley, 2 June - 30 July 2014.
- Tracy Campbell, University of Missouri, 1 June - 30 July 2015.
- Rachael Dennis, University of Miami, 1 June - 30 July 2015.
- Phil Jelcic, University of Illinois, 1 June - 30 July 2015.
- Alex Ryan, Clemson University, 1 June - 30 July 2015.
- Sory Soumare, Des Moines Area Community College, 1 June – 30 July 2015.
- Kelvin Wong, University of Minnesota, 1 June - 30 July 2015.
- Kevin Wu, University of Houston, 1 June - 3 August 2016.
- Michael Calfe, Clemson University, 1 June - 3 August 2016.
- Emma Palermo, Syracuse University, 1 June - 3 August 2016.

- **Additional Collaborations**

ARS-Lincoln provided seed, establishment guidelines, and management guidelines for most of the systems analysis plots, factor analysis plots, and on-farm demonstration sites established for CenUSA. ARS-Lincoln planted on-farm demonstration sites near Beaver Crossing and Humboldt, Nebraska, a demonstration site at Vermeer Manufacturing near Pella, IA, and a wetland site in eastern North Dakota. ARS-Lincoln provided feedstock to a number of collaborators including ADM, Renmatix, and Kimberly-Clark for evaluation through proprietary processes. Semi-loads of large round bales of switchgrass were provided to Iowa State University for feedlot-scale beef cattle feeding trials. Feedstock samples were processed and evaluated for a number of collaborators to determine treatment effects on compositional characteristics using NIRS analysis.

cenusa bioenergy

Quarterly Progress Report

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

October 2016

Agriculture and Food Research Initiative Competitive Grant

No. 2011-68005-30411

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Tables

Figures

Exhibits

Exhibit 1. Abstracts - Manuscripts submitted to the Journal of the American Water Resources Association

- Kling, C.L., I. Chaubey, C. Raj, P.W. Gassman & Y. Panagopoulos. 2016. Policy Implications from Multi-Scale Watershed Models of Biofuel Crop Adoption across the Corn Belt. Journal of the American Water Resources Association (accepted).
- Cibin, R, I. Chaubey, R.L. Muenich, K.A. Cherkauer, P. Gassman, C. Kling & Y. Panagopoulos. 2016. Ecosystem Services Evaluation of Futuristic Bioenergy-based Land Use Change and Their Uncertainty from Climate Change and Variability. Journal of the American Water Resources Association (accepted).
- Gassman, P.W., A. Valcu, C.L. Kling, Y. Panagopoulos, C. Raj, I. Chaubey, C.F. Wolter & K.E. Schilling. 2016. Assessment of Bioenergy Cropping Scenarios for the Boone River Watershed in North Central Iowa, United States. Journal of the American Water Resources Association (revised and resubmitted).
- Panagopoulos, Y., P.W. Gassman, C.L. Kling, R. Cibin & I. Chaubey. 2016. Assessment of Large-scale Bioenergy Cropping Scenarios for the Upper Mississippi and Ohio-Tennessee River Basins. Journal of the American Water Resources Association (first review received; revisions being performed).

LEGAL NOTICE

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

The opinions expressed in this report do not necessarily reflect those of Iowa State University, the USDA-NIFA, Purdue University, United States Department of Agriculture-Agricultural Research Service, University of Minnesota, University of Nebraska, Lincoln, University of Vermont, or the University of Wisconsin and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it.

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

First Quarter Report: August 1, 2016 – October 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. Becky Staedtler (ISU Bioeconomy Institute) provides assistance with project financial matters.

- **CenUSA Bioenergy Advisory Board**

  Our Advisory Board continues to be engaged in the project and provide feedback to the project director and leadership team

- **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 bimonthly 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.

Germplasm to Harvest

Objective 1. Feedstock Development

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

1. **Planned Activities**

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

- ✓ Conduct fall biomass harvests on field trials.
- ✓ Harvest seed on new polycrosses of selected switchgrass and big bluestem populations.

- **Feedstock Quality Analysis (Bruce Dien – ARS Peoria and Akwasi Boateng – ARS Wyndmoor)**
  - ✓ Begin compositional analysis on 'Liberty' switchgrass samples harvested at various heights at two different maturities.
  - ✓ Finalize manuscripts on field studies looking at the impact fertilizer rate and type and harvest time has on conversion, biochemical and thermochemical.

- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Finalize resistance-screening studies.
  - ✓ Finalize arthropod survey publication.
  - ✓ Complete writing of a paper describing differential resistance to rust disease among switchgrass populations.

2. **Actual Accomplishments**

- **Breeding and Genetics – Lincoln, Nebraska and Madison, Wisconsin (Mike Casler and Rob Mitchell)**
  - ✓ Completed all biomass harvests and data collection
  - ✓ Prepared plots for winter

- **Feedback Quality Analysis (Bruce Dien and Akwasi Boateng)**
  - ✓ Conducted data analysis of 'Liberty' switchgrass and prepared one abstract for presentation.

- **Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Completed analysis of all sticky traps in Nebraska and Wisconsin.
  - ✓ Completed all data collection for 2016 growing season.

3. **Explanation of Variances**

None to report.

4. Plans for Next Quarter

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**
  - ✓ Collect all 2016 data from 13 locations in field-trial network.
  - ✓ Conduct final data analyses.
- **Feedstock Quality Analysis (Bruce Dien and Akwasi Boateng)**
  - ✓ Conduct laboratory analyses of 'Liberty' samples in comparison to control varieties.
- **Pathology and Entomology (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Compile the data for 2016.
  - ✓ Complete analysis of the electronic feeding monitoring.

5. Publications / Presentations/Proposals Submitted

Dien, B., P. Slininger, J. Quarterman, R. Mitchell, K. Vogel & M. Casler. (2016). Switchgrass for ethanol and lipid production. Sustainable Packaging Symposium. University of Massachusetts. 12-13 Dec.

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**
  - **Planned Activities**

    The team has completed its activities and is preparing manuscripts for publication.

    - ✓ Fidel, R.B. D.A. Laird & T.B. Parkin. 2017. Impact of six lignocellulosic biochars on C and N dynamics of two contrasting soils. GCB Bioenergy (Early View). doi.

10.1111/gcbb.12414. (Open Access: http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12414/full#references).

- ✓ Fidel, R.B., D.A. Laird, M.L. Thompson & M. Lawrinenko. 2017. Characterization and quantification of biochar alkalinity. Chemosphere 167:367-373.

- **Purdue University**

The first quarter was spent harvesting plots from the 2016 growing season and processing (drying, grinding) samples for analysis. Yield results are available including preliminary statistical analyses.

- **Table 1. Yield (kg DM/ha) responses of Shawnee switchgrass to phosphorus (P) and potassium (K) fertilization at the Throckmorton Purdue Ag Center**. Plots that had previously been in alfalfa production (1997-2005) and during that time annually received five rates of K fertilizer ranging from 0 to 400 kg K/ha and four rates of P fertilizer ranging from 0 to 75 kg P/ha. These contrasting fertilizer application rates created large differences in soil test P and K. Shawnee switchgrass was over-seeded into plots in 2007. Plots were harvested in mid-October of 2016. Analysis of variance revealed that the P x K interaction and the P main effects were not significant. However, the main effect of K was significant (P=0.01) with biomass yield being reduced at the highest K rate.

Table 1. Yield (kg DM/ha) responses of Shawnee switchgrass to phosphorus (P) and potassium (K) fertilization at the Throckmorton Purdue Ag Center.

	K Fertilizer, kg K/ha					
P Fertilizer, kg P/ha	0	100	200	300	400	P-rate Mean
0	6660	6487	6129	6583	5231	6218
25	6646	6351	5727	6650	5941	6263
50	6049	5669	6129	6070	5582	5900
75	5799	5857	5793	6322	5352	5825
K-rate Mean	6289	6091	5944	6406	5527	

- **Table 2. Yield (kg DM/ha) response of Shawnee switchgrass to nitrogen (N), phosphorus (P) and potassium (K) fertilization at the Throckmorton Purdue Ag Center**. Plots had previously been in alfalfa production (1997-2005) and during that time annually received two rates of K fertilizer (0, 400 kg K/ha) and two rates of P fertilizer (0, 75 kg P/ha). These contrasting fertilizer application rates created large differences in soil test P and K. Shawnee switchgrass was over-seeded into plots in 2007 and fertilized with four N rates ranging from 0 to 150 kg N/ha/year. Plots were harvested in mid-October of 2016. Analysis of variance revealed that the N x P x K interaction was not significant (*P*=0.15).

Table 2. **Yield (kg DM/ha) response of Shawnee switchgrass to nitrogen (N), phosphorus (P) and potassium (K) fertilization at the Throckmorton Purdue Ag Center**

	0 K		400 K	
N Fertilizer, kg N/ha	**0 P**	**75P**	**0 P**	**75 P**
0	6175	5875	6347	6439
50	5367	5352	6507	5944
100	5540	6047	5885	5607
150	5645	5455	4979	6336

- **Table 3. Yield (kg DM/ha) response of *Miscanthus x giganteus* (IL clone) to nitrogen (N), phosphorus (P) and potassium (K) fertilization at the Throckmorton Purdue Ag Center**. Plots had previously been fallowed and rhizomes of Miscanthus were transplanted into the site in 2008. Plots were fertilized with four N rates ranging from 0 to 150 kg N/ha/year beginning in 2010. These N rate treatment plots were split with one-half of the plot receiving 300 kg K and 75 kg P per hectare annually (300K/75P) and the other half of the plot not receiving K and P (0K/0P). Plots were harvested in mid-October of 2016. Analysis of variance revealed that the N x K/P was not significant (*P*=0.67). The main effect of N also was not significant (*P*=0.43) nor was the K/P fertilizer main effect significant (*P*=0.22).

Table 3. **Yield (kg DM/ha) response of *Miscanthus x giganteus* (IL clone) to nitrogen (N), phosphorus (P) and potassium (K) fertilization at the Throckmorton Purdue Ag Center.**

	K and P Fertilizer		
N Fertilizer	0K/0P	300K/75P	Mean
0	21930	25026	23478
50	23419	22715	23067
100	24119	27043	25581
150	24577	25611	25094
Mean	23511	25099	

- **Table 4. Yield (kg DM/ha) of perennial grass biomass systems are the Southern Purdue Ag Center (SIPAC), the Northeast Purdue Ag Center (NEPAC) and the Throckmorton Purdue Ag Center (TPAC)**. Plots of Liberty switchgrass, the IL clone of *Miscanthus x giganteus*, and a 50:50 mix of Scout Indiangrass and Bonanza big bluestem were planted in 2011. Plots of switchgrass and *Miscanthus* were fertilized with 50 kg N/ha/year beginning in 2012. Plots were harvested in mid-October of 2016. Analysis of variance revealed that both species and site main effects were significant (P<0.05) with *Miscanthus* having the greatest biomass production and the TPAC location having the highest yields.

Table 4. Yield (kg DM/ha) of perennial grass biomass systems are the Southern Purdue Ag Center (SIPAC), the Northeast Purdue Ag Center (NEPAC)m and the Throckmorton Purdue Ag Center (TPAC).

	Perennial Species			
Location	Switchgrass	*Miscanthus*	Indiangrass Big Bluestem	Location Mean
SIPAC	6313	22228	3552	10698
NEPAC	8601	19034	4543	10726
TPAC	9673	24153	5979	13268
Species Mean	8195	21805	4691	

- **Sustainability Analysis at Purdue's Water Quality Field Station**.

  As in previous years' biomass yields also differed among systems at the Water Quality Field Station. Yields effectively doubled from the unfertilized prairie (2772±238 kg/ha) to Shawnee switchgrass (5223±499 kg/ha) to sorghum (9587±12334 kg/ha) that was similar to maize (11431±412) to the highest biomass yields of Miscanthus (20382±1243).

- **Soil Water Assessment Tool Modeling (Indrajeet Chaubey)**

  ✓ A calibrated and validated SWAT model for Upper Mississippi River Basin (UMRB) was used to evaluate the impacts of climate change and variability, including impacts of drought on UMRB water quality, crop yield and hydrology.

  ✓ We worked with Objective 4 (Iowa State University) to develop common bioenergy production scenarios and analyzed impacts of those scenarios on hydrology, water quality and environmental sustainability. We submitted four manuscripts to the journal of American Water Resources Association. Two of the manuscripts have been accepted for publication (Cibin et al., Kling et al.).

- **University of Minnesota**

  - **Becker Location**

    ✓ We completed our post-frost harvest on October 13, 2016. Samples have been weighed and dried, and yield data are being compiled.

Fig. 1. Carter harvest at Becker, 10-13-16.

  - **Lamberton.**

    ✓ We completed our post-frost harvest on October 26, 2016. Samples have been weighed and dried, and yield data are being compiled.

Fig. 2 Carter harvest at Lamberton, 10-26-16.

  - **Additional Activities.**

Anne Sawyer gave a talk at the SSSA International Annual Meeting in Phoenix regarding yield and N uptake/removal at both locations. She discussed three years of post-establishment data at Becker and two years of post-establishment data at Lamberton. Anne also presented a poster about our work at a *Buffer Science and Design Symposium* at the University of Minnesota in September 2016.

In 2015, Minnesota passed a law mandating that all public ditches and water bodies have perennial crop buffers to a certain minimum distance, which varies by water body type. We are also in the process of preparing a manuscript based on biomass yields and N uptake/removal at both locations, but are going to incorporate the final 2016 yield data prior to submission. A manuscript is in preparation describing bacterial community composition and function in the rhizosphere of 'Shawnee', 'Sunburst' and 'Liberty' switchgrass as a function of N rate in the near-anthesis harvest. We also harvested plots in October 2016 for our study of bacterial and fungal community composition in the switchgrass rhizosphere as a function of cultivar and P rate on low-P soils.

- **USDA-ARS, Lincoln**
  - **Actual Accomplishments**
    - ✓ Monitored growth on all plots.
    - ✓ Sampled greenhouse gases (GHG).
    - ✓ Completed perennial grass anthesis harvest.
  - **Current Actions**
    - ✓ **Factor Analysis Plots**
      - ➢ The plots continue to be monitored.
      - ➢ Yield data for 2012-2015 is being summarized.
      - ➢ Samples collected in 2012, 2013, 2014, & 2015 have been processed and are being scanned and predicted.
    - ✓ **System Analysis Plots**
      - ➢ Samples collected in 2012, 2013, 2014, & 2015 are being scanned and predicted.
      - ➢ Samples have been sent for mineral analysis.
      - ➢ GHG samples from 2013-2015 are being summarized.
      - ➢ VOM and elongated leaf height data are being summarized.

- ➢ Anthesis harvest for the harvest height and harvest date study has been completed.
- ➢ Field-scale plots are being prepared for harvest.

- ✓ The Crop/Livestock/Bioenergy Production System Demonstration site in eastern Nebraska was leveraged to get additional funding through the new SDSU NIFA-CAP to increase sampling intensity and graze this site in 2016-2019. Fields were monitored.

- **Plans for Next Quarter**
  - ✓ Complete corn harvest.
  - ✓ Plant triticale cover crop.
  - ✓ Complete post-frost harvests.
  - ✓ Scan and predict biomass samples forwarded from other locations.
  - ✓ Finalize the scanning & predicting of 2012, 2013, 2014, & 2015 Nebraska biomass samples.
  - ✓ Analyze and summarize field data.
  - ✓ Collect samples for GHG emissions at scheduled intervals.
  - ✓ Submit manuscripts on CenUSA projects.

▪ **USDA-ARS, Madison**

- **Planned Activities**
  - ✓ Complete harvesting of 2016 biomass.
  - ✓ Prepare manuscripts.
- **Actual Accomplishments**
  - ✓ Completed harvesting biomass for 2016, the last year of production.
  - ✓ Began writing two manuscripts.
- **Plans for Next Quarter**
  - ✓ Finish two manuscripts and submit to journals.
  - ✓ Complete 2016 final data analysis for another manuscript.

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

  - **Proposal Submitted**

    Leveraged CenUSA research sites to garner additional funding from the North-Central SunGrant on a project titled *Growing Bioenergy Crops on Marginally Productive Croplands: Implications on Erosion and Water Quality Parameters*.

  - **Publications, Presentations and Posters**

✓ Bakshi, S., D.M. Aller, D.A. Laird & R. Chintala, 2016. Comparison of the Physical and Chemical Properties of Laboratory- and Field-Aged Biochars. J. Environ. Qual. 45(5):1627-1634. https://www.ncbi.nlm.nih.gov/pubmed/27695754. doi:10.2134/jeq2016.02.0062. (Abstract).

✓ Fidel, R.B. D.A. Laird & T.B. Parkin. 2017. Impact of six lignocellulosic biochars on C and N dynamics of two contrasting soils. GCB Bioenergy (in Press).

✓ Fidel, R.B., D.A Laird, M.L. Thompson, and M. Lawrinenko. 2017. Characterization and quantification of biochar alkalinity. Chemosphere 167:367-373.

✓ Mitchell et al. 201X. Perennial warm-season grasses for producing biofuel and enhancing soil properties: an alternative to corn residue removal. GCB Bioenergy.

✓ Rogovska, N., D.A. Laird, and D.L. Karlen. 2016. Corn and Soil Response to Biochar Application and Stover Harvest. Field Crops Res. 187:96-106. doi: 10.1016/j.fcr.2015.12.013.

✓ Sawyer, A. E., C.J. Rosen, J.A. Lamb & C.C. Sheaffer. 2016. Switchgrass and Mixed Perennial Biomass Production on Two Marginally Productive Soils as Affected by Nitrogen Fertility and Harvest Management. Presented at ASA, CSSA, SSSA International Annual Meetings, Phoenix, AZ. 9 Nov. https://scisoc.confex.com/scisoc/2016am/webprogram/Paper99966.html.

✓ Sawyer, A., C. Rosen, J. Lamb & C. Sheaffer. 2016. Biomass plantings for buffers: Switchgrass and mixed native perennial yield as a function of nitrogen and harvest regime. Buffer Science and Design Symposium University of Minnesota, St. Paul MN. 16 Sep. https://docs.google.com/document/d/1aXEYHh0FGRi4XRqJMXXQj6SeD9srMq5VB2sDmxVJK_g/edit.

- ✓ Serapiglia, M.J., A.A. Boateng, D.K. Lee & M.D. Casler. 2016. Switchgrass crop management can impact biomass yield and nutrient content. BioEnergy Res. 56(4):1970-1980. doi:10.2135/cropsci2015.08.0527

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**

   Research activities planned included:

   - Completion and finalization 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.

2. **Actual Accomplishments**

   - Two journal papers have been accepted and published in the *Journal of Applied Energy* and the *Journal of Agricultural and Forest Meteorology*.
   - Four drying rate models were also finalized to predict the moisture change in switchgrass based on environmental conditions and swath densities. These models were developed for predicting moisture change in day conditions and for night conditions at different maturity stages. During day time conditions in both maturity stages, solar radiations and vapor pressure deficit (VPD) were positively correlated with drying rate whereas, wind speed and swath density were negatively correlated. During night conditions in both maturity stages, VPD was positively correlated and swath density was negatively correlated with drying rate. However, the effect of wind speed was positive in seed developed stage and negative in seed shattering and seed shattered stage of maturity. Moisture content predicted by models were in good agreement with the moisture change observed in the experimental field drying studies.
   - 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

- Development and validation of biomass "drying prediction models" to predict relative increase in biomass moisture levels during a rainfall event and subsequent drying profile after the re-wetting of biomass materials. This will require additional laboratory testing that included re-wetting events.
- Continued development and evaluation of prototype real-time biomass moisture sensor for switchgrass and corn stover.

5. Publications, Presentations, and Proposals Submitted

Khanchi, A. & S.J. Birrell, 2017. Drying models to estimate moisture change in switchgrass and corn stover based on weather conditions and swath density. Agricultural and Forest Meteorology. 237-238:1-8. (Accepted Jan, 2017, available online: http://dx.doi.org/10.1016/j.agrformet.2017.01.019).

- Sharma, B., S. Birrell & F.E. Miguez. 2017. Spatial modeling framework for bioethanol plant siting and biofuel production potential in the U.S. Applied Energy, 191:75–86.

University of Wisconsin

1. Planned Activities

Our efforts in this quarter were to include:

- Complete field evaluation of the experimental high-density baler in switchgrass and corn stover.
- Compress large square bales of switchgrass and corn stover and quantify the pressure-density relationship.
- Continue work on twine tension for large square bales.
- Conduct an outdoor storage study of large square bales covered with breathable film.

- Finish data collection on the energy required to create conventional high-density large-square bales.

- Complete manuscripts for publication review.

2. Actual Accomplishments

- We redesigned an experimental baler from an independent inventor and modified it to improve its performance. During this quarter the baler was tested in switchgrass and corn stover. The baler could produce bales with density ranging from 15 to 20 lbs./ft^3, considerably denser than conventional bales of similar crop material. We collected power and fuel-use data at a variety of bale densities.

- We recompressed bales of switchgrass, reed canarygrass, wheat straw and corn stover wee in an experimental bale press intended to recompress large square bales to double density. We collected force, energy and density data so that a model of the recompression process can be developed. The energy required to compress biomass bales over a relatively long period (~20 s) is about one-tenth that required to produce much less-dense bales in a conventional baler. We also collected additional data related to the tension in the bale restraining straps. We have finished collecting data on the energy requirement to make high-density biomass bales using conventional baling practices and these results will be used to compare the energy required to recompress bales or to form bales with the experimental high-density baler.

- The system we developed to measure twine tension as the bale is made was used this fall to collect data when making switchgrass, native grasses, and corn stover across a wide variety of bale densities. Models of twine tension as a function of bale density have been developed. Although twine tension certainly increased with bale density, the measured tensions were less than maximum tensile strength of the twine, so there may be opportunities to reduce twine cost if the root-cause of twine failures, other than pure tensile failure, can be determined.

- A model of the switchgrass drying rate had been developed where major inputs are solar insolation, vapor pressure differential, conditioning level, raking, and swath density. A final drying rate study was conducted this fall to validate the developed model. This drying rate model was used to develop a model to predict the harvest progression of switchgrass across the fall harvest season in the Upper Midwest. During development of the manuscript for this work, so anomalies were identified in the harvest progression model, so the model is undergoing modifications to address these issues.

- We have started a storage study where the main objective is to explore cost-effective means to store large-square-bales (LSB) outdoors. The LSB package has many advantages, but the requirement for covered storage adds considerable cost. We are exploring wrapping the top-layer of stacked bales with a breathable film that not only allows bales to “breath” but also prevents precipitation from penetrating the bale. A large number of bales were placed into storage this fall and will be removed in early summer. We will quantify DM loss, moisture distribution and bale temperature over the storage period.

3. **Explanation of Variance**

Work continues on manuscripts, but progress is slower than desired. The two-drying rate model manuscripts are close to submission.

4. **Plans for Next Quarter**

- Redesign the experimental high-density baler to address crop flow issues.
- Continue to compress large square biomass bales to increase the dataset size.
- Continue work on twine tension for large square bales.
- Continue the outdoor storage study of large square bales covered with breathable film.
- Complete manuscripts for publication review.

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

None.

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

Our efforts have been focused on moving the set of four manuscripts submitted to the *Journal of the American Water Resources Association* SWAT Special Series through the review process (See Exhibit 1).

2. Actual Accomplishments

The status of the four manuscripts are noted in the citations listed below. Two of the manuscripts (Kling et al. and Cibin et al.) are now accepted. The Gassman et al. manuscript has been revised and resubmitted after the initial review and is currently in the second phase of review. Finally, the Panagopoulos et al. manuscript is currently being revised and will be resubmitted in early January.

A very short introductory article for the special series is now available on-line (see http://onlinelibrary.wiley.com/doi/10.1111/1752-1688.12486/abstract) along with three other articles that will form most of the first set of papers in the special series. We anticipate that our complete set of four articles will be published in a later issue as part of the overall special series.

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Quarter

We expect to receive review comments back from the second round of reviews for both the Gassman et al. and Panagopoulos et al. manuscripts. We further plan to complete final revisions to both manuscripts and are hopeful that all four articles will be published before the end of the first quarter in 2017 (but final publication may not occur until the second quarter of 2017).

5. Publications, Presentations, and Proposals Submitted

- Kling, C.L., I. Chaubey, C. Raj, P.W. Gassman, Y. Panagopoulos. 2016. Policy Implications from Multi-Scale Watershed Models of Biofuel Crop Adoption across the Corn Belt. Journal of the American Water Resources Association (accepted).

- Cibin, R, I. Chaubey, R.L. Muenich, K.A. Cherkauer, P. Gassman, C. Kling and Y. Panagopoulos. 2016. Ecosystem Services Evaluation of Futuristic Bioenergy-based Land Use Change and Their Uncertainty from Climate Change and Variability. Journal of the American Water Resources Association (accepted).
- Gassman, P.W., A. Valcu, C.L. Kling, Y. Panagopoulos, C. Raj, I. Chaubey, C.F. Wolter, K.E. Schilling. 2016. Assessment of Bioenergy Cropping Scenarios for the Boone River Watershed in North Central Iowa, United States. Journal of the American Water Resources Association (in review).
- Panagopoulos, Y., P.W. Gassman, C.L. Kling, R. Cibin and I. Chaubey. 2016. Assessment of Large-scale Bioenergy Cropping Scenarios for the Upper Mississippi and Ohio-Tennessee River Basins. Journal of the American Water Resources Association (first review received; revisions being performed).

University of Minnesota

1. Planned Activities

We continued submission of manuscripts from output of previous quarters.

2. Actual Accomplishments

This quarter, we submitted three manuscripts related to the output of previous quarters, the first on the air quality impacts of increased switchgrass production, and the second and third on the modeling platform developed to support air quality impact assessment.

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Quarter

Continued submission of manuscripts from output of previous quarters.

5. Publications, Presentations, and Proposals Submitted

See (2) above.

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

The team has focused on preparing manuscripts based on the March 2016 presentation made at the American Chemical Society annual meeting.[1]

2. Actual Accomplishments

Progress has been made on manuscript preparation.

3. Explanation of Variance

No variance.

4. Plans for Next Quarter

We will continue to work on manuscript preparation. We are also developing a manuscript on Zerovalent iron solid residue/char formation from pyrolysis of FeCl3 treated feedstock.

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 to produce 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

[1] Rover, M., P. Hall, R. Smith & R.C. Brown. 2016. Application of Low Temperature, Low Pressure Hydrogenation to Liquefy and Stabilize Lignin Streams. Oral Presentation, American Chemical Society National Meeting, San Diego, CA. 13 Mar.

- Estimate threshold returns that make feasible biomass production for biofuels.

1. **Planned Activities**

   To our work on the economic feasibility of grasses, modelling the cost optimization problem of a unique plant under different market structures and, using assumptions based on local commercial biomass processors, the estimate input requirements and costs of grass feedstocks to meet the cellulosic mandate.

2. **Actual Accomplishments**

   Our work on the economic feasibility of grasses is ongoing.

3. **Explanation of Variance**

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

4. **Plans for Next Quarter**

   During the second quarter of year 6 our team will continue work on the economic feasibility of grasses.

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

   - We submitted *The Supply Curve for Cellulosic Ethanol* (Authors Chao Li, Keri L. Jacobs and Dermot J. Hayes.) for peer review to a top agricultural economics journal. The article is currently in revision (revise and resubmit).

   - Dumortier, J., N. Kauffman & D. Hayes. 2016. Production and Spatial Distribution of Switchgrass and Miscanthus in the United States under Uncertainty and Sunk Cost. Working Paper 16-WP 568, Center for Agricultural and Rural Development (CARD), Iowa State University, September 2016.

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**

We will finalize the preparation of the manuscript for a peer review journal article that shares the development and results of the model. This manuscript will be submitted to the selected journal.

- **Actual Accomplishments**

Several draft manuscripts have been prepared, however the final version to submit to the *Journal of Agriculture and Safety and Health* is still being developed. Extra care is being used to address earlier comments made by the journal reviewers about the risk model development and results sections.

- **Explanation of Variance**

None to report.

- **Plans for Next Quarter**

Submit the manuscript to the *Journal of Agriculture and Safety and Health* for review and publication.

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

- Ryan, S. J., C. V. Schwab & G. A. Mosher. 2016. Comparing worker injury risk in corn and switchgrass production systems: Results from a probabilistic risk assessment model. International Society for Agriculture Safety and Health. International Meeting Normal, Illinois. ISASH Paper No. 16-03. ISASH Urbana, IL 61801.

- Ryan, S. J., C. V. Schwab & 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 Agriculture Safety and Health. International Meeting Normal, Illinois. ISASH Paper No. 15-01. ISASH Urbana, IL 61801.

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**

  The approval for modifications to the human subjects study and authorization to start selection of subjects was not obtained.

- **Explanation of Variance**

  None to report.

- **Plans for Next Quarter**

  Develop a plan for collecting pilot data of dust exposures without employing human subjects for collection tasks.

- **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

- **CenUSA MOOC – "Introduction to Perennial Grasses for Biofuels"**

- ✓ Secure final IRB approval for evaluation activities.
- ✓ Make MOOC active to the public and ran marketing campaign to increase participation.

- **Modules 3 and 14**

  Complete internal review of content.

2. **Actual Accomplishments**

- **CenUSA MOOC**
  - ✓ Final IRB approval was secured for evaluation activities.
  - ✓ MOOC was made public in late September 2016 and a marketing campaign was started.

- **Module Harvesting**

  Additional edits were made to the Moodle lesson.

3. **Explanation of Variance**

   No variance was experienced.

4. **Plans for Next Quarter**

- **CenUSA MOOC – "Introduction to Perennial Grasses for Biofuels"**
  - ✓ Review preliminary participation.
  - ✓ Close inaugural MOOC offering and determine plans for a possible CenUSA MOOC version 2 in the spring.

- **Module 14. Biochemical Conversion**

  Submit module to external reviewers.

- **Module 10. Plant Breeding**

  Integrate video recordings and additional data from Michael Casler, Co-PD for the feedstock development objective.

- **Module 16 – Quality/Nutrient Management**

  Continue editing draft and merge voice recordings into presentation slides.

5. Publications, Presentations, and Proposals Submitted

None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. Planned Activities

- Coordinate the return of partner institution placed students to Iowa State University on August 3, 2016.
- On August 4, 2016, all CenUSA student interns will participate in a morning program celebration reception and the Iowa State University wide undergraduate research poster session and reception. This poster session, the culminating event of the CenUSA Bioenergy Internship Program, will include all undergraduate research interns who have participated in summer research internships at Iowa State University. This event will showcase over 100 students.
- All students will complete a post-program survey conducted by Iowa State University's Research Institute for Studies in Education (RISE). The purpose of this assessment is to (1) assess the program's activities; (2) evaluate immediate program successes and challenges; (3) promote continued interest in the program by alumni after they complete their research experience; and (4) track the career paths of our graduates.
- On August 5, 2016, all student interns depart Iowa State University.
- Finalize and process all payments related to the internship program.

2. Actual Accomplishments

- Students returned to Iowa State University on August 3, 2016.
- On August 4, 2016 CenUSA student interns participated in a morning program celebration reception and the ISU university-wide undergraduate research poster session and reception in the afternoon. The poster session included all undergraduate research interns who have participated in summer research internships at Iowa State University.
- Students completed a post-program survey conducted by Iowa State University's Research Institute for Studies in Education (RISE).
- On August 5, 2016 student interns depart Iowa State University.
- All process payments related to the internship program were finalized.

3. Explanation of Variance

None.

4. **Plans for Next Quarter**

None as this was strictly a PY1 - PY5 program activity. No forward planning is required.

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**

None.

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 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

  - Continue development of content and graphics for the legacy fact sheet.
  - Continue development of the pyrolysis video.
  - Launch CenUSA Bioenergy MOOC and gather analytics data.
  - Continue maintenance of CenUSA eXtension Index.
  - Continue maintenance of index: Resources from CenUSA - to include ALL CenUSA resources (http://www.extension.org/pages/68136).
  - Catch into indexes all journal publications published through the final quarter of CenUSA project. Reorganize index as needed to provide bioenergy info into the future once the project has closed.
  - Begin guidelines and instructions for future access and management of eXtension publications.
  - Continue work on a legacy publication to provide impact details of the project in concise format. The expected publication date is November 2016.
  - Publish fact sheets: Research Summary on potential for farmer adoption of

switchgrass production (Richard Perrin and Susan Harlow).

- Use eXtension Farm Energy Social Media sites to broadcast final information from CenUSA.

2. **Actual Accomplishments**

- **BLADES Newsletter**

  Published the October 2016 issue of BLADES that featured a preview of CenUSA's free, open and online course (MOOC), "Introduction to Perennial Grasses for Biofuels." https://proxy.qualtrics.com/proxy/?url=http%3A%2F%2Fblades-newsletter.blogspot.com%2Fp%2Foctober.html&token=yNDKTCgKTwBrPfzXWhBHIo8VyZmvOrb7fFrSTPB3GsI%3D.

- Completed the summary video, CenUSA Legacy: Creating a Midwestern Sustainable Biofuels and Bioproducts System (8 min. 29 sec).

- Created a marketing campaign for the CenUSA MOOC.

- Launched the CenUSA MOOC and began gathering analytics data.

- Continued development of legacy fact sheet content and graphics.

- Continued development of the pyrolysis video.

- Continued maintenance of the CenUSA eXtension Index.

  ✓ We used the eXtension Farm Energy Social Media sites to broadcast information from CenUSA.

  ✓ Began guidelines and instructions for future access and management of eXtension pubs.

  ✓ Continued maintenance of index: Resources from CenUSA http://articles.extension.org/pages/72584 to include ALL CenUSA resources.

    ➢ The CenUSA index includes all journal publications from the Feedstock Development and Feedstock Production Objectives which were published through the last quarter of the CenUSA project.

    ➢ The Index has been reorganized as needed to provide bioenergy info into the future once the project has closed. Added images, "go to top" buttons, listed FAQs.

✓ Google Analytics data for CenUSA articles/fact sheets on the eXtension Farm Energy Site, 8/1-10/31/2016:

- **Site Usage**. Compared to last quarter page views are up by 7% and users are up by 11%. In a comparison to last year, the same quarter shows page views and users up 10% and 15% respectively.
- **Pageviews**. Received 5010 page views by 3,827 users; 82% of those are new sessions, averaging 1.2 pages per session. The bounce rate is 88% and average time on page is 5:20 minutes.
- **Traffic Sources.** 89% search engines ("organic", Google, etc.), 8% direct traffic and 3% referring sites. Efforts continue to optimize publications for search engines.
- The top 10 states accessing CenUSA articles were TX, IL, CA, IA, PA, MN, MI, NC, NY and OH; England and Ontario consistently top international use.

- **Website.** The CenUSA web site had 659 visitors this quarter. These visitors logged a total of 1,922 pageviews during 869 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, and the user returns, a new session is started.
- **Continuing Impact of Vimeo Channel**. During this quarter, the 54 CenUSA videos archived on Vimeo have had 232 plays or views of the videos on our Vimeo site, or on a web site that embedded a CenUSA video. The 54 videos also had 4,327 loads; 4,089 of those loads came from our videos embedded on other sites. When a video is loaded, people see the video but they do not click "play". The embedded videos were played 136 times. Vimeo videos were downloaded 15 times. This 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 a video). Once the video is downloaded, it is available on their computer to watch at their convenience.
- **Continuing Impact of YouTube Channel**. CenUSA videos are also posted on YouTube, and those videos have been viewed 1,100 times between August 1, 2016 and October 31, 2016. 622 views were from the United States. Demographic analytics report an audience that is 83% male and 17% female. Our viewers ranged in age from 13-65+. The top 3 represented age groups were 25-34 (34%), 45-54 (20%), and 35-44 (16%).

  YouTube also provides data related to how users access the videos. Videos were viewed on their associated watch page, the YouTube Channel page, or on web pages where the videos were embedded. 97% of the videos were viewed on their associated YouTube watch page (each video has a unique "watch page"). Embedded videos on another site accounted for 3.3% of the views, and .2% of video views came from the YouTube Channel page. 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. 42% of our views came from users accessing videos suggested by YouTube. YouTube search accounted for 30% of our views. Referrals from outside YouTube (google search or access through external web sites) account for 15% of video views. Direct URL usage accounted for 5.4% 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. CenUSA bioenergy has 900 followers currently, up from 861 followers last quarter.
- **Facebook**. By the end of October 2016, CenUSA's Facebook page had 253 likes, up from 248 the previous quarter. Our most liked post from this quarter received 5 reactions. The highest daily reach of the quarter had a total reach of 247 individuals.
- Published Switchgrass Hay Could Be a Useful Roughage in Beef Diets While Offering a Market Alternative to Biofuels - Chris Clark. *http://articles.extension.org/pages/74031/*

3. Explanation of Variance

None noted.

4. Plans for Next Quarter

- Finish the Pyrolysis video.
- Publish a December BLADES newsletter.
- Finish the Legacy publication.
- Continue MOOC course support and user data collection.
- CenUSA eXtension Index.
    - ✓ Continue maintenance of CenUSA eXtension Index. http://articles.extension.org/pages/72584.

- Add all journal publications published through the end of the CenUSA project for sections not yet completed. Feedstock Logistics: Harvest & Storage, http://articles.extension.org/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa - Module%204System Performance, Feedstock Conversion and Co-Products, Markets and Distribution, Health and Safety.

- Complete final edits, additions and reorganization for the index.

✓ Continue guidelines and instructions for future access and management of eXtension pubs.

✓ **Publish**:

- Legacy flyer which provides impact details of the project in concise format.

- CenUSA Feedstock Development – Team Overview of objectives and accomplishments.

- CenUSA Feedstock Conversion and Refining – Team Overview of objectives and accomplishments.

- CenUSA Feedstock Logistics – Team Overview of objectives and accomplishments.

- CenUSA Extension and Outreach – Team Overview of objectives and accomplishments.

- CenUSA Water Quality and Perennial Grasses - objectives and accomplishments.

- Research Summary on potential for farmer adoption of switchgrass production - Richard Perrin and Susan Harlow. (assuming Journal article has been published).

✓ Use eXtension Farm Energy Social Media sites to broadcast final information from CenUSA.

5. Publications, Presentations, Proposals Submitted

BLADES Newsletter October 2016: http://blades-newsletter.blogspot.com/p/october.html.

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

1. **Planned Activities**

- **Indiana**

  ✓ Conduct session about biofuels for Indiana agriculture and science teachers, including information about CenUSA/perennial grass production for biofuels.

  ✓ Provide presentation and lead discussion for Purdue Agronomy graduate student seminar class.

  ✓ Provide CenUSA exhibit for the Purdue Phenomics Center.

  ✓ Harvest the CenUSA plots at Indiana FFA Leadership Center, Sweeten Farm and at Throckmorton.

  ✓ Sample grasses from each location.

  ✓ Provide presentation for IN Creation Care Group about Bioenergy/CenUSA.

- **Iowa**

  Present CenUSA information and decision spreadsheet at eleven farmland leasing meetings. Poll participants by simple raise of hands methodology to gage their interest in growing perennial grasses if a market for them develops and if a market is not available.

- **Minnesota**

  ✓ Share information about CenUSA/perennial grasses at a symposium on the new crop buffer law in Minnesota.

  ✓ Harvest and complete grassland assessment for the two CenUSA demo plots.

- **Nebraska**.

  Provide CenUSA presentations for:

  ✓ Lincoln, NE Executive Club (August 26).

  ✓ Lincoln Regional Center (October 27).

  ✓ Collect visual data and harvest the CenUSA plot and Beaver Crossing plot.

  ✓ Conduct CenUSA sessions for youth attending bioenergy camp at the Lincoln, Nebraska YMCA and the Applejack Festival in Nebraska City.

2. Actual Accomplishments

- **Indiana**

  Indiana (Purdue): The Purdue CenUSA Extension team reached a total of 101 people (60 male, 41 females; 3 Hispanic, 96 white, 2 African American) via the following activities:

  ✓ Conducted session about biofuels for Indiana agriculture and science teachers, including information about CenUSA/perennial grass production for biofuels.

  ✓ Provided presentation and lead discussion for Purdue Agronomy graduate student seminar class.

  ✓ Provided a CenUSA exhibit for the Purdue Phenomics Center.

  ✓ Harvested the CenUSA plots at Indiana FFA Leadership Center, Sweeten Farm and at Throckmorton.

  ✓ Sampled grasses from each location.

  ✓ Provide a presentation for IN Creation Care Group about bioenergy and CenUSA.

- **Iowa**

  We presented CenUSA information and demonstrated the switchgrass decision tool at 10 Farmland Leasing meetings in east central Iowa, reaching a total of 202 people (234 male, 68 females; all white). Poll results: 33% of participants indicated they would be interested in growing the grasses if a market developed in their area; 2% indicated they would be interested in growing the grasses if there is no market for them.

- **Minnesota**

  ✓ Presented a poster about the CenUSA research on establishing switchgrass and other native perennials in Minnesota at the "Buffer Science and Design Symposium" on September 16, 2016 ("Biomass plantings for buffers: Switchgrass and mixed native perennial yield as a function of nitrogen and harvest regime.") Twenty-five people visited the poster (20 male and 5 females; 23 white, 1 Hispanic, 1 Asian). The symposium agenda is available at https://proxy.qualtrics.com/proxy/?url=https%3A%2F%2Fdocs.google.com%2Fdocument%2Fd%2F1aXEYHh0FGRi4XRqJMXXQj6SeD9srMq5VB2sDmxVJK_g%2Fedit&token=nvl8BfDdJwBGswctoasLpCgXjgvlPAxaFkB51EaolLc%3D.

- ✓ We harvested and completed grassland assessment for the two Minnesota CenUSA demo plots.

- **Nebraska**

  We reached 58 adults through these presentations:

  - Lincoln, NE Executive Club (August 26).
  - Lincoln Regional Center (October 27).

  325 youth participated in the CenUSA C6 activity at the Applejack Festival in Nebraska and 100 youth participated in the Bioenergy session at the Lincoln, Nebraska YMCA.

3. Explanation of Variance

None.

4. Plans for Next Quarter

- **Indiana**

  ✓ Organize and conduct a "Purdue Webinar" to share overall results from Purdue components of the CenUSA project.

  ✓ Prepare a plan for the future of the CenUSA on-farm demonstration plots.

- **Iowa**

  Present CenUSA session at the Integrated Crop Management Conference December 1, 2016.

- **Minnesota**

  Attend and participate in the Soil Science Society of America meetings to present data from CenUSA studies.

- **Nebraska**

  None.

5. Publications, Presentations, Proposals Submitted

Poster: *Biomass plantings for buffers: Switchgrass and mixed native perennial yield as a function of nitrogen and harvest regime*.

- **Economics and Decision Tools**

1. Planned Activities

- Continue work on the *Crop Enterprise and Environmental Budgeting Tool for Evaluating Biomass, Forage, Agroforestry, Annual and Orchard Crops.* The tool includes a crop enterprise budgeting component along with the Century Carbon Account Model. The model was developed with partial funding from CenUSA.
- Continue marketing the *Ag Decision Maker Switchgrass Decision Tool*.

2. Actual Accomplishments

- Demonstrated the *Crop Enterprise and Environmental Budgeting Tool for Evaluating Biomass, Forage, Agroforestry, Annual and Orchard Crops Tool* at the *Green Lands Blue Waters Conference*.
- Continued promotion of the CenUSA switchgrass decision tool. The tool was downloaded/completed by 134 people this quarter.

3. Explanation of Variance

None.

4. Plans for Next Quarter

- Conduct a CenUSA session at the Iowa State University *Integrated Crop Management Conference*.
- Continue the promotion of the *Crop Enterprise and Environmental Budgeting Tool for Evaluating Biomass, Forage, Agroforestry, Annual and Orchard Crops*.
- Continue promotion of the CenUSA Switchgrass Decision Tool.

5. Publications, Presentations, Proposals Submitted

None.

- **Health and Safety**

See Objective 7.

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

  - **Youth Development**

1. **Planned Activities**

- **Indiana**

  ✓ Plan and implement CenUSA teacher training, in conjunction with Indiana FFA Center, Indiana Corn Marketing Council, Chad Martin and Keith Johnson.

  ✓ Present an overview of the high school curriculum and demonstration plot app to matched pairs of Agriculture and Science teachers from Indiana. Prepare packets for each teacher with supplies to complete pilot of curriculum and provide feedback.

- **Iowa**

  Plan for 2017 summer workshops for Agricultural Education and science teachers that will provide professional development on the CenUSA C6 curriculum for implementation in classrooms for the 2017 school year. One workshop will be conducted in northwest Iowa and will use a peer to peer teaching model to allow the teachers to engage as both teachers and learners to create a deeper understanding of the C6 curriculum and game. The teachers will also be engaged as collaborators on the curriculum to allow for making the curriculum better from an implementer perspective.

  We will also begin application for a second workshop to be conducted at the National Ag in the Classroom conference that will be held in Kansas City June 20-23rd, 2017.

2. **Actual Accomplishments**

- **Indiana**

  ✓ Presented an overview of the high school curriculum and demonstration plot app for 25 (10 male and 15 female) Agriculture and Science teachers from Indiana. Teachers that attended were provided supplies to complete the curriculum pilot and provide feedback. We designed survey to gather feedback and reviews to gather impact data.

- **Iowa**

  ✓ CenUSA C6 hosted a booth at the *National Bioenergy Day* at Iowa State University. In addition, the C6curriculum is now in a packaged format for use by educators and is hosted on the Iowa State University Extension's 4-H

Youth website for download.

- ✓ Worked with Tom Paulsen, Associate Professor and Chair, Applied Agricultural and Food Studies, Morningside College (108 Buhler Rohlfs Hall, 1501 Morningside Ave, Sioux City, IA 51106) to begin negotiations with the Area Education Association in NW Iowa to offer a 45-hour training for Vo-Ag and STEM teachers in June, 2017. Teachers will receive licensure renewal credit and/or graduate credit for completing the training.

3. Explanation of Variance

None noted.

4. Plans for Next Quarter

- **Indiana**

  - ✓ We will continue work on curriculum, app finalization, online learning modules finalized and planning for the March 2017 workshop. We will continue improvements and plans for the 4-H Science Academy (Summer 2017).
  - ✓ We will continue to work towards completing CenUSA goals by the end of the funding period.
  - ✓ WE will present and disseminate information at the *National Science Teachers Association National Conference* (Los Angeles CA).

- **Iowa**

  The next quarter will focus on the continuing of C6 Outreach at STEM events in Iowa. The summer workshops will be promoted and finalized. Applications and forms needed get the workshops qualified for teacher licensure renewal and graduate credit will be completed. Application for workshop at *National Ag in the Classroom* workshop will be completed and submitted.

5. Publications, Presentations, Proposals Submitted

- **Indiana**

  Our presentation was accepted by the National Science Teachers Association for the 2017 national meeting (March 2017, Los Angeles).

- **Iowa**

C6 BioFarm Curriculum has been published on the Iowa State University Extension and Outreach website: https://proxy.qualtrics.com/proxy/?url=http%3A%2F%2Fwww.extension.iastate.edu%2F4h%2Fcontent%2Fclassroom&token=LW%2BEQQ6BsHFqk%2BZ061dydaO%2BfjHy%2B6zdCsCF8GnyWkk%3D.

- **Broader Public Education/Master Gardener Program**

This component of the project was only funded from Years 1-4 of the CenUSA project. However, a journal article summarizing the research is under development for submission to the *Journal of Extension*.

- **Evaluation and Administration**

1. Planned Activities

- Develop survey instruments, conduct analysis of surveys completed by participants, and produce reports summarizing the impact of CenUSA Extension efforts.
- Collect information from CenUSA Extension teams and prepare reports.
- Prepare and submit abstract for session about CenUSA for Iowa State University's *Integrated Crop Management Conference*.
- Plan for 2017 summer workshops for Agricultural Education and science teachers. The workshops will provide professional development on the CenUSA C6 curriculum for implementation in classrooms in the 2017 school year. One workshop will be conducted in northwest Iowa and will use a peer to peer teaching model to allow the teachers to engage as both teachers and learners to create a deeper understanding of the C6 curriculum and game. The teachers will also be engaged as collaborators on the curriculum to allow for making the curriculum better from an implementer perspective.
- Begin application for a second workshop to be conducted at the *National Ag in the Classroom Conference* that will be held in Kansas City June 20-23rd, 2017.
- Continue work on the CenUSA Legacy publication.

2. Actual Accomplishments

- Collected information for and prepared CenUSA Extension team reports.

- Prepared and submitted an abstract for a session about CenUSA for Iowa State University's *Integrated Crop Management Conference*. The abstract was accepted for presentation.
- Prepared proposals for the CenUSA teacher training program for Northwest Iowa Area Education Agency and Morningside College (June 2017). Teachers will participate in 45 hours of training about biorenewables and will receive teacher licensure renewal credit and/or graduate credit for completing the training. Applications are currently under review.
- Continued work on CenUSA Legacy publication.

3. Explanation of Variance

None.

4. Plans for Next Quarter

- Develop survey instruments, conduct analysis of surveys completed by participants, and produce reports summarizing the impact of CenUSA Extension efforts.
- Collect information from CenUSA team members and prepare reports.
- Plan and deliver session at Iowa State University *Integrated Crop Management Conference*.
- Develop marketing plan for recruiting teachers to participate in CenUSA teacher training program for Northwest Iowa Area Education Agency and Morningside College (June 2017). Teachers will participate in 45 hours of training about biorenewables and the CenUSA C6 Bioenergy curriculum and receive teacher certification credit and/or graduate credit.
- Prepare and submit abstracts to provide training sessions for Extension Educators at the *2017 National Extension Energy Summit* (April 3-6, 2017 in Knoxville, TN) and the *National Agriculture in the Classroom Conference* (June 20-23, Kansas City, MO).

5. Publications, Presentations, Proposals Submitted

None this quarter.

Objective 10. Commercialization

Sub Objective 10A. Archer-Daniels-Midland

No activities were undertaken as this was strictly a Year 1 to Year 5 activity. No forward planning is required.

Sub-Objective 2. Renmatix

1. **Planned Activities**

   Evaluate higher-value lignin applications to improve biorefinery economics

2. **Actual Accomplishments**

   At the 2016 annual meeting, we reported that lignin from perennial grasses may be a viable component in adhesives for plywood panel production. This has the potential to make significant economic improvements to a biorefinery using the Renmatix Plantrose® process to convert perennial grasses into sugars and lignin.

   Since then we tested lignin that was produced from corn-stover and switchgrass in the Plantrose pilot plant to produce OSB (oriented strand board) wood panels. The lignins were blended with a commercial, OSB phenol-formaldehyde resin. A lignin similarly derived from hardwood was used for comparison. All the lignin blend adhesives showed similar reactivity when tested with maple veneer strips in our Automated Bonding Evaluation System.

   Next we produced actual 3'x3' OSB wood panels at the University of Maine's Advanced Structures and Composites Center. Commercial aspen strands were used in random orientation to produce ½" thick panels. Visually the boards look acceptable. At press time, the panels are being tested using US and Canadian commercial standards for internal bond strength, modulus of elasticity, modulus of rupture and thickness swell.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

   Analyze data from panel trials and complete corresponding report.

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

   None.

Objective 10C. USDA-ARS, Lincoln, Nebraska - Alternative Uses for Native Perennial

Warm-season Grasses

Nothing of significance to report this quarter.

Exhibit 1

Abstracts for Set of Four Studies Submitted to JAWRA

Kling, C.L., I. Chaubey, C. Raj, P.W. Gassman, Y. Panagopoulos. 2016. "Policy Implications from Multi-Scale Watershed Models of Biofuel Crop Adoption across the Corn Belt," *Journal of the American Water Resources Association* (accepted).

Abstract: The implications and value of SWAT-based simulations of the productive potential and water quality impacts associated with switchgrass, Miscanthus or corn stover removal biofuel cropping systems are discussed. Specifically, the three accompanying studies describe the water quality implications of adopting the three biofuel cropping systems via large-scale conversion of cropland or targeting to marginal lands for three smaller watersheds located in the western or eastern Corn Belt, or across the Upper Mississippi and Ohio-Tennessee River Basins. Other results such as climate change related impacts for two eastern Corn Belt watersheds are also discussed. These studies are supported by the CenUSA Bioenergy coordinated agricultural project funded by the USDA to develop a regional system for producing cellulosic biofuels. A description of the evolving federal policy related to cellulosic biofuel production and consumption is provided as are other potential drivers for encouraging the adoption of stover removal, switchgrass, and Miscanthus as perennial feedstocks. Findings from the SWAT studies and their implications for environmental and economic performance in their respective agroecosystems are discussed, and commonalities and divergences in results are identified. The potential for policy design to improve the performance of these systems based on the findings of these modeling studies, and continuing research needs and directions for improved policy design are discussed.

Cibin, R, I. Chaubey, R.L. Muenich, K.A. Cherkauer, P. Gassman, C. Kling and Y. Panagopoulos. 2016. Ecosystem Services Evaluation of Futuristic Bioenergy-based Land Use Change and Their Uncertainty from Climate Change and Variability." *Journal of the American Water Resources Association* (accepted).

Abstract: Land use change can significantly affect the provision of ecosystem services and the effects could be exacerbated by projected climate change. We quantify ecosystem services of bioenergy based land use change and estimate the potential changes of ecosystem services due to climate change projections. We considered seventeen bioenergy based scenarios with Miscanthus, switchgrass, and corn stover as candidate bioenergy feedstock. Soil and Water Assessment Tool simulations of biomass/grain yield, hydrology and water quality were used to quantify ecosystem services fresh water provision (FWPI), food (FPI) and fuel provision, erosion regulation (ERI), and flood regulation (FRI). Nine climate projections from Coupled Model Intercomparison Project phase-3 were used to quantify the potential climate change variability. Overall, ecosystem services of heavily row cropped Wildcat creek watershed were lower than St.

Joseph River watershed which had more forested and perennial pasture lands. The provision of ecosystem services for both study watersheds were improved with bioenergy production scenarios. Miscanthus in marginal lands of Wildcat creek (9% of total area) increased FWPI by 27% and ERI by 14% and decreased FPI by 12% from the baseline. For St. Joseph watershed, Miscanthus in marginal lands (18% of total area) improved FWPI by 87% and ERI by 23% while decreasing FPI by 46%. The relative impacts of land use change were considerably larger than climate change impacts in this study.

Gassman, P.W., A. Valcu, C.L. Kling, Y. Panagopoulos, C. Raj, I. Chaubey, C.F. Wolter, K.E. Schilling. 2016. "Assessment of Bioenergy Cropping Scenarios for the Boone River Watershed in North Central Iowa, United States." *Journal of the American Water Resources Association* (revised and resubmitted).

Abstract: Several biofuel cropping scenarios were evaluated with an improved version of SWAT as part of the CenUSA Bioenergy consortium for the Boone River watershed (BRW), which drains about 2,370 km^2 in north central Iowa. The adoption of corn stover removal, switchgrass or *Miscanthus* biofuel cropping systems were simulated to assess the impact of cellulosic biofuel production on pollutant losses. The stover removal results indicate that removal of 20% or 50% of corn stover in the BRW would have negligible effects on streamflow and relatively minor or negligible effects on sediment and nutrient losses, even on higher sloped cropland. Complete cropland conversion to switchgrass or *Miscanthus* resulted in streamflow or sediment, nitrate and other pollutant reductions ranging between 23% to 99%. The predicted nitrate reductions due to *Miscanthus* adoption were over two times greater compared to switchgrass, with the largest impacts occurring for tile drained cropland. Targeting of switchgrass or *Miscanthus* on cropland ≥ 2% slope or ≥ 7% slope revealed that a disproportionate amount of sediment and sediment-bound nutrient reductions could be obtained by protecting these relatively small areas of higher sloped cropland. Overall, the results indicate that all biofuel cropping systems could be effectively implemented in the BRW, with the most robust approach being corn stover removal adopted on tile drained cropland in combination with a perennial biofuel crop on higher sloped landscapes.

Panagopoulos, Y., P.W. Gassman, C.L. Kling, R. Cibin and I. Chaubey. 2016. "Assessment of Large-scale Bioenergy Cropping Scenarios for the Upper Mississippi and Ohio-Tennessee River Basins." *Journal of the American Water Resources Association* (first review received; revisions being performed).

Abstract: The Upper Mississippi River Basin (UMRB) and Ohio-Tennessee River Basin (OTRB) comprise the majority of the U.S. Corn Belt Region. The combined basins are the primary U.S. food, feed and biofuel production region, resulting in degraded Mississippi River and Gulf of Mexico water quality. To address the water implications of increased biofuel production, biofuel scenarios were tested with a SWAT mode revision featuring improved biofuel crop representation. Scenarios included corn stover removal and switchgrass or Miscanthus grown on marginal lands (slopes>2% and erosion rates>2 t/ha), non-marginal lands, or both. The results reveal that stover removal is environmentally neutral, even in the most sloping and erodible marginal land and perennial bioenergy crops can reduce sediment, nitrogen (N) and phosphorus (P) yields by up to 60%. In particular, sediment and P reductions were generally twice in the marginal than in the non-marginal lands, but the highest unit area reductions of N occurred in the less sloping tile-drained lands. Productivity results showed that corn grain yield was independent from stover removal, while both switchgrass and Miscanthus yields were similar in the marginal and non-marginal lands. The study indicates that biofuel production planning in the Corn Belt may include the removal of stover in highly productive corn areas and the growth of perennials in the environmentally marginal land and in the lowland tile drained areas of the highest N pollution.

cenusa bioenergy

"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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cenusa bioenergy

Quarterly Progress Report

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

February 2017

Agriculture and Food Research Initiative Competitive Grant

No. 2011-68005-30411

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EXHIBITS

LEGAL NOTICE

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

Second Quarter Report: November 1, 2016 – January 31, 2017

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. Mary Scott Hall (ISU Bioeconomy Institute) provides assistance with project financial matters.

- **CenUSA Bioenergy Advisory Board**

  Our Advisory Board continues to be engaged in the project and provide feedback to the project director and leadership team

- **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 bimonthly 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.

Germplasm to Harvest

Objective 1. Feedstock Development

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

1. **Planned Activities**

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

- ✓ Collect all 2016 data from 13 locations in field-trial network.
- ✓ Conduct final data analyses.

- **Feedstock Quality Analysis (Bruce Dien – ARS Peoria and Akwasi Boateng – ARS Wyndmoor)**

  Conduct laboratory analyses of 'Liberty' samples in comparison to control varieties.

- **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Compile the data for 2016.
  - ✓ Complete analysis of the electronic feeding monitoring.

2. Actual Accomplishments

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

  All 2016 data and samples from the 10-state grass field trial systems have been collected in Madison.

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

  Conducted data analysis of 'Liberty' switchgrass and prepared two abstracts for presentation.

- **Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**
  - ✓ Completed all data collection for 2016 growing season.
  - ✓ Data analysis and manuscript preparation have been partially completed.

3. Explanation of Variances

None to report.

4. Plans for Next Quarter

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**
  - ✓ Conduct final data analyses.

- ✓ Begin preparation of three manuscripts.

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

  Prepare one manuscript and two presentations for scientific meetings.

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

  Continue data analysis and manuscript preparation.

5. Publications / Presentations/Proposals Submitted

None.

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.

▪ **Purdue University**

Grinding and other processing continued for the 2016 biomass samples. We may not have funds in the current CenUSA budget for analysis of fiber, nonstructural carbohydrates, and minerals, but we want to archive the samples for these analyses in the case additional funding is obtained and monies become available.

We are completing the analyses of 2015 samples including N, P, K and sugars. Preliminary results include the following.

- **Table 1. Mineral, ash, and sugar concentrations of biomass crops grown at the Water Quality Field Station in 2015.** The least significant difference at the 5% level of probability is provided. Concentrations of all constituents differed significantly among species. Biomass nitrogen (N) concentrations were higher in the annual biomass systems (maize, sorghum) when compared to the perennial species. Miscanthus had the lowest N concentrations of any species. Patterns of phosphorus (P) concentrations in these biomass systems mirrored N concentrations, however, maize biomass P concentrations were greater than those observes in sorghum. Potassium (K) concentrations in sorghum biomass were higher than all other species. Prairie biomass contained very low K concentrations, with the other species generally intermediate K levels. Total ash in biomass was greatest in the prairie, lowest in the maize biomass, and intermediate in tissues of the other species. Intermediate sugar concentrations were observed in biomass of maize, switchgrass and Miscanthus while concentrations were highest in sorghum and lowest in prairie biomass samples.

Table 1. Mineral, ash, and sugar concentrations of biomass crops grown at the Water Quality Field Station in 2015.

Species	N, g/kg	P, g/kg	K, g/kg	Total Ash, g/kg	Sugar, g/kg
Maize	9.22	1.79	3.95	21.9	11.6
Prairie	4.69	0.80	1.84	58.0	6.1
Shawnee Switchgrass	4.27	0.78	4.11	46.7	12.3
Miscanthus	3.30	0.38	4.71	41.2	14.9
Dual-Purpose Sorghum	9.52	1.44	6.82	44.1	18.9
LSD, 0.05	0.79	0.23	0.68	5.2	5.1

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- **Table 2. Biomass yield and removal of nitrogen (N), phosphorus (P), and potassium (K) with biomass grown at the Water Quality Field Station in 2015.** Biomass yield (previously reported) was greatest in Miscanthus, lowest in the prairie, with the other species intermediate. Removal of N, P, and K in biomass was estimated as the product of yield and concentrations of these minerals reported in Table 1 above. Maize removed the most N, followed by sorghum, Miscanthus, switchgrass and the prairie. Removal of P followed this same pattern, however, differences among the prairie, switchgrass and Miscanthus were not always significant. In contrast, K removal was much higher in Miscanthus, intermediate in maize and sorghum, and lowest in the prairie.

Table 2. Biomass yield and removal of nitrogen (N), phosphorus (P), and potassium (K) with biomass grown at the Water Quality Field Station in 2015.

Species	Biomass, kg/ha	N, kg/ha	P, kg/ha	K, kg/ha
Maize	14871	137	27	59
Prairie	2757	13	2	5
Shawnee Switchgrass	8509	36	6	36
Miscanthus	23693	78	9	112
Dual-Purpose Sorghum	10908	104	16	75
LSD, 0.05	3202	21	6	18

- **Table 3. Concentrations of minerals, ash and soluble sugars in three biomass species grown at three Purdue Agricultural Centers (PAC) in 2015.** The least significant difference (LSD) is provided at the 5% level of probability. The biomass x species interaction was significant. Biomass nitrogen (N) concentrations were lowest in Miscanthus, but differences were not significant at NEPAC. The highest biomass N concentrations were observed in switchgrass at TPAC for all biomass species; the most fertile site of the three in this study. Biomass P concentrations mirrored N with lowest concentrations observed in *Miscanthus*. Biomass K concentrations of species did not differ at NEPAC or SEPAC, but were higher in switchgrass and the indiangrass/big bluestem system at TPAC. Averaged over locations total ash concentrations were greatest in the indiangrass/big bluestem. Sugar concentrations were greater in Miscanthus biomass, especially at NEPAC and TPAC.

Table 3. Concentrations of minerals, ash and soluble sugars in three biomass species grown at three Purdue Agricultural Centers (PAC) in 2015.						
Location	Species	N, g/kg	P, g/kg	K, g/kg	Total Ash, g/kg	Sugar, g/kg
Northeast PAC	Liberty Switchgrass	4.44	0.53	3.83	27.6	7.1
(NEPAC)	Miscanthus	3.83	0.35	3.72	22.9	14.3
	Indiangrass + Big Bluestem	3.91	0.49	3.94	45.7	4.9
Throckmorton PAC	Liberty Switchgrass	8.05	0.90	4.15	43.4	6.1
(TPAC)	Miscanthus	4.11	0.24	2.59	25.2	20.9
	Indiangrass + Big Bluestem	5.34	0.95	5.34	49.9	5.9
Southeast PAC	Liberty Switchgrass	4.40	0.46	1.80	33.0	8.3
(SEPAC)	Miscanthus	3.37	0.18	2.04	29.3	11.1
	Indiangrass + Big Bluestem	4.68	0.52	2.61	46.5	6.1
LSD, 0.05		0.90	0.18	1.03	ns	4.0

- **Table 4. Biomass yield and removal of nitrogen (N), phosphorus (P), and potassium (K) in biomass of Liberty switchgrass, Miscanthus (IL clone) and a 50-50 mixture of indiangrass and big bluestem.** Removal was estimated as the product of tissue mineral concentration reported in Table 3 and biomass yield (previously reported). The site x species interaction was not significant so data are averaged over three Purdue Agricultural Centers (PAC) in 2015. Unless otherwise indicated the least significant difference (LSD) is provided at the 5% level of probability. A threefold range in biomass yield was observed with the greatest yield found in *Miscanthus*. Removal of N in biomass scaled with biomass yield with the greatest removal observed in *Miscanthus* and the least in the indiangrass-big bluestem mixture. Removal of P in biomass was lowest in indiangrass-bluegrass, and greatest in switchgrass. Removal of K was greatest in *Miscanthus*.

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Table 4. Biomass yield and removal of nitrogen (N), phosphorus (P), and potassium (K) in biomass of Liberty switchgrass, Miscanthus (IL clone) and a 50-50 mixture of indiangrass and big bluestem.

Species	Biomass, kg/ha	N, kg/ha	P, kg/ha	K, kg/ha
Liberty Switchgrass	12203	68	7.8	41
Miscanthus	23824	93	6.5	69
Indiangrass + Big Bluestem	7081	33	4.9	30
LSD, 0.05	2904	22	2.0 (P=0.10)	16

- **University of Illinois**

Biomass was harvested on September 18, 2016 for H1 (post anthesis stage) treatment, and on Nov 18, 2016 for H2 (after killing frost) and H3 (alternate H1 and H2) treatment.

Biomass yield for each plot was calculated, and tissue and soil samples were processed for future analyses. All plant tissue samples were shipped to University of Nebraska-Lincoln on Feb 20, 2016.

Biomass yields varied depends on N fertilization rate, harvest timing, and species. Currently we are preparing two manuscripts for biomass yield and N and P harvest.

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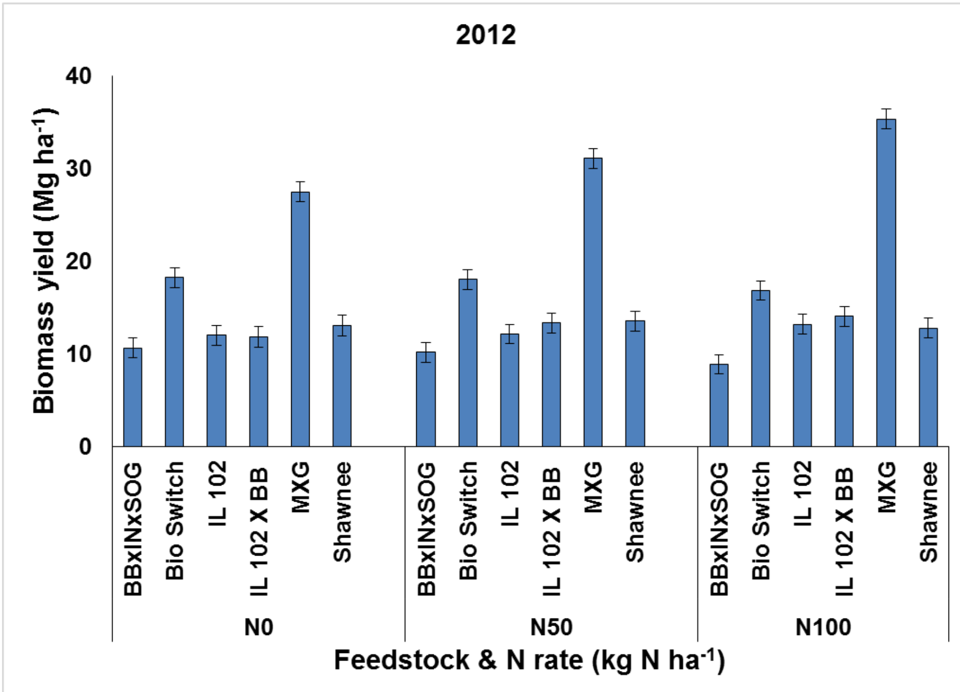


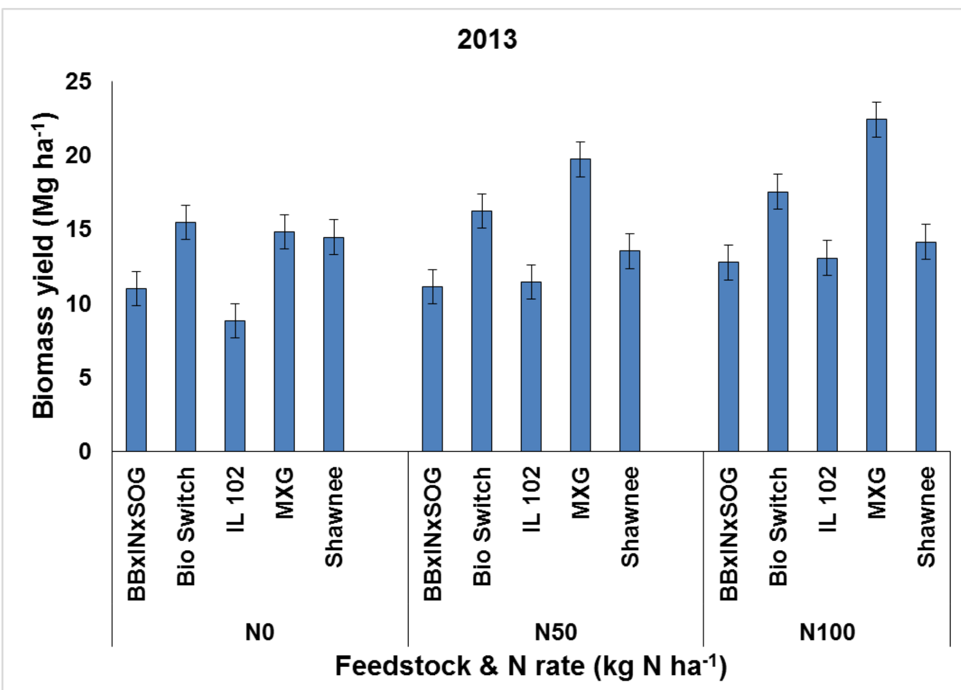
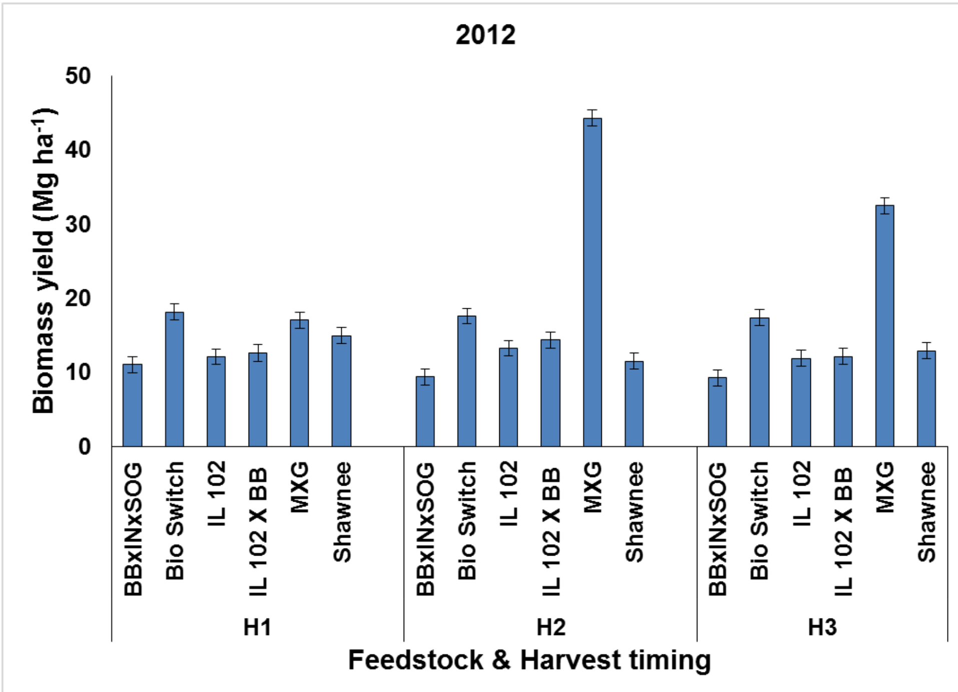


Fig 1. Effects of N rate on biomass yield of High diversity mixture (BBxINxSOG), Bioenergy switchgrass (Bio Switch), Prairie cordgrass (IL102), Miscanthus x giganteus (MXG), and switchgrass (Shawnee) and Prairie cordgrass and big bluestem mixture (IL102xBB), grown on wet marginal land during 2016. Biomass yields were averaged across harvest treatment. *Top plots were established in 2012; bottom plots were established in 2013.



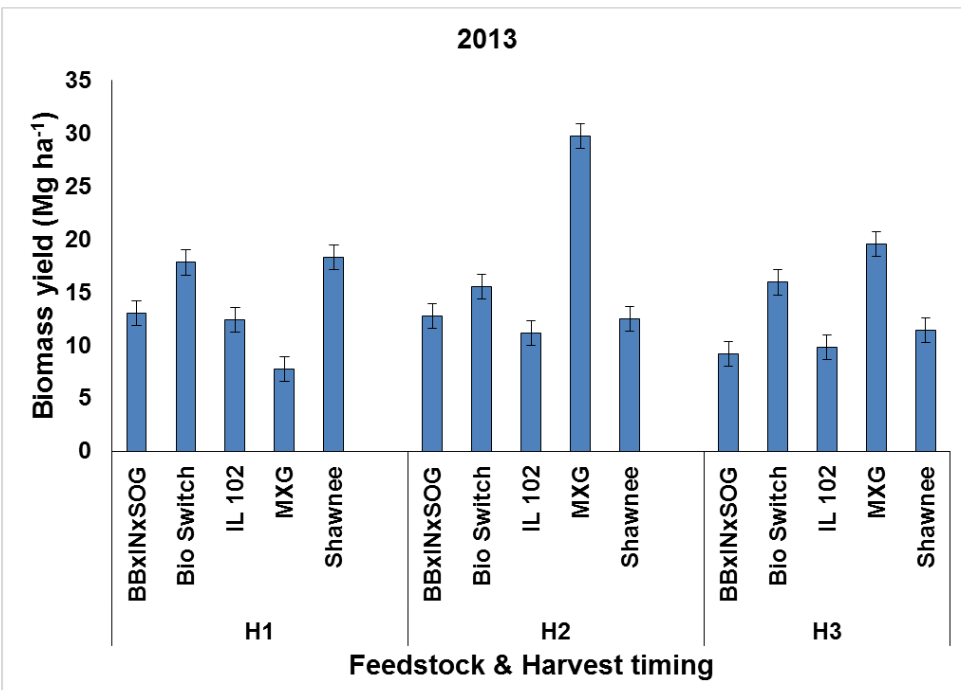


Fig 2. Effects of harvest timing (H1: post anthesis stage, H2: after killing frost, H3: alternate H1 and H2) on biomass yield of High diversity mixture (BBxINxSOG), Bioenergy switchgrass (Bio Switch), Prairie cordgrass (IL102), Miscanthus x giganteus (MXG), and Switchgrass (Shawnee) and two-way mixture (IL102xBB), grown on wet marginal land in Urbana, IL. Biomass yields were averaged across N rates.

- **University of Minnesota**

  - **Becker Location**

    We completed our post-frost harvest on October 13, 2016. Samples have been weighed, dried, and ground.

  - **Lamberton Location.**

    ✓ We completed our post-frost harvest on October 26, 2016. Samples have been weighed, dried, and ground.

  - **Additional Activities.**

    Anne Sawyer is making progress on her dissertation using data collected from CenUSA. The first chapter is entitled, "Switchgrass and mixed perennial biomass production as affected by nitrogen fertility and harvest management", which will be ready for submission to peer-review after 2016 yield and tissue N data from Lamberton are incorporated. Ms. Sawyer has also nearly completed a draft of her second chapter, which has a working title of "Rhizobacteria community structure as a function of cultivar and nitrogen in switchgrass grown on two marginal soils". She will have one final chapter regarding switchgrass rhizosphere microflora (fungi and bacteria) as a function of cultivar and P rate. She is planning to finish her PhD in July 2017.

- **USDA-ARS, Lincoln**

  - **Actual Accomplishments**

    ✓ Harvested all plots.

    ✓ Sampled greenhouse gases (GHG).

    ✓ Ground and milled all NE samples.

  - **Current Actions**

    ✓ **Factor Analysis Plots**

    ➢ Yield data for 2012-2016 is being summarized.

    ➢ Samples collected in 2012, 2013, 2014, 2015 and 2016 have been processed and are being scanned and biomass composition predicted.

    ✓ **System Analysis Plots**

   - Samples collected in 2012, 2013, 2014, 2015 and 2016 are being scanned and predicted.
   - Samples have been sent for mineral analysis.
   - GHG samples from 2013-2015 are being summarized.
   - VOM and elongated leaf height data are being summarized.
   - Harvests for the harvest height and harvest date study were completed and data is being summarized.
   - Samples for the Iowa plots were scanned, predicted, and data forwarded to collaborators.
   - Field-scale plots were harvested and bales transported.

- **Plans for Next Quarter**
  - ✓ Repair grass seed combine.
  - ✓ Complete triticale harvest.
  - ✓ Plant corn.
  - ✓ Burn areas to clean up standing material.
  - ✓ Scan and predict biomass samples forwarded from other locations.
  - ✓ Finalize the scanning and predicting of 2012, 2013, 2014, 2015 and 2016 Nebraska biomass samples.
  - ✓ Analyze and summarize field data.
  - ✓ Submit manuscripts on CenUSA projects.

▪ **USDA-ARS, Madison**

We will finish two manuscripts and submit to journals. The only thing we have left to accomplish is to finish writing up our research for publication. We have two papers that are both partly written, and have made progress on both during the past three months.

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

Research activities planned included:

- Development and validation of biomass “drying prediction models” to predict relative increase in biomass moisture levels during a rainfall event and subsequent drying profile after the re-wetting of biomass materials.
- Continued development and evaluation of prototype real-time biomass moisture sensor for switchgrass and corn stover.

2. Actual Accomplishments

The biomass “drying prediction models” predict relative increase in biomass moisture levels during a rainfall event and subsequent drying profile after the re-wetting of biomass materials have been developed. The model results have been compared to the laboratory and field drying experiments. In general, the models can predict the re-wetting events and subsequent drying of the biomass. The prediction error is higher immediately after transient events immediately after rainfall events, although the prediction error decreases after these transient events.

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:

- Integration and finalization of the different logistics and cost models.
- Continued development and evaluation of prototype real-time biomass moisture sensor for switchgrass and corn stover.

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

- None this quarter.

University of Wisconsin

1. **Planned Activities**

Our efforts in this quarter were to include:

- Re-design the experimental high-density baler to address crop flow issues.
- Continue to compress large square biomass bales to increase the dataset size.
- Continue work on twine tension for large square bales.
- Continue the outdoor storage study of large square bales covered with breathable film.
- Complete manuscripts for publication review.

2. **Actual Accomplishments**

- A new baler pick-up was acquired and work continues on the redesign of the experimental baler to accommodate this pick-up. Parts fabrication and planned modifications should begin within the next month.
- Compression data for large-square biomass bales of biomass continues. Data is being collected and processed on the stress relaxation, energy recovery and required restraint (i.e. twine) tension as a function of achieved density. Components were purchased to allow lab test of twine knot failures. When completed, these combined datasets should help manufacturers suggest the most economical twine for a given crop and target bale density.
- A storage study was begun in the fall where the main objective is to explore cost-effective means to store large-square-bales (LSB) outdoors. These bales are being monitored for moisture content during the storage period and will be removed from storage in the late spring or early summer.
- Two publications have been submitted for peer review and work has shifted to a new publication dealing with biomass harvest energy requirements.

3. **Explanation of Variance**

Work has progressed as planned.

4. **Plans for Next Quarter**

Our efforts in the next quarter will include

- Finish re-design of the experimental high-density baler and begin part fabrication and baler modifications.
- Continue to compress large square biomass bales to increase the dataset size.
- Continue work on twine tension for large square bales.
- Continue the outdoor storage study of large square bales covered with breathable film
- Complete one additional manuscript for publication review.

5. Publications, Presentations, and Proposals Submitted

- Shinners, K.J. & J.C. Friede. 2017. Enhancing switchgrass drying rate. Submitted to BioEnergy Research. (2 Feb).
- Shinners. K.J., B.K. Sabrowsky; C.L. Studer & R.L. Nicholson. 2017. Switchgrass harvest progression in the North-Central US. Submitted to BioEnergy Res. (2 Feb.)

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**

Our efforts remain focused on moving the set of four manuscripts submitted to the Journal of the American Water Resources Association SWAT Special Series through the review process. Abstracts are again provided for the four manuscripts in the appendix to this report.

2. **Actual Accomplishments**

As reported previously, two of the manuscripts (Kling et al. and Cibin et al.) are now accepted (see citations below). The *Gassman et al.* manuscript has been revised and resubmitted on December 1, 2016, and is still under review. Lead author Gassman learned recently that the manuscript was sent to an entirely new reviewer after one of the original reviewers decided he/she could not complete the second review The *Panagopoulos et al.* manuscript was revised and resubmitted on January 3, 2017, and remains in the second phase of review at present.

Note that a very short introductory article for the special series is now published on-line (see http://onlinelibrary.wiley.com/doi/10.1111/1752-1688.12486/abstract) along with three other articles that will form most of the first set of papers in the special series. We anticipate that our complete set of four articles will be published in a later issue as part of the overall special series.

3. **Explanation of Variance**

No variance has been experienced.

4. **Plans for Next Quarter**

We are still hopeful that the review processes for the *Gassman et al.* and *Panagopoulos et al.* manuscripts will be finished by the end of the first quarter of 2017. But it is possible that additional required revisions and review could extend into the second quarter of 2017. Our goal is that all four articles will be accepted and published on-line by the end of the second quarter in 2017 but we obviously do not have control over this process so it is not certain when final acceptance and publication will occur.

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

See above.

University of Minnesota

1. **Planned Activities**

We continued submission of manuscripts from output of previous quarters.

2. **Actual Accomplishments**

This quarter, we resubmitted, after revision, three manuscripts related to the output of previous quarters, the first on the air quality impacts of increased switchgrass production, and the second and third on the modeling platform developed to support air quality impact assessment. Three papers, supported in part by CenUSA, were published (See below).

3. **Explanation of Variance**

No variance has been experienced.

4. **Plans for Next Quarter**

Continued submission of manuscripts from output of previous quarters.

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

- Harding, K., T. Twine, A. VanLoocke & J. Hill. 2016. Impacts of second-generation biofuel feedstock production in the central U.S. on the hydrologic cycle and global warming mitigation potential. Geophys. Res. Lett. 43:10773–10781. (Open Access: http://onlinelibrary.wiley.com/doi/10.1002/2016GL069981/abstract. doi: 10.1002/2016GL069981.

- Keeler, B., J. Gourevitch, S. Polasky, F. Isbell, C. Tessum, J. Hill & J. Marshall. 2016. The social costs of nitrogen. Sci. Adv. 2:1–9. (Open Access: http://advances.sciencemag.org/content/2/10/e1600219.full). doi: 10.1126/sciadv.1600219.

- Sun, J., T. Twine, J. Hill, R. Noe, J. Shi & M. Li. 2017. Effects of land use change for crops on water and carbon budgets in the Midwest USA. Sustainability 9:1–14. (Open Access: http://www.mdpi.com/2071-1050/9/2/225). doi: 10.3390/su9020225.

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

The team has focused on preparing manuscripts.

2. Actual Accomplishments

Progress has been made on manuscript preparation.

3. Explanation of Variance

No variance.

4. Plans for Next Quarter

We will continue to work on manuscript preparation. We continue to develop a manuscript on Zerovalent iron solid residue/char formation from pyrolysis of FeCl3 treated feedstock.

5. Publications, Presentations, and Proposals Submitted

- Aller, D., S. Bakshi, & D.A. Laird. 2017. Modified method for proximate analysis of biochars. J. Anal. Appl. Pyrolysis. (In Press). doi.org/10.1016/j.jaap.2017.01.012.
- Lawrinenko, M., J. (Hans) van Leeuwen & D.A. Laird. 2017. Sustainable pyrolytic production of zerovalent iron. ACS Sustainable Chem. & Eng. 2017(5):767–773. http://pubs.acs.org/doi/ipdf/10.1021/acssuschemeng.6b02105. doi: 10.1021/acssuschemeng.6b02105.
- Lawrinenko, M., Z. Wang, R. Horton, D. Mendivelso-Perez, E. Smith, T. Webster, D.A. Laird & J. (Hans) van Leeuwen. 2017. Macroporous carbon supported zerovalent iron for remediation of trichloroethylene. ACS Sustainable Chem. & Eng. 2017(5):1586–1593. http://pubs.acs.org/doi/full/10.1021/acssuschemeng.6b02375. doi: 10.1021/acssuschemeng.6b02375.
- Li, W., Q. Dang, R. Smith, R.C. Brown & M. Mba Wright. 2016. Techno-economic analysis of the stabilization of bio-oil fractions for insertion into petroleum refineries. ACS Sustainable Chem. Eng. 2017(5):1528-1537. http://pubs.acs.org/doi/ipdf/10.1021/acssuschemeng.6b02222. doi. 10.1021/acssuschemeng.6b02222.

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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 to produce 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

Continue work on the economic feasibility of grasses, modelling the optimization problem of a unique plant under different market structures and, using assumptions based on local commercial biomass processors, estimate input requirements and costs of grass feedstocks to meet the cellulosic mandate.

2. Actual Accomplishments

- Our work on the economic feasibility of grasses is ongoing.
- Graduate student Chao Li, whose dissertation work has been supported by the CenUSA project funds, successfully defended his dissertation and received his PhD. One chapter of his dissertation provided the theoretical model and simulation of the supply of stover for biofuel, a model that can be adapted for the case of perennial grasses.

3. Explanation of Variance

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

4. Plans for Next Quarter

During the third quarter our team will continue work on planned activity listed above.

5. Publications, Presentations, and Proposals Submitted

None at this time.

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**

     Submit the manuscript to the *Journal of Agriculture and Safety and Health* for review and publication.

   - **Actual Accomplishments**

     A manuscript was submitted to the *Journal of Agricultural Safety and Health* by the American Society of Agricultural and Biological Engineers. The manuscript title was *Agricultural Worker Injury Comparative Risk Assessment Methodology: Assessing Corn and Biofuel Switchgrass Production Systems*. The manuscript review indicated acceptance with minor revisions.

     Additionally, a general public manuscript was prepared and expected to be published by eXtension.org. A manuscript was submitted and reviewed.

   - **Explanation of Variance**

     None to report.

   - **Plans for Next Quarter**

     We will address the reviewers' comments for the *Journal of Agricultural Safety and Health* manuscript. Page proofs are expected to be review and this journal article be completed. The authors will also address comments raised by the eXtension.org reviewer.

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

     ✓ Ryan, S. J., C. V. Schwab & G. A. Mosher. 2016. Comparing worker injury risk in corn and switchgrass production systems: Results from a probabilistic risk assessment model. International Society for Agriculture Safety and Health. International Meeting Normal, Illinois. ISASH Paper No. 16-03. ISASH Urbana, IL 61801.

- ✓ Ryan, S. J., C. V. Schwab & 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 Agriculture Safety and Health. International Meeting Normal, Illinois. ISASH Paper No. 15-01. ISASH Urbana, IL 61801.

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

- **Planned Activities**

  Develop a plan for collecting pilot data of dust exposures without employing human subjects for collection tasks.

- **Actual Accomplishments**

  A plan for collecting pilot data of dust exposures without employing human subjects was developed but not implemented at this time. The timing of sample collection is waiting for field activities to begin.

- **Explanation of Variance**

  None to report.

- **Plans for Next Quarter**

  Have one or two pilot samples taken.

- **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

- **CenUSA MOOC – "Introduction to Perennial Grasses for Biofuels"**
  - ✓ Review preliminary participation data
  - ✓ Close inaugural MOOC offering and determine plans for a possible CenUSA MOOC Version 2 in the spring.
- **Module 10 – Plant Breeding**

  Integrate video recordings and additional data from Michael Casler (Feedstock Development, Co-PD) for the feedstock development objective.
- **Module 14 - Biochemical Conversion**

  Submit module to external reviewers.
- **Module 16 – Quality and Nutrient Management**

  Continue editing draft and merge voice recordings into presentation slides.

2. Actual Accomplishments

- **CenUSA MOOC– "Introduction to Perennial Grasses for Biofuels"**

  Initial review of participation data suggests definitive conclusions may not be drawn due to limited participant responses.
- **Module 10 – Plant Breeding**

  Content draft completed.
- **Module 14 – Biochemical Conversion**

  Additional material covering anaerobic digestion is being prepared.

- **Module 16 – Quality and Nutrient Management**

  Continue editing module content.

3. **Explanation of Variance**

   No variance was experienced.

4. **Plans for Next Quarter**

- Continue editing final module content.
- Determine repository location for modules at end of CenUSA.
- **Module 10. Plant Breeding**
  - ✓ Convert draft content to on-line version.
- **Module 14. Biochemical Conversion**

  Continue editing module content.

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

  None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. **Planned Activities**

   None as this was strictly a prior year activity. No forward planning is required.

2. **Actual Accomplishments**

   None as this was strictly a prior year activity. No forward planning is required.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

   None as this was strictly a prior year activity. No forward planning is required.

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**

   None.

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 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

- Finish Pyrolysis video.
- Publish December BLADES newsletter.
- Finish Legacy publication.
- Continue MOOC course support and user data collection eXtension work:
- CenUSA Index - http://articles.extension.org/pages/72584.
  - ✓ Add all journal publications published through the end of the CenUSA project for sections not yet completed: Feedstock Logistics: Harvest & Storage, http://articles.extension.org/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa - Module%204System Performance, Feedstock Conversion and Co-Products, Markets and Distribution, Health and Safety.
  - ✓ Final edits, additions and reorganization of the index
- Continue guidelines and instructions for future access and management of eXtension publications.
- Publish:
  - ✓ Legacy flyer which provides impact details of the project in concise format.
  - ✓ CenUSA Feedstock Development: Team Overview of Objectives and Accomplishments.
  - ✓ CenUSA Feedstock Conversion and Refining: Team Overview of Objectives and Accomplishments.

- ✓ CenUSA Feedstock Logistics: Team Overview of Objectives and Accomplishments.
- ✓ CenUSA Extension and Outreach: Team Overview of Objectives and Accomplishments.
- ✓ CenUSA Water Quality and Perennial Grasses - objectives and accomplishments
- ✓ Research Summary on potential for farmer adoption of switchgrass production (Richard Perrin and Susan Harlow, assuming the journal article has been published).

- Use eXtension Farm Energy Social Media sites to broadcast final information from CenUSA.

2. Actual Accomplishments

- **BLADES Newsletter**

  Wrote stories for the January 2017 issue of the BLADES newsletter.

  - ✓ CenUSA Bioenergy Engineers Cut Switchgrass Drying Time by 50%.
  - ✓ Plant Breeders Increase Switchgrass Yield by 40%.
  - ✓ New Market Place Opportunities for Biobased Products.

- MOOC Course

  Continued MOOC course.

- eXtension

  - ✓ support and user data collection eXtension work. See CenUSA Index at http://articles.extension.org/pages/72584
  - ✓ Added latest journal publications to eXtension site and worked on final edits, additions and reorganization of the index.
  - ✓ Developed guidelines and instructions for future access and management of eXtension publications.
  - ✓ Published eXtension articles:
    - ➢ *The CenUSA Legacy: Creating a Sustainable Biofuels and Bioproducts System for the Midwest*

(http://articles.extension.org/sites/default/files/CenUSA-Legacy-Flyer.pdf) which provides impact details of the project in concise format

- *What Would it Take to Convince Farmers to Grow Switchgrass for Biomass?* - Richard Perrin and Susan Harlow (http://articles.extension.org/pages/74212).
- *Research* Summary: *Overview of Comparative Injury Risk Between Annual Corn and Perennial Switchgrass Production* - Saxon Ryan, Charles Schwab, and Mark Hanna (http://articles.extension.org/pages/74211).
- Team Overview articles – Objectives and Accomplishments:
  - *CenUSA Feedstock Development* - Mike Casler and Susan Harlow http://articles.extension.org/pages/74210.
  - *CenUSA Feedstock Logistics: Innovative Systems for Harvest, Transportation, and Storage of Perennial Grass Biomass* - Kevin Shinners and Susan Harlow. http://articles.extension.org/pages/74073.
  - *CenUSA Feedstock Conversion and Refining* - Ryan Smith and Susan Harlow. http://articles.extension.org/pages/74206.
  - *CenUSA Extension and Outreach: Perennial Grass Bioenergy Research and Knowhow for Producers, Students and Stakeholders* - Jill Euken, Amy Kohmetcher and Susan Harlow. http://articles.extension.org/pages/74209.
  - *CenUSA Models Predict Large Water Quality Improvements from Perennials*. Pamela Porter. http://articles.extension.org/pages/74213.

✓ **Google Analytics Data**

- **eXtension Farm Energy Site**
  - **Site Usage**. Compared to last quarter page views are up by 12% and users are down by 8%. In a comparison to last year, the same quarter shows page views and users up 45% and 39% respectively.
  - **Pageviews**. Received 5,622 page views by 3,803 users, 74% of those are new sessions, averaging 1.4 pages per session. The bounce rate is 84% and average time on page is 4:34 minutes.
  - **Traffic Sources.** Traffic sources are 88% search engines (“organic”, Google, etc.), 8% direct traffic and 4% referring sites. Efforts continued to optimize publications for search engines.

- The top 10 states accessing CenUSA articles were North Carolina, Illinois, New York, Wisconsin, California, Pennsylvania, Texas, Michigan, Massachusetts and Minnesota. England and Ontario consistently top international use.

- **Website.** The CenUSA web site had 746 visitors this quarter. These visitors logged a total of 2,828 pageviews during 1140 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, and the user returns, a new session is started.

- **Continuing Impact of Vimeo Channel**. During this quarter, the 54 CenUSA videos archived on Vimeo have had 125 plays or views of the videos on our Vimeo site, or on a web site that embedded a CenUSA video. The 54 videos also had 1,107 loads; 927 of those loads came from our videos embedded on other sites. When a video is loaded, people see the video but they do not click "play". The embedded videos were played 8 times. Vimeo videos were downloaded 0 times. This 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 a video). Once the video is downloaded, it is available on their computer to watch at their convenience.

- **Continuing Impact of YouTube Channel**. CenUSA videos are also posted on YouTube, and those videos have been viewed 1385 times between November 1, 2016 and January 31, 2017. 857 views were from the United States. Demographic analytics report an audience that is 73% male and 27% female. Our viewers ranged in age from 13-65+. The top 3 represented age groups were 25-34 (35%), 35-44 (23%), and 18-24 (17%).

  YouTube also provides data related to how users access the videos. Videos were viewed on their associated watch page, the YouTube Channel page, or on web pages where the videos were embedded. 98% of the videos were viewed on their associated YouTube watch page (each video has a unique "watch page"). Embedded videos on another site accounted for 1.8% of the views, and .2% of video views came from the YouTube Channel page. 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 browse features (subscription feed, homepage navigation options, etc.). 34% of our views came from users accessing videos suggested by YouTube.

YouTube search accounted for 30% of our views. Referrals from outside YouTube (google search or access through external web sites) account for 24% of video views. Browse features accounted for 3.5% 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. CenUSA bioenergy has 977 followers currently, up from 900 followers last quarter

- **Facebook**. By the end of January 2017, CenUSA's Facebook page had 254 likes, up from 253 the previous quarter.

- **BLADES Newsletter**. Writing and publication of six stories for the January 2017 issue:

  ✓ *CenUSA Bioenergy Engineers Cut Switchgrass Drying Time by 50%*

  ✓ *Models Predict Large Water Quality Improvements from Perennials*

  ✓ *Switchgrass - Newest Product in the $2.5 Billion Cat Litter Market?*

  ✓ *Extension and Outreach: Takin' it to the streets and fields*

  ✓ *Plant Breeders Increase Switchgrass Yield by 40%*

  ✓ *New Market Place Opportunities for Biobased Products*

3. Explanation of Variance

- The December BLADES Newsletter was pushed back to January 2017 due to difficulty scheduling interviews during the holidays.

- The pyrolysis video was not finished as the MOOC and other projects needed to meet original deliverables outline and were prioritized over the video. The pyrolysis video will still be finished by the end of the no cost extension of the grant.

4. Plans for Next Quarter

Finish the pyrolysis video, which will also be utilized by the Education Objective. This is the only holdover activities for this component of the project. All other work is complete.

5. Publications, Presentations, Proposals Submitted

- January 2017 Edition of BLADES Newsletter (completed, but publication held until 2017).

- CenUSA eXtension materials including:
  - ✓ *The CenUSA Legacy: Creating* a Sustainable Biofuels and Bioproducts System for the Midwest, which provides impact details of the project in concise format. http://articles.extension.org/sites/default/files/CenUSA-Legacy-Flyer.pdf
    - ➢ *What Would it Take to Convince Farmers to Grow Switchgrass for Biomass?* - Richard Perrin and Susan Harlow. http://articles.extension.org/pages/74212
    - ➢ *Research Summary: Overview of Comparative Injury Risk Between Annual Corn and Perennial Switchgrass Production* - Saxon Ryan, Charles Schwab, and Mark Hanna. http://articles.extension.org/pages/74211

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

1. Planned Activities

- **Indiana**
  - ✓ Organize and conduct a webinar to share overall results from Purdue components of the CenUSA project.
  - ✓ Plan for the future of the CenUSA on-farm demonstration plots.
- **Iowa**

  Present CenUSA session at the Iowa Integrated Crop Management Conference (December 1, 2016) and a session at the SW Iowa Crop Advantage Series.
- **Minnesota**
  - ✓ Finish grassland assessment and harvest the CenUSA demonstration plots.
  - ✓ Attend and participate in the Soil Science Society of America meetings to present data from CenUSA studies.
- **Nebraska**.

  None, work was completed in October 2016.

2. Actual Accomplishments

- **Indiana**
  - ✓ Evaluated weekly growth and development data collected from ‘Shawnee’ and ‘Liberty’ at the CenUSA demonstration field plots.

- ✓ Ground tissue from field samples collected during the growing season.
- ✓ Presented a CenUSA session at Southwest Indiana Ag Summit (65 participants; 35 males and 30 females).

- **Iowa**
  - ✓ Summarized and reported data from CenUSA demonstration plots.
  - ✓ Shared data with 5 males.
- **Minnesota**
  - ✓ Finished grassland assessment and harvested the CenUSA demonstration plots.
  - ✓ Presented a session at Soil Science Society of America meeting in November (see: https://scisoc.confex.com/scisoc/2016am/webprogram/Paper99966.html).
- **Nebraska**

  None, project is complete.

3. **Explanation of Variance**

None.

4. **Plans for Next Quarter**

- **Indiana**

  None, project is complete.
- **Iowa**

  None, project is complete.
- **Minnesota**

  None, project is complete.
- **Nebraska**

  None, project is complete.

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

Switchgrass and Mixed Perennial Biomass Production on Two Marginally Productive

Soils As Affected By Nitrogen Fertility and Harvest Management. https://scisoc.confex.com/scisoc/2016am/webprogram/Paper99966.html.

- **Economics and Decision Tools**

1. Planned Activities

Continue to share perennial grass economics information via workshops and continue promoting use of CenUSA Perennial Grass Decision Tool (http://www.extension.iastate.edu/AgDM/crops/html/a1-29.html).

2. Actual Accomplishments

- Conducted CenUSA session to present final CenUSA results and promote the CenUSA Decision tool at the Iowa State University Crop Management Conference on December 1st. 58 people attended.

- Conducted CenUSA session to present final CenUSA results and promote the CenUSA Decision tool at the SW Iowa Crop Advantage Workshop on January 17th. 112 people participated in the session.

- 108 people downloaded/completed the CenUSA Decision Tool this quarter ((http://www.extension.iastate.edu/AgDM/crops/html/a1-29.html).

3. Explanation of Variance

None.

4. Plans for Next Quarter

Conduct final extension economics outreach events in Iowa.

5. Publications, Presentations, Proposals Submitted

Perrin, R.K., L.E. Fulginiti & Alhassan. (2017). Biomass from marginal cropland: willingness of North Central US farmers to produce switchgrass on their least productive fields. Biofuels, Bioproducrts & Biorefining 11(2): 281–294. Abstract: http://onlinelibrary.wiley.com/doi/10.1002/bbb.1741/abstract.

- **Health and Safety**

See Objective 7.

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

- **Youth Development**

1. **Planned Activities**

- **Indiana**

✓ Continue to work on curriculum, app finalization, online learning modules finalized, planning for March workshop.

✓ Plan for 4-H Science Academy for summer 2017.

✓ Plan for presentation and dissemination at National Science Teachers Association National conference, Los Angeles (March).

- **Iowa**

✓ Plan for 2017 summer workshops for Ag Ed and science teachers. Submit abstract to National Agriculture in the Classroom conference (NAICC) to present CenUSA C6 BioFarm session at NAICC summer conference.

✓ Prepare exhibit and session for session at NAICC.

2. **Actual Accomplishments**

- **Indiana**

✓ Curriculum, app, on-line learning modules are finalized. Final versions will be uploaded to the web in March 2017.

✓ Planning for presentation at National Science Teachers Association National conference completed.

- **Iowa**

An abstract was submitted for presentation at NAICC summer conference.

3. **Explanation of Variance**

None noted.

4. **Plans for Next Quarter**

- **Indiana**

A presentation at National Science Teachers Association Conference meeting.

- **Iowa**

  Plan for a session and exhibit at NIACC.

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

- **Indiana**

  Final products will be published in March 2017

- **Iowa**

  ✓ Abstract to NAICC.

  ✓ NW Iowa AEA Teacher Curriculum Application (for teacher renewal credit) for participation in CenUSA C6 Curriculum training.

Broader Public Education/Master Gardener Program

This component of the project was only funded from Years 1-4 of the CenUSA project. However, a journal article summarizing the research is under development for submission to the *Journal of Extension*.

Evaluation and Administration

1. **Planned Activities**

- Collect information from CenUSA Extension teams and prepare reports.
- Continue promotion of CenUSA C6 Youth app, videos, curriculum.
- Prepare and submit applications to Northwest Iowa AEA and Morningside College to provide teacher renewal credit and graduate credit for teachers completing the CenUSA C6 BioFarm training program in June 2017.
- Prepare and negotiate contract with Morningside College to host training CenUSA C6 BioFarm training program on their campus in June 2017.
- Submit abstract to National Agriculture in the Classroom Conference to present session in June 2017.

2. **Actual Accomplishments**

- Compiled reports from the CenUSA Extension team.
- Received approval for CenUSA C6 teacher renewal credit for professional

development course to be offered in June 2017 (see: https://staffdev.aea4.k12.ia.us/4DCGI/SC003599761801INV&*).

- Selected for presentation at plenary session and breakout session at the National Agriculture in the Classroom Conference (http://naitcconference.usu.edu/index.cfm).
- Abstract submitted last quarter to National Extension Energy Summit (April 2017) was selected for presentation (https://ag.tennessee.edu/solar/nees2017/Pages/Agenda.aspx).
- Presented results from CenUSA and promoted use of CenUSA Decision Tool at Iowa Integrated Crop Advisor Conference (57 participants) on December 1, 2016.
- Presented results from CenUSA and promoted use of CenUSA Decision Tool at SW Iowa Crop Advantage (112 participants) on January 17, 2017.

3. **Explanation of Variance**

None.

4. **Plans for Next Quarter**

- Produce report summarizing impact of CenUSA Extension efforts.
- Prepare for, and present CenUSA C6 session at National Extension Energy Summit in April in Tennessee.
- Advertise for, and recruit teachers to register to participate in the CenUSA C6 teacher training program to be held June 2017.
- Create exhibit for National Agriculture in the Classroom conference.

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

None this quarter.

Objective 10. Commercialization

Sub Objective 10A. Archer-Daniels-Midland

No activities were undertaken as this was strictly a Year 1 to Year 5 activity. No forward planning is required.

Sub-Objective 2. Renmatix

1. **Planned Activities**

   Evaluate higher-value lignin applications to improve biorefinery economics

2. **Actual Accomplishments**

   Work continues on lignin applications that have the potential to make significant economic improvements to a biorefinery using the Renmatix Plantrose® process to convert perennial grasses into sugars and lignin. We have indicated previously that lignin from perennial grasses may be a viable component in adhesives for the wood panel industry.

   Lignins derived from corn stover and switchgrass were produced in the Plantrose® pilot plant. These lignin products were converted to thin alkaline slurries and used in partial replacement of phenol-formaldehyde (PF) adhesive in the manufacture of OSB (oriented strand board) wood panels at the University of Maine's Advanced Structures and Composites Center. Commercial aspen strands were used in random orientation to produce ½" thick panels.

   The resinated strands were formed into 3-layer, non-oriented mats on top of steel screens using hand lay-up techniques. The panels were hand-trimmed to 30" x 30". The resulting panels were tested for their mechanical strength and durability against the stringent criteria of the evaluation standards ASTM D1037 and Canadian CSA 0437. Under industrially realistic OSB manufacturing conditions, glue mixes from hardwood, switchgrass and corn stover at up to 25% PF resin substitution rate in the OSB face layers passed the requirements of the standards in terms of internal bond strength, bending strength, water resistance and accelerated aging.

   The wood panel and engineered wood products industry is under increasing environmental and regulatory pressure, and is looking for alternative wood adhesives that are environmentally friendly and preferable derived completely or partially from biomaterials that are competitive in cost and performance. The testing results described are important in that they identify a high value application for switchgrass derived lignin from a Plantrose® biorefinery that has the potential to meet the wood industry needs while adding to the biorefinery economics.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

   Examine the applicability of switchgrass derived lignin for use in thermoplastic composites as an additional higher-value lignin product from a biorefinery.

5. Publications / Presentations /Proposals Submitted

None.

Objective 10C. USDA-ARS, Lincoln, Nebraska - Alternative Uses for Native Perennial Warm-season Grasses

Nothing of significance to report this quarter.

Exhibit 1

Creating a Sustainable Biofuels and Bioproducts System for the Midwest

Reaching Our Objectives:

More than 40 million acres of land within the Central United States could be shifted from row crop production to perennial crops, reducing runoff of agricultural nutrients and helping to make agriculture more sustainable and profitable.

Since 2012, CenUSA's systems approach has made important contributions to this goal, laying the groundwork for a sustainable, regional system for biofuels and bioproducts.

Germplasm to Harvest

Feedstock Development

Plant breeders from USDA ARS created 'Liberty', a new switchgrass variety which yields 40% higher and is widely adapted throughout the Midwest, by combining yield traits from southern lowland types with winterhardiness of upland types.

Eight gene pools of switchgrass were identified, which could improve commercial varieties, and an NIR calibration to analyze switchgrass properties was developed.

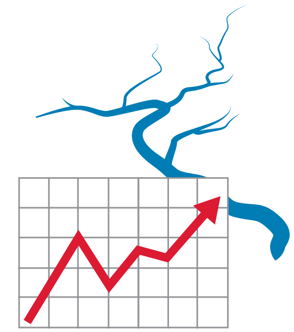
Sustainable Feedstock Production Systems

Researchers created an extensive library of information on leading bioenergy crops through a network of 14 research fields across the Central United States. Result: 28-peer reviewed publications. They developed best management practices for growing and managing switchgrass, showing that it is well-suited to marginal soils where crops like corn and soybean are less productive.

Feedstock Logistics

Engineers designed methods and equipment that decreased field drying time of switchgrass by 50%, increased bale densities and reduced grinding energy, thereby improving harvest, handling and transportation efficiency, and storage costs.

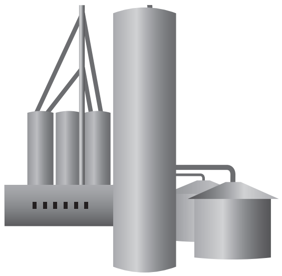
The project team developed methods to determine optimal machinery selection for switchgrass harvest and transportation, evaluated different switchgrass storage scenarios and conducted an analysis of feedstock supply costs.



System Performance Metrics, Data Collection, Modeling, Analysis, and Tools

A multidisciplinary scientific team assessed the impacts of introducing switchgrass and miscanthus, perennial biofuel crops, on cropland exceeding 2% slopes for watersheds in Indiana, Iowa and across the Corn Belt. When the grasses were introduced, nitrate, total P or sediment losses were found to decrease between 1% to 52%, depending on the combinations of pollutants and the watershed system.

Post Harvest



Feedstock Conversion/Refining

A new way of looking at the pyrolytic process–using perennial grasses in a thermal process to extract sugars and then substitute the sugars in a traditional fermentation–was developed. This technology, along with Renmatix's supercritical hydrolysis and ADM's acetosolv processing, will lead to conversion of grasses into biofuels and value-added products such as biochar, bioasphalt, cellulose pulp, fermentable sugars and carbon fibers.

Markets and Distribution

Researchers developed production cost estimates for switchgrass, using best production practices for the Midwest. From those, a new decision tool was created that guides producers in understanding how net returns to switchgrass production on their land compare with alternative land uses.

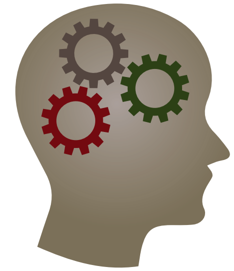
Based on market experiences of commercial cellulosic production, economists show that conventional agricultural systems do not supply enough residues to meet the cellulosic ethanol mandate, leaving room for grasses and other biomass to be competitive in that market.

Health and Safety

A new probabilistic risk assessment model was developed to estimate the difference in human safety risk between two agricultural production systems over a region. The model will improve the understanding of risks in biomass feedstock production as compared to the current crop production systems.

Results were presented at professional meetings and in journal and Extension publications.

Education



Sixty-six students went through CenUSA's undergraduate interdisciplinary internship program in which interns worked on research projects at several universities.

Seventeen online education modules were created, covering relevant topics across the bioenergy supply chain.

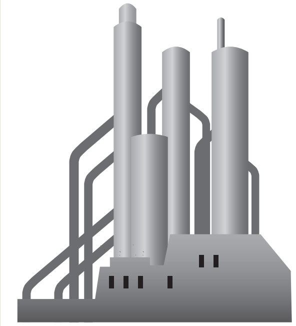
The Massive Open Online Course (MOOC): ***Introduction to Perennial Grasses for Biofuels*** was created, using CenUSA education and extension materials. It is a packaged curriculum, allowing free public access to an online self-paced learning experience for farmers, industry leaders and students.

Extension and Outreach

More than 5,000 farmers and agricultural industry leaders, 600 Extension Educators, 3,000 youth and 6,000 gardeners/horticulturalists gained new knowledge of CenUSA research by participating in seminars, workshops, field days, conferences, and camps.

A range of decision support tools and easy-to-use information on seeding rate, planting depth and equipment, weed control, harvest, crop yield, soil health and fertility are found in more than 50 publications and videos created by the CenUSA team and archived on the eXtension and CenUSA Bioenergy websites.

Commercialization



Results of partnerships with commercial businesses:

- Renmatix patented a process that could lead to cost-effective production of industrial sugars from perennial grasses on a commercial scale.
- Archer Daniels Midland is testing pulping potential of perennial grasses for use in producing personal care products such as paper towels and toilet paper.
- Vermeer Corp. advised CenUSA and hosted demonstration plots of switchgrass and other perennial grasses.

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

HD16107

United States Department of Agriculture

National Institute of Food and Agriculture

Research Summary: What Would it Take to Convince Farmers to Grow Switchgrass for Biomass?

Exhibit 2

Farm Energy - March 01, 2017 (20170301) Print (http://www.printfriendly.com)

Researchers delve into the economic incentives that would induce farmers to grow switchgrass for cellulosic biofuel.

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Abstract

A survey of crop farmers in the North-Central region of the United States finds that they would ask for an average of $230 per acre, or about $82 per dry ton, to grow switchgrass for cellulosic biofuel on their marginal crop land. The survey also found that farmers are more willing to use that land to produce switchgrass themselves, rather than lease out the land to another entity for growing switchgrass.

Research Purpose

The U.S. Congress has mandated, under the Renewable Fuel Standard, that cellulosic biofuels provide 16 billion gallons a year of transportation fuel by the year 2022. However, a sustainable biofuel industry requires a steady supply of cellulosic biomass, and in order to establish that supply, farmers must have an economic incentive to grow the feedstock.
For the last decade, researchers have been trying to determine how much cellulosic feedstock U.S. producers are willing and able to supply. Richard Perrin, Mustapha Alhassan, and Lilyan E. Fulginiti of the Department of Agricultural Economics at the University of Nebraska, Lincoln (UNL), wanted to refine and add to that research. They sought to find out how much revenue farmers in the North-Central region, the most productive grain-producing region in the country, would need in order to shift their marginal crop land into switchgrass production.

Switchgrass field, NE. *Image: CenUSA*

Switchgrass is an attractive feedstock crop for cellulosic ethanol because it produces large amounts of biomass, is native to the region and familiar to farmers, and can be grown across much of the United States.

Research Activities

Perrin and his colleagues used one of four standard approaches, called the contingent valuation approach, to gather information directly from farmers on potential choices. During the winter of 2014-2015, the researchers sent surveys to 2,100 farmers in 10 North-Central states and received responses from 54 percent.

Their research area was divided into three economic regions, defined by opportunity costs; they used Conservation Reserve Program rental rates to determine suggested prices for each region. (The Conservation Reserve Program, administered by the Natural Resources Conservation Service, pays farmers to grow grass rather than crops on marginal cropland.)

Their survey asked producers two whether, if they were offered a specific net return per acre, they would be willing to accept a contract to grow switchgrass on their least-productive field for the next five years. They were also asked if they would be willing to lease out that land for switchgrass production. The farmers were given information on the average cost of establishing, growing, and harvesting switchgrass, as well as average annual net revenue.

Each producer was randomly assigned one of nine different net return levels, providing information about potential production response at different price levels. The researchers then analyzed the results.

Their work was supported by the USDA National Institute of Food and Agriculture and by UNL's Agricultural Research Division.

What We Have Learned

The average farm-gate net returns that farmers said they would accept—$230 per acre, or $82 per dry ton—is close to the goal of $84 per dry ton, delivered to the biorefinery, set by the U.S. Department of Energy (DOE), which leads the country's renewable energy efforts. Regional land values and rental rates had a strong influence on the prices that farmers were willing to accept to convert to switchgrass. In the two sub-regions with lower land values and rental rates, average net returns of $75 and $82 per dry ton were acceptable. In the third region, however, where land values were highest, the acceptable $99-per-dry-ton price was much higher than the DOE's goal.

Interestingly, farmers were more willing to grow their own switchgrass than lease out their land for that purpose. Farmers would only accept an average of $14 per acre more to lease their land (about $3.50 per ton), rather than to grow switchgrass themselves.

But in the biofuel system, that extra cost to biorefineries could be offset by savings in transaction costs and the scale of production. Biorefineries face significant transaction costs in trying to negotiate individual production contracts with the hundred or more producers required to supply the plant. The refieneries could instead offer to lease land at a blanket rate, producing and delivering the switchgrass from the individual farms themselves. While biorefineries would need to pay a higher rate to the farmer for the leasing approach, they could likely produce at lower cost because of scale economies, and reduce the transaction costs related to negotiating with farmers.

The research also found that the more pasture a farmer grew, the less likely he or she was to opt for switchgrass production, perhaps because switchgrass was viewed as a competitor to current grass and pasture activities. Likewise, the more grain a farmer grew, the more likely he or she was to favor switchgrass, perhaps because the two crops are complementary.

Why Is This Important?

Although the development of a cellulosic biofuel industry is lagging, it may someday thrive—but only if there is a consistent supply of affordable feedstocks, such as switchgrass. This study investigates more deeply the economic incentives that could persuade farmers to produce switchgrass for biomass. It also gives biofuel processors more information on how to obtain feedstocks, through negotiation with producers or leasing land to grow their own supply.

For More Information

- Perrin, Richard K, Lilyan Fulginiti and Mustapha Alhassan. 2017. Biomass from Marginal Cropland: Willingness of North Central US Farmers to Produce Switchgrass on Marginal Fields (http://dx.doi.org/10.1002/bbb.1741) . Biofuels, Bioproducts and Biorefining (1/27/2017). DOI: 10.1002/bbb.1741
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- Perrin, Richard K. 2014. Switchgrass Economics in the North Central Region of the U.S.A (https://vimeo.com/87694103) . Webinar.
- Perrin, Richard K. and Susan J. Harlow. 2014. T (/pages/71073/the-economics-of-switchgrass-for-biofuel) he Economics of Switchgrass for Biofuel (/pages/71073/the-economics-of-switchgrass-for-biofuel) . extension.org.
- CenUSA Project Resources (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

Contributors to This Summary

Authors:

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- Susan J. Harlow, Freelance Journalist

Peer Reviewer:

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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 is supported by Agriculture and Food Research Initiative (http://nifa.usda.gov/cenusa-bioenergy) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

Research Summary: Overview of Comparative Injury Risk Between Annual Corn and Perennial Switchgrass Production

Exhibit 3

Farm Energy - February 28, 2017 (20170228) Print (http://www.printfriendly.com)

A probabilistic risk assessment model has been created to compare estimated worker injury risk of corn vs switchgrass production.

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Introduction

Switchgrass is a perennial crop alternative for biofuel production on marginal land in the U.S. Cornbelt. Estimating change in worker injury risk moving from corn to switchgrass production would be helpful before major production changes occur.

Safety risk assessment in agriculture has been limited for whole production systems and across regions. A comparative risk assessment model between corn and switchgrass has been developed that makes use of limited agricultural injury data. The assessment uses published USDA and Bureau of Labor Statistics (BLS) data along with Midwestern U.S. data on injuries with various pieces of farm equipment.

Injury Risk Model

The model develops a probability distribution of agricultural worker exposure to specific machines and processes, and couples this with a probability of injury distribution relating to specific machines. A more complete description of the modeling method is in Ryan et al., 2016. Probability of exposure is developed by Midwestern state and enterprise (corn or switchgrass) from USDA Ag Census data using acres of corn or grass crops (e.g. hay, grass forage). Probability of injury is developed from state and enterprise (corn or switchgrass) injuries and the number of farms, assuming one worker (farmer) per farm.

Comparing a perennial crop (switchgrass) to an annual crop (corn) requires a multi-year evaluation, in this case ten years (equaling the assumed life of a switchgrass planting). Exposure scenarios during production are divided into establishment/seeding (March – May), mid-season management (May – September; e.g. pest control), and harvest (September – November). Although corn is planted and harvested each year, switchgrass is planted the first year with an assumed replanting activity of 50% of the area the second year. Switchgrass harvest begins with an assumed harvest of 50% of the area during the second year, but harvest of 100% of the area thereafter (years 3 – 10).

Harvesting switchgrass. *Photo: CenUSA*

Injuries by agricultural machine type and month have been reported by Gerberich et al. (1998) for several Midwestern states. Gerberich et al. reported 83.44% of total annual injuries occurred during the March – November period, the period of interest for establishment through harvest. Distribution of injuries by machine type (e.g. planter, combine, baler) were calculated as a percentage of all agricultural related injuries by state for specific years. For total injuries, BLS agricultural injury counts (1996 – 2011) were selected as most consistent and representative data available. These annual statewide counts were multiplied by the injury distribution percentage by machine for individual states (i.e., Indiana planter, Wisconsin baler) to obtain a range of injuries due to various machines in various states for various years. Probability of injury for any combination of machine type by state and by year, equaled the number of injuries divided by the number of exposed workers to that machine operation. Total exposed workers equaled the number performing that operation in the state that year (as based on USDA Ag Census data, assuming one worker per farm and allocating machine operations to various crops).

Individual machine operations were placed within the appropriate exposure scenario (establishment, management, or harvest) to group machine activities rather than imply precise measurement of risk with any single machine. The combination of estimated probability of injury and probability of exposure from a range of years and locations (states) allows use of a stochastic (Monte Carlo type (https://en.wikipedia.org/wiki/Stochastic_simulation#Monte_Carlo_simulation)) simulation model to capture the range of risk considering all possible values of year, location, and machines across the Midwestern U.S. for which data are obtained.

Comparing Injury Risk in Corn and Switchgrass Production Systems

Random chance was used to select various combinations and calculate worker injury risk (likelihood of injury given that exposure to a machine hazard has occurred) for 500,000 runs, each over a 10-yr period, using the exposure and injury data developed for the model. A frequency distribution of worker risk for establishment, management, and harvest was constructed to identify the greatest contributing factor to worker risk in each system as well as the comparative overall risk difference between switchgrass and corn production systems in the Midwestern U.S.

Figures 1 and 2 show frequency distributions of worker injury risk, respectively for corn and switchgrass production, during establishment, management, or harvest periods from 500,000 runs of randomly selected exposure and injury data across years and locations.

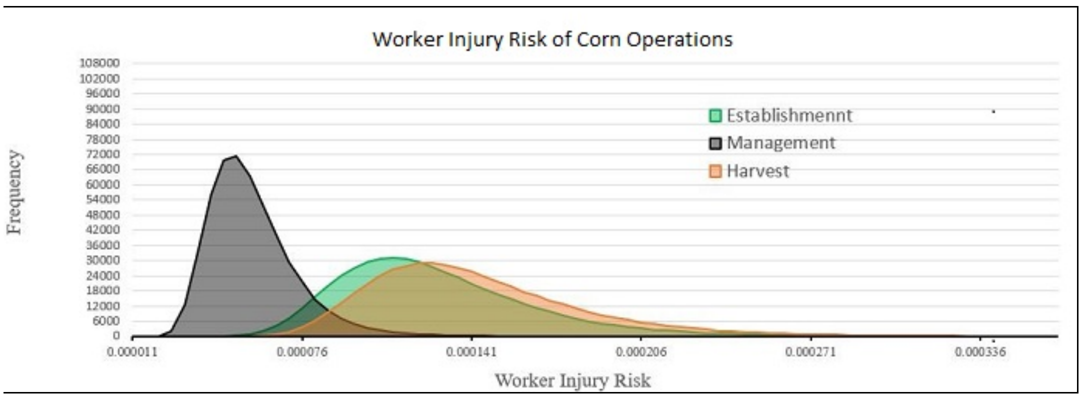


Fig.1. Worker injury risk frequency distributions for corn establishment, management, and harvest operations.

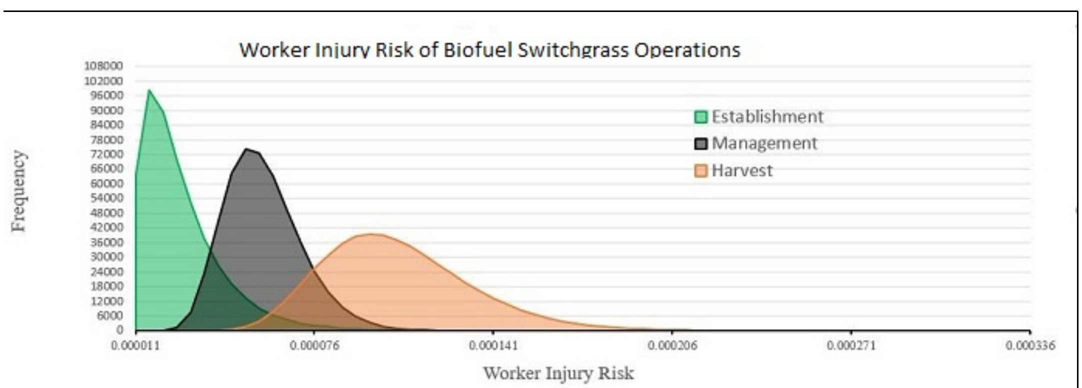
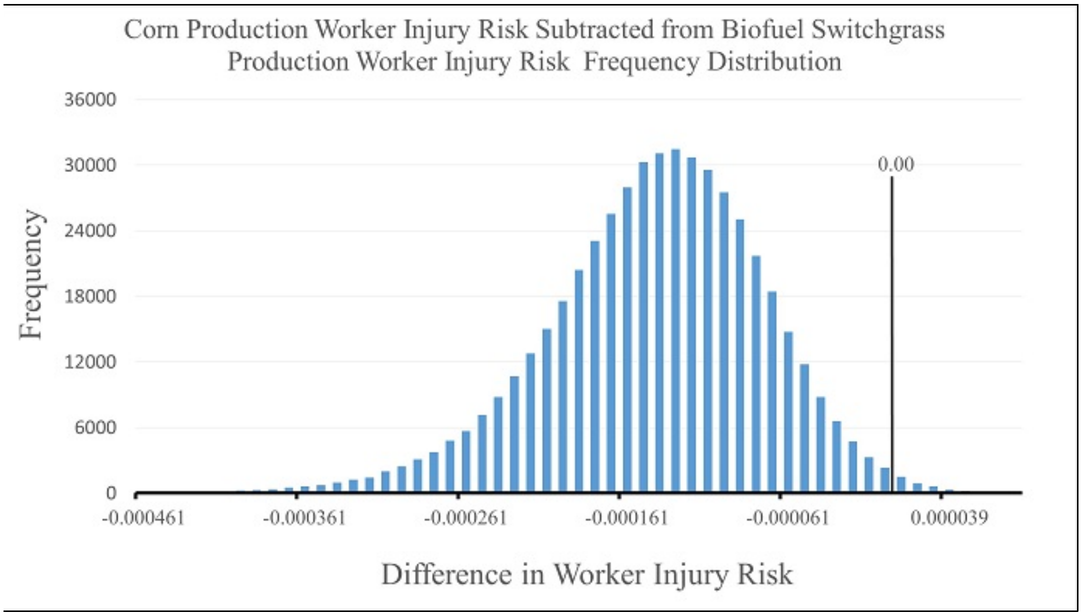


Fig.2. Worker injury risk frequency distributions for biofuel switchgrass establishment, management, and harvest operations.

Harvest activity has the greatest worker injury risk in both corn and switchgrass enterprises with a mean risk for injury during the ten year life cycle of 137 per 100,000 workers for corn and 101 per 100,000 workers for switchgrass. Establishment (tillage and seeding) is the next greatest risk for worker injury in corn as it is seeded and established each year. Conversely for switchgrass production, worker injury risk during establishment is lower than risk during the management period as seeding occurs only the first year and again partially the second year. Management occurs each year during the ten-year life cycle of annual corn and has a smaller worker injury risk than harvest and establishment.

The comparative risk of worker injury for switchgrass production as compared to corn production summing all three exposure scenarios of establishment, management, and harvest is shown as a frequency distribution of all 500,000 runs developed from random combinations of years and locations. Injury risk was less for switchgrass production in 99% of the cases (i.e., runs).

Fig.3. Difference between switchgrass and corn worker injury risk frequency distribution for 500,000 variations of years and



ocation. Injury risk was less for switchgrass production.

Summary

Limited data are available to estimate agricultural worker injuries. A probabilistic risk assessment model to estimate worker injury risk has been developed using USDA and Bureau of Labor Statistics (BLS) data of farming operations and worker injuries.

Data imply harvest is more prone to injury risk than crop establishment or mid-season management activities. Annual corn production is estimated to have greater injury risk than perennial switchgrass production, in part due to annual required seeding establishment.

References

- Gerberich, S. G., Gibson, R. W., French, L. R., Lee, T., Carr, W. P., Kochevar, L., Renier, C. M., & Shutske, J. (1998). Machinery-related injuries: Regional Rural Injury Study—I (RRIS—I), Accident Analysis & Prevention, 30(6), 793-804.
- Ryan, S. J., Schwab, C. V., and Mosher, G. A. (2016). Comparing worker injury risk in corn and switchgrass production systems: Results from a probabilistic risk assessment model. International Society of Agricultural Safety and Health. Paper no. 16-03.
- CenUSA Project Resources (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

Contributors to This Summary

Authors: Saxon J. Ryan, Charles V. Schwab, and H. Mark Hanna, Agricultural and Biosystems Engineering Department, Iowa State University

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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 is supported by Agriculture and Food Research Initiative (http://nifa.usda.gov/cenusa-bioenergy) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

CenUSA Feedstock Development Creates Improved Switchgrass Varieties

Exhibit 4

Farm Energy - March 01, 2017 (20170301) Print (http://www.printfriendly.com)

CenUSA Feedstock Development Team identifies gene pools and genetic diversity for improved switchgrass varieties and increased yields.

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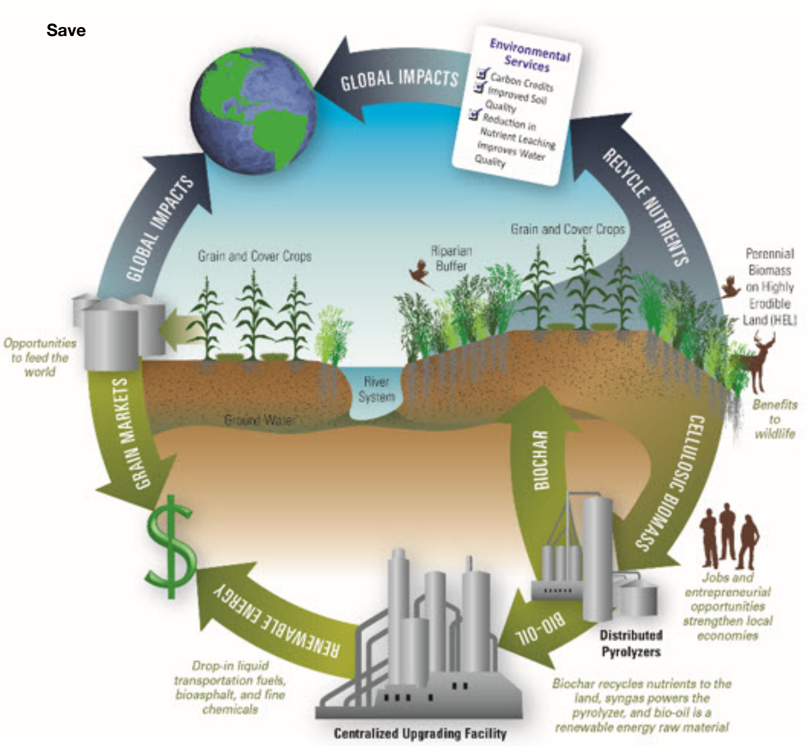

The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed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

Team Objectives

The objective of the CenUSA Feedstock Development team is to develop new and improved perennial grass varieties and hybrids that can be used on marginal cropland in the Central United States for the production of biomass for bioenergy and bioproducts.

The Team and Collaborators

The team's **Project Directors** are Mike Casler, Plant Breeder at the U.S. Dairy Forage Research Center and Rob Mitchell, Research Agronomist at the USDA Agricultural Research Service (ARS).

Team Collaborators provided expertise across a number of disciplines: Bruce Dien, bioenergy researcher and chemical engineer at the USDA-ARS; Gary Yuen, plant pathologist at the University of Nebraska – Lincoln; Tiffany Heng-Moss, entomologist at the University of Nebraska – Lincoln; Akwasi Boateng, chemical engineer specializing in biofuels, USDA-ARS; and Ken Moore, agronomist at Iowa State University.

Team Activities

The CenUSA's Feedstock Development team worked on developing new switchgrass varieties and ways to produce more biomass with the goal of doubling switchgrass yields by 2020, primarily through boosting the rate of annual gain. The team's efforts focused on switchgrass, a perennial warm-season grass native to most of North America, because of its potential for high yields on marginal cropland and adaptation to a wide range of habitats and climates.

By employing new methods such as hybridization, delayed flowering, and genomics, the team worked to generate new switchgrass varieties for both bioenergy and forage that are more vigorous and better adapted to marginal lands. They also studied how to better manage switchgrass plants.

Researchers and graduate students scoured fields and prairies for switchgrass plants of many varieties. They brought hundreds of leaf or seed samples back to their laboratories and then spent even more hours in the lab, studying and sequencing plant DNA. Other team members sampled switchgrass plants to discover how they are threatened by insects and diseases.

Outcomes from The Team's Work

The team's achievements ranged widely. Researchers:

- **Created Liberty,** a new switchgrass variety that yields 40% more than other varieties and is widely adapted throughout the Midwest**.** Plant breeders combined yield traits from southern lowland types with winterhardiness of northern upland types to create Liberty.
- **Developed a system for classifying gene pools** of switchgrass that could provide germplasm for improvement of varieties for biofuels and ecosystems services.
- **Identified eight gene pools** of switchgrass across the United States that could be a rich source of germplasm to improve commercial switchgrass varieties for biofuel production, and in restoration and conservation work. These gene pools harbor a great deal of genetic variety, providing a potential source of improved germplasm for new varieties that can respond better to climate change. Identification of gene pools gives plant breeders more information, leading to development of a wider range of varieties, adapted to specific regions, for producers to choose from.
- **Identified the origins and the genetic diversity** of the two switchgrass ecotypes, upland and lowland, in their native habitats. Because the two ecotypes are adapted to different environments, that identification is important in the classification of gene pools.
- **Identified potential pests of switchgrass**. Entomologists found that insects such as aphids could threaten switchgrass production for biofuels. They found that some varieties have resistance to these pests, information important in the development of new varieties. A significant question for researchers to answer in the future: how will manipulating switchgrass varieties to improve them affect their resistance to pests?
- **Identified the Panicum mosaic virus** as a significant pathogen that could stymie production of switchgrass for biofuels. Geneticists are studying the plant's response to this and other pathogens. Results will help pathologists make recommendations on preventing and managing diseases in switchgrass.
- **Developed a method of NIR calibration** to measure more plant properties in switchgrass. This will be valuable in breeding improved bioenergy crop lines and will eventually be used by commercial biorefiners in thermochemical and biochemical conversion processes.

Knowledge of composition directly affects product conversion yields and reaction conditions for optimal processing. A rapid and inexpensive method for analyzing chemical composition of switchgrass and other warm-season grasses will enable effective plant breeding of better bioenergy crop lines, and is now being adopted by other perennial grass researchers. It will also help commercial biorefiners to efficiently and accurately grade biomass delivered at the factory gate.

Why This Work Is Important

The work of CenUSA's Feedstock Development Team is a cornerstone in the creation of a flourishing biofuels industry. It is valuable to perennial-grass producers, to processors and refineries, and to geneticists and plant breeders who will create the varieties of the future.

By identifying and classifying switchgrass gene pools, then employing them to develop new varieties, the team opens up more possibilities for successful switchgrass production. For example, introduction of the new variety, 'Liberty,' gives potential producers in the Midwest an excellent choice that is well adapted to their area, so they have a greater opportunity for success.

Plant breeders are providing important new information for the successful management of switchgrass.

These findings provide a foundation for continued work into the future, including:

- Developing more varieties, better adapted to marginal lands, later flowering, and higher yielding.
- Employing new genomic technologies to accelerate development of new varieties and genetically modified switchgrass, and to improve winter survival in southern types of switchgrass.
- Developing more efficient fermentation of biomass, a plus for producing either animal products from forage or liquid fuels from biomass.
- Improving the plant's capacity to recycle more nitrogen (N) back into its roots before it is harvested, so growers need apply less N fertilizer.

Contributors to This Report

Authors:

- Michael D. Casler (http://www.ars.usda.gov/pandp/people/people.htm?personid=32258) , USDA-ARS, U.S. Dairy Forage Research Center
- Susan J. Harlow, Freelance Journalist

CenUSA Feedstock Development Team Publications

Fact Sheets

- 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))
- 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

Research Summaries

- 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 Finds Strong Genetic Diversity in Switchgrass Gene Pools (/pages/70383/research-summary:-research-finds-strong-genetic-diversity-in-switchgrass-gene-pools) - Michael Casler

Webinars

- Switchgrass and Perennial Grasses, Biomass and Biofuels - Part 1 (http://farmenergymedia.extension.org/video/part-1-switchgrass-and-perennial-grasses-biomass-and-biofuels-captions) - Ken Vogel, USDA-ARS
- 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
- Diversifying Cellulosic Feedstocks (http://farmenergymedia.extension.org/video/diversifying-cellulosic-feedstocks-native-perennial-grasses) - DK Lee
- Aphid Resistance in Switchgrass CenUSA Bioenergy (http://farmenergymedia.extension.org/video/aphid-resistance-switchgrass) - Kyle Koch

Instructional Video

- Plant Breeding to Improve Yield and Sustainability of Perennial Grasses (http://farmenergymedia.extension.org/video/plant-breeding-improve-yield-and-sustainability-perennial-grasses) - Michael Casler
- 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

FAQs (Frequently Asked Questions)

- Why is it important to be able to grow a consistent and uniform supply of a biomass feedstock? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%201)
- Should I begin establishing switchgrass in case they put a cellulosic ethanol plant near by? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2015)

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- CenUSA Project Resources (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

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 is supported by Agriculture and Food Research Initiative (http://nifa.usda.gov/cenusa-bioenergy) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

CenUSA Feedstock Logistics: Innovative Systems for Harvest, Transportation, and Storage of Perennial Grass Biomass

Exhibit 5

Farm Energy - February 28, 2017 (20170228) Print (http://www.printfriendly.com)

New strategies, equipment, and processes make for improved efficiency and sustainability in the production of perennial grasses.

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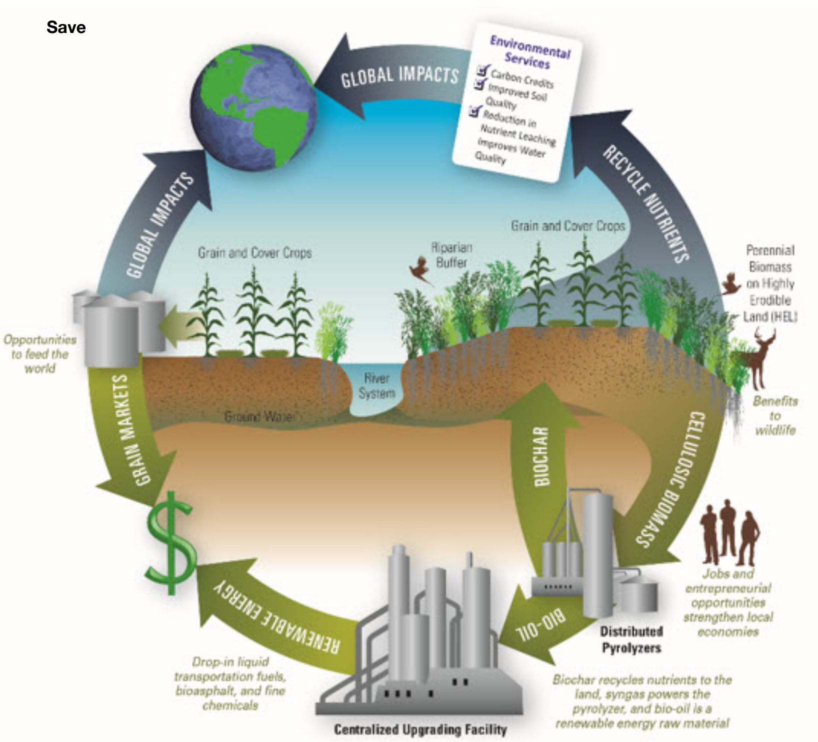

The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed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

Team Objectives

The CenUSA's Feedstock Logistics team's objective is to develop innovative systems and strategies for sustainable and economical harvest, transportation, and storage of perennial grasses. These activities can account for half of the production cost of biofuel feedstocks.

The team focuses on the development and evaluation of harvest and logistics systems that are easily adaptable, produce consistent and quality feedstock for conversion, and are economically, energetically, and environmentally efficient and sustainable. The team also investigates novel harvest and transport systems, demonstrating these systems at field scale, and evaluating harvest and supply chain costs. It evaluates technologies for more efficient feedstock deconstruction and drying.

Speeding Up Drydown at Harvest

Switchgrass harvest. *Photo: Kevin Shinners, University of Wisconsin.*

Harvesting switchgrass, with its large, stiff stems, for biofuels requires a different approach than harvesting annual forage grasses. But just like forage, the faster switchgrass or other perennial grasses dry down at harvest, the fewer weather delays and quality losses producers will suffer.

To help speed up drydown, the Feedstock Logistics team developed a single-pass, intensive conditioning-tedding process that can reduce switchgrass drying from 3 or 4 days to often less than 2 days. It combines greater stem conditioning than conventional hay equipment can provide, with wide-swath drying that captures a larger fraction of available solar energy.

Bale Compression for Increased Density

Tedding a switchgrass crop mowed in wide swaths speeds drying. *Photo: Kevin Shinners, University of Wisconsin.*

The tough stems of perennial grasses pose another harvesting problem—they resist compression into conventional bales, which are often much less dense than the 15 lbs. per square foot that meets legal transport weight limits. Denser bales would mean lower costs for aggregation, storage, and, especially, transport for farmers.

By using a pre-cutter on either large-round or large-square balers, the logistics team was able to increase the density of switchgrass bales by 4 to 6 percent. But where precutting the long, tangled grasses before they went into the baler really paid off was through increased grinding productivity, by 35 to 40%, while reducing the grinding energy requirement by 40 to 45%. These bales handled and stored the same as un-cut bales.

Precutting alone did not produce the desired bale density to meet the maximum for weight- and volume-limited transport[1] (#_ftn1) . The logistics team also evaluated a commercial plungerhead baler that makes high-density large bales specifically to determine how achieving greater density affected specific energy requirements. While this machine achieved the desired bale densities, the fuel requirements increased considerably. Future work for the team is an economic analysis comparing the cost of achieving high density with the potential savings.

The team also looked at alternative ways to achieve high-density bales without using these conventional plungerhead balers, by designing a bale re-compression press intended to almost double the density of either large-round or large-square bales. Compressing biomass bales in this fashion required only about one-tenth of the fuel needed to produce less-dense bales with plungerhead balers.

The Logistics Team evaluated how much energy a commercial, high-density, large-square baler uses when making bales of greater density, critical to efficient transport of bales.*Photo: Kevin Shinners, University of Wisconsin.*

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[1] (#_ftnref1) Detail about bale density and transportation: State DOTs control volume by restricting height, width and length of trailers. There is also a weight limit. Current switchgrass bales will fill the legal volume before they hit the weight limit. By increasing bale density, we can push toward the weight limit – and 15 lbs/cu ft gets us right at legal volume and weight limit in many states. There is a point where too great a density causes a truck to go over weight when filling to volume limits. Because bales are “integer packages”, we have to then take off one complete bale and again we drop below weight limit

Logistics Team designed this recompression press to increase the density of round bales while saving fuel.*Photo: Kevin Shinners, ersity of Wisconsin.*

Quantifying Necessary Tension of Baling Twine

The team was the first to quantify the tension of baling twine needed for high-density biomass crops. These bales need stronger twine, but that can cost more than $3 per dry ton, or almost one-quarter of the cost of baling. The team's work will help baler and twine manufacturers understand how to develop cost-effective solutions to maintaining a high bale density.

Designing a Baler That's Lighter, Cheaper, Simpler

The team spent plenty of time in the fields but also on their computers, developing models to help producers do a better job of harvesting and storing perennial grass crops. One model predicts the switchgrass drying rate based on weather conditions and configuration of harvest equipment. Another model, of harvest progression, uses the drying rate model to predict the rate and extent of switchgrass harvest across the Upper Midwest. This model will help optimize the harvest fleet size required for a particular size of biorefinery.

Modeling for Improved Harvest and Storage

The team spent plenty of time in the fields but also on their computers, developing models to help producers do a better job of harvesting and storing perennial grass crops. One model predicts the switchgrass drying rate based on weather conditions and configuration of harvest equipment. Another model, of harvest progression, uses the drying rate model to predict the rate and extent of switchgrass harvest across the Upper Midwest. This model will help optimize the harvest fleet size required for a particular size of biorefinery.

The Out-Takes

Just as important as finding improved strategies that work, is discovering what does not. The team researched some harvest and storage methods that turned out to be too expensive or inefficient to recommend or pursue—wrapping bales with protective material, increasing bale size and aggregating bales in different configurations.

Outcomes

For producers to be willing to grow switchgrass for a sustainable biofuel industry, they must be able to do so efficiently and profitably. Feedstock logistics, from harvesting through storage and delivery, represents 40 to 50% of the cost of switchgrass production. Anything that can help producers save on those costs will help build production and help the industry to advance.

Researching how switchgrass bales can be transported efficiently and affordably is an important part of the Logistics Team's efforts. *Photo: Kevin Shinners, University of Wisconsin.*

CenUSA's Feedstock Logistics team has addressed this issue on several fronts:

- By improving equipment and developing a single-pass, intensive conditioning-tedding process, the team helps producers save time and money by decreasing the amount of days that it takes to dry switchgrass after harvest.
- By finding new ways to increase bale density, the team makes storage and transport of switchgrass bales easier and more affordable.
- By developing new computer models that predict the rate of drying, the team helps farmers better time their

harvest.

- Through models that predict the rate of switchgrass harvest across the Midwest, biorefineries that harvest their own perennial-grass feedstocks can optimize the size of their harvest fleet.
- By investigating the possibilities for a new, more affordable baler, the team opens the way for better equipment in the future.

Authors Of This Report

- Kevin Shinners (http://bse.wisc.edu/Kevin_Shinners.htm) , Professor of Agricultural Engineering, University of Wisconsin
- Susan J. Harlow, Freelance Journalist

CenUSA Logistics Team Publications (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa#Module%203)

Fact Sheets

- Storing Perennial Grasses Grown for Biofuel (/pages/70635/storing-perennial-grasses-grown-for-biofuel) , Kevin Shinners
- 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.
- 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))

Webinars

- Switchgrass and Bioenergy Crop Logistics (http://farmenergymedia.extension.org/video/switchgrass-and-bioenergy-crop-logistics) – Stuart Birrell

Instructional Video

- 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 (related PDF handout (/sites/default/files/Factsheet1.OptimizingHarvest.pdf))

Technical Papers

- See http://agriculturalmachineryengineering.weebly.com/technical-papers.html (http://agriculturalmachineryengineering.weebly.com/technical-papers.html)
- Shinners, K.J. & Friede, J.C. (2013). Improving the drying rate of switchgrass. ASABE Technical Paper No. 1591968.
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- Shinners, K.J. & Friede, J.C., & Kraus, J. & Anstey, D. (2013). Improving bale handling logistics by strategic bale placement. ASABE Technical Paper No. 1591987.

FAQs (Frequently Asked Questions)

- Can I use my regular haying equipment to harvest switchgrass grown for biofuel? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%207)
- How high should I cut switchgrass? I am growing it as a bioenergy crop. (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%206)
- How can I get a switchgrass crop to dry faster in the field once it's been cut for biomass? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%208)
- How can I reduce dry matter losses to a biomass crop during storage? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%209)

Journal Publications

- Williams,S.D. and K.J. Shinners. 2014. Farm-scale anaerobic storage and aerobic stability of high dry matter perennial grasses (http://agriculturalmachineryengineering.weebly.com/uploads/9/0/5/7/9057090/grassstorage2014.pdf) as biomass feedstock. Biomass & Bioenergy. 64:91-98.
- Shinners, K.J. G.C. Boettcher, R.E. Muck, P.J. Weimer and M.D. Casler. 2010. Harvest and storage of two perennial grasses as biomass feedstocks

(http://agriculturalmachineryengineering.weebly.com/uploads/9/0/5/7/9057090/perennialgrasses2010.pdf) . Transactions of the ASABE – 53(2):359-370.

- CenUSA Project Resources (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

cenusa bioenergy

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 is supported by Agriculture and Food Research Initiative (http://nifa.usda.gov/cenusa-bioenergy) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

CenUSA Feedstock Conversion, Refining and Co-Products

Farm Energy - March 01, 2017 (20170301)

Thermochemical processes convert biomass to liquid bio-fuel and produce biochar, a valuable co-product for soil quality and reduced greenhouse gas emissions.

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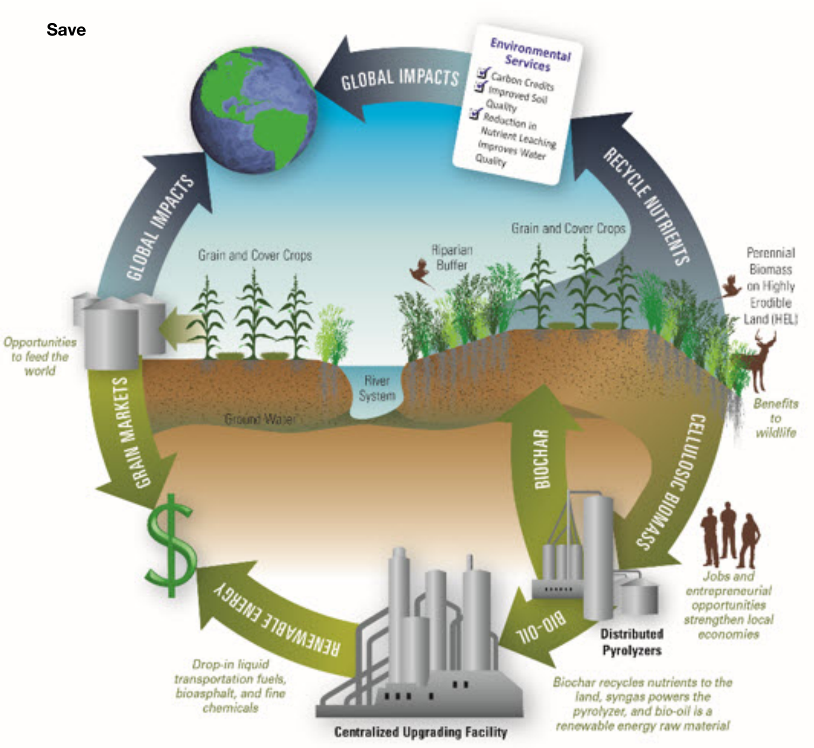


The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed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

Team Objectives

The work of CenUSA's Feedstock Conversion and Refining Team begins after the perennial-grass feedstock leaves the farmgate. What to do with the raw biomass to make it most useful for the producer and the processor?

Converting biomass into value-added products on a commercial scale is crucial to a sustainable biofuel supply chain. While waiting for the biofuel market to develop, biorefineries must find profitable products to keep them in business.

One of the team's first objectives was to develop a technoeconomic analysis (TEA) model of the potential for converting perennial grasses used for biofuels and biorefinery co-products into value-added fuels and useful chemicals, through catalytic pyrolysis processing. A TEA is a using available data from commercial operations. The model can determine the economics of turning perennial grass feedstocks and their co-products, especially lignin, into marketable, value-added products that can help a biorefinery turn a profit.

Many of those products may not look much like transportation fuel, but this product diversity strengthens the economics and positive environmental benefits of the biofuel supply chain. Take biochar: long consigned to use as a low-value process heat, this carbon-rich by-product of the fast pyrolysis process is gaining favor as a soil amendment. The Feedstock Conversion and Refining Team is helping to support that advance. Their findings show that value-added biochar can make biomass production for renewable energy more profitable and therefore sustainable.

Collaborators

Robert Brown, director of Iowa State University's Bioeconomy Institute led CenUSA's conversion and refining projects, while David Laird has led investigations of biochar amendment impacts on soil quality and greenhouse gas emissions. In efforts aimed at commercialization, the team worked closely with two partners: global food processor ADM, and Renmatix, a technology company based in Pennsylvania. Both companies fractionate—or break down into various components—biomass. The cellulose and hemicellulose components are readily marketable, but another major component, lignin, has few profitable uses, so it is mostly burned as a low-value fuel in boilers.

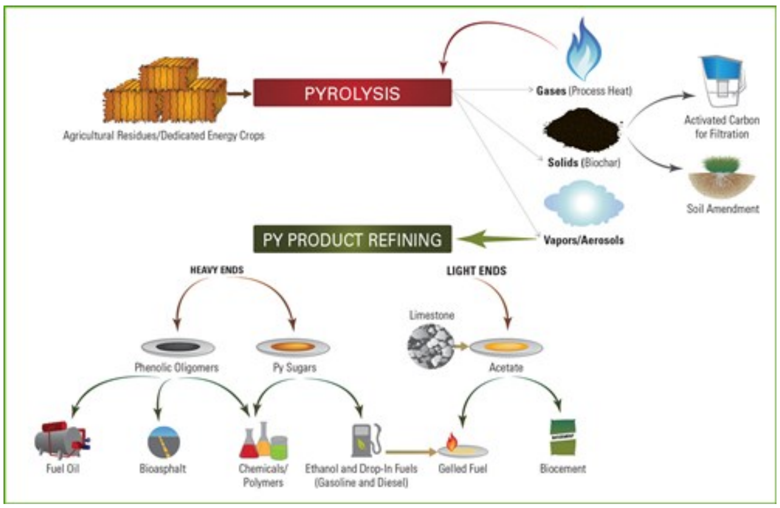
Team Activities

CenUSA's soil scientists and agronomists discovered that biochar can markedly improve soil quality. Biochar is highly porous, helping soil retain water and fertilizer and curb runoff. It has been shown to reduce nitrate leaching by 10% and phosphorus leaching by 40 to 70%, and boost soil aeration, allowing roots to grow. Biochar retains about half the nutrients of the original biomass, and also increases soil organic matter. It is not surprising that research has found that biochar can increase crop yields in poorer soils.

Biochar has another benefit, the team found. By returning biochar created by fast pyrolysis to the soil, more stover residue can be harvested for bioenergy without degrading soil quality or hurting crop yields in the long run.

Outcomes from The Team's Work

Much of the research looked at how to maximize the value of lignin from the two commercial partners' processes and improve their economic performances, by developing two processes to convert lignin into streams of stable, phenolic-rich oil that can be upgraded to fuels, chemicals, and other products. New thermochemical-process technologies developed by the team at Iowa State University will help the partners get more value from the lignin than they currently generate. In the long run, these advances will lead to conversion of grasses into biofuels and such value-added products as bioasphalt, cellulose pulp, fermentable sugars, and carbon fibers.



Concept for Pyrolysis Refinery *Photo: Bioeconomy Institute at Iowa State University.*

Future Work

Future research by the team will focus on:

- Developing lignin-specific conversion technology and working with companies that don't have a good home for their lignin co-product.

- Working with industrial collaborators to develop demonstration- and commercial-scale pyrolysis.

- Developing nonfuel uses, in addition to biochar, for perennial grasses. The team's TEA showed that chemical and other nonfuel uses of perennial grasses can be more profitable than producing transportation fuels right now.

Some day, small biorefineries will be able to make money turning biomass into fuel. But at the current time, they must rely on nonfuel products to turn a profit and stay in business. Meanwhile, new conversion and refining technologies are establishing themselves in the commercial supply chain, waiting for the large-scale development of transportation fuels sure to happen in the future.

Contributors to This Report

Authors:

- Ryan Smith, Deputy Director, Bioeconomy Institute's Thermochemical Research Program (https://www.biorenew.iastate.edu/research/thermochemical/)
- Susan J. Harlow, Freelance Journalist

CenUSA Feedstock Conversion, Refining and Biofuel Co-Products Team Publications

Case Study

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

Fact Sheets

- CenUSA Biochar Research Flyer (PDF) (/sites/default/files/Cenusa_Biochar_Research_2016_flyer.pdf) - David Laird and Jill Euken
- 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
- Utilization of Mature Switchgrass as Roughage in Feedlot Diets (PDF) (/sites/default/files/CenUSA_Switchgrass_Beef_Feeding.pdf) - Chris Clark and Dan Loy
- Index of Recent Biochar Publications (/pages/72947/recent-publications-about-biochar)

Research Summaries

- 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
- Switchgrass Hay Could Be a Useful Roughage in Beef Diets While Offering a Market Alternative to Biofuels (/pages/74031/research-summary:-switchgrass-hay-utillization-as-roughage-in-beef-diets) - Chris Clark

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
- Biochar and Beyond with ARTi (http://farmenergymedia.extension.org/video/biochar-and-beyond-arti) - Matt Kieffer, Juan Proano and Bernardo del Campo

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
- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird
- University of Minnesota Extension Master Gardener Biochar Research Summary (http://farmenergymedia.extension.org/video/university-minnesota-extension-master-gardener-biochar-research-summary) - Julie Weisenhorn

Journal Publications

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- 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.

- CenUSA Project Resources (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

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 is supported by Agriculture and Food Research Initiative (http://nifa.usda.gov/cenusa-bioenergy) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

CenUSA Extension and Outreach: Perennial Grass Bioenergy Research and Knowhow for Producers, Students and Stakeholders

Exhibit 7

Farm Energy - February 28, 2017 (20170228) Print (http://www.printfriendly.com)

Bioenergy research is translated into practical know-how by extension educators, farmers and Master Gardeners.

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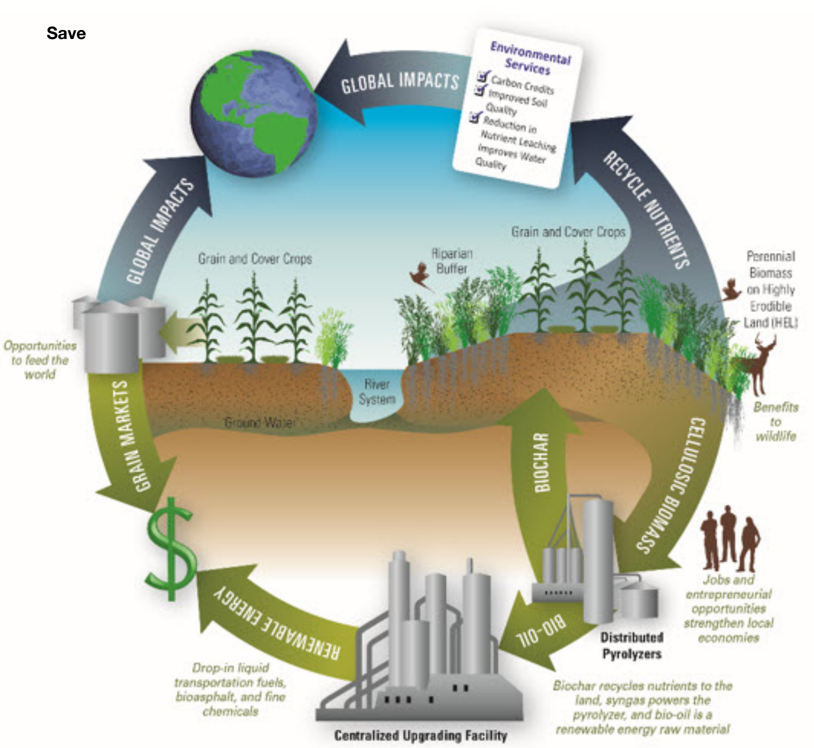
The CenUSA Extension and Outreach Team

On the streets, in the fields, and online, the CenUSA Extension and Outreach Team collaborators (https://cenusa.iastate.edu/outreach-extension) deliver programming and educational materials critical to the CenUSA Bioenergy vision.



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

The mission of the Extension team was to help farmers and others learn about the environmental impacts of perennial grass production and utilization of biochar, best practices for growing and supplying perennial grasses for the biofuels/bioproducts industry, potential markets that may develop for the grasses; and to help farmers evaluate how grasses might work in their operations once a market develops.

Accomplishing this mission was a team effort led by Project Co-Directors Jill Euken and Sorrel Brown from Iowa State University, along with 33 collaborators from seven universities and volunteer Extension Master Gardeners from Minnesota and Iowa.

Citizen Science and Farm Research Provide Hands-On Learning

Under the direction of professional scientists and their institutions, citizen science (http://www.extension.umn.edu/environment/citizen-science/about/) projects amplified the impact of the CenUSA program. Farm demonstration sites and garden research plots provided hands-on learning opportunities for participants and produced valuable research data for CenUSA to share with the public.

Extension and outreach professionals and farmers in Indiana, Iowa, Minnesota, and Nebraska established nine on-farm demonstration sites. Farmers established plots, collected data, and shared information with others at field days. Extension agents provided guidance, organized the field days, tours of plots, and informational meetings, which eventually reached more than 5,000 agricultural producers, consultants, and agricultural industry leaders.

CenUSA Bioenergy field day in Dawson, NE. *Photo: CenUSA*

University of Minnesota Extension and outreach professionals and Extension Master Gardener volunteers established five citizen science research garden sites studying biochar (a charcoal like co-product of pyrolyzing (/pages/72722/fast-pyrolysis-efficiently-turns-biomass-into-renewable-fuels) biomass for energy production) as a soil amendment. More than 7,000 people visited the sites and/or participated in educational programs, and exhibits.

itizen Science: Master Gardeners in MN and IA conduct biocar research.

Programs for Youth

Two groups of Extension collaborators focused specifically on youth outreach programming. Purdue University Extension and outreach professionals created interactive electronic lessons and established demonstration plots of perennial grasses for STEM (science, technology, engineering, and math) career events, reaching more than 900 high school students. [Plot or Career event Picture] Faculty and student interns at Iowa State University combined forces to create *C6 BioFarm* (http://www.extension.iastate.edu/4h/content/c6-biofarm) , a robust suite of STEM materials, for middle-school-aged youth. *C6BioFarm* includes an iPad app, supporting curricula and an iBook. These materials are available online (http://www.extension.iastate.edu/4h/content/c6-biofarm) to teachers and other youth mentors, such as 4-H and FFA leaders. *C6BioFarm* underwent two pilot tests, reaching 350 and 330 youth and adults respectively. The C6 program has been used by more than 2000 people.

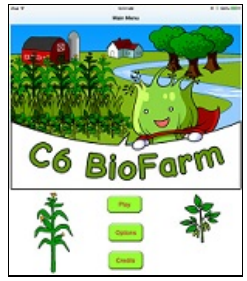
C6 at the Iowa State Fair. *Photo: CenUSA*

"The main purpose of *C6BioFarm* is to help connect the idea that fuels can be made from renewables and to help increase options for agriculture," said Jay Staker, director of Extension science, engineering and technology at Iowa State University and a member of CenUSA's Extension and Outreach Team. "The sub purpose is to help people better understand agriculture production in STEM careers and the economy." [C6 Picture]

C6 BioFarm iPad game

Challenges

Education efforts by Extension and outreach were not without challenges. Most notable was the lack of an established market for perennial grasses – due to lack of commercial facilities to process the grasses and depressed fossil fuel prices. Without biomass markets, it was not possible (in fact, it was unethical) for team members to encourage farmers to transition acres to production of perennial grasses.



The Extension team overcame this challenge by focusing on helping people understand that markets *could* develop. The easily accessible educational materials generated by the project team will help farmers, industry leaders and Extension and outreach professionals move rapidly to produce perennial grasses once a market for them opens up.

Resources for Ongoing Learning

Working with CenUSA scientific researchers, the Extension team developed an in-depth portfolio of online educational materials, providing science-based information in easily understandable terms. Publications include decision support tools, fact sheets, research summaries, and videos. These educational materials will help producers, industry leaders, Extension and outreach professionals proceed quickly to produce perennial grasses when a market for them becomes more widely available.

These materials are available at eXtension.org (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) , the CenUSA web site (https://cenusa.iastate.edu) , and CenUSA's video sites (https://vimeo.com/cenusabioenergy (https://vimeo.com/cenusabioenergy) and https://www.youtube.com/user/CenusaBioenergy (https://www.youtube.com/user/CenusaBioenergy)).

Contributors to This Report

Authors:

- Jill Euken, Deputy Director, Bioeconomy Institute (http://www.biorenew.iastate.edu/) at Iowa State University
- Amy Kohmetscher, Distance Education Specialist, Agronomy and Horticulture, University of Nebraska-Lincoln.
- Susan J. Harlow, Freelance Journalist

CenUSA Extension and Outreach Team Publications

CenUSA Project Resources (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

Fact Sheets, Guides and Articles

- Biochar: Prospects of Commercialization (/pages/71760/biochar:-prospects-of-commercialization) - David Laird and Pam Porter
- CenUSA Biochar Research Flyer (PDF) (/sites/default/files/Cenusa_Biochar_Research_2016_flyer.pdf) - David Laird and Jill Euken
- CenUSA Feedstock Conversion, Refining and Co-Products (/pages/74206/cenusa-feedstock-conversion-refining-and-co-products) - Ryan Smith
- CenUSA Extension and Outreach: Perennial Grass Bioenergy Research and Knowhow for Producers, Students and Stakeholders (/pages/74209/cenusa-extension-and-outreach:-perennial-grass-bioenergy-research-and-knowhow-for-producers-students) - Jill Euken
- CenUSA Feedstock Development (/pages/74210/cenusa-feedstock-development) - Mike Casler
- CenUSA Feedstock Logistics: Innovative Systems for Harvest, Transportation, and Storage of Perennial Grass Biomass (/pages/74073/cenusa-feedstock-logistics:-innovative-systems-for-harvest-transportation-and-storage-of-perennial-g) - Kevin Shinners
- Control Weeds in Switchgrass (Panicum Virgatum L.) Grown for Biomass (/pages/70396/control-weeds-in-switchgrass-panicum-virgatum-l-grown-for-biomass) - Rob Mitchell
- Economics of Switchgrass for Biofuel (/pages/71073/the-economics-of-switchgrass-for-biofuel) - Richard Perrin
- 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
- Fast Pyrolysis Efficiently Turns Biomass into Renewable Fuels (/pages/72722/fast-pyrolysis-efficiently-turns-biomass-into-renewable-fuels) - Robert Brown
- Guidelines to Growing Perennial Grasses for Biofuel and Bioproducts (PDF) (/sites/default/files/Cenusa_Guide_to_Perennials.pdf) - Rob Mitchell
- Index of Recent Biochar Publications (/pages/72947/recent-publications-about-biochar)
- 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
- Master Gardeners' Safety Precautions for Handling, Applying and Storing Biochar

(/sites/default/files/MasterGardenerSafetySheet20120412.pdf) - Charles Schwab and Mark Hanna

- Plant Breeders Create New and Better Switchgrass Varieties for Biofuels (/pages/70389/plant-breeders-create-new-and-better-switchgrass-varieties-for-biofuels) - Michael Casler
- Storing Perennial Grasses Grown for Biofuel (/pages/70635/storing-perennial-grasses-grown-for-biofuel) - Kevin Shinners
- 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))
- 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))
- 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))
- Utilization of Mature Switchgrass as Roughage in Feedlot Diets (PDF) (/sites/default/files/CenUSA_Switchgrass_Beef_Feeding.pdf) - Chris Clark and Dan Loy

Research Summaries & Case Studies

- Switchgrass Hay Could Be a Useful Roughage in Beef Diets While Offering a Market Alternative to Biofuels (/pages/74031/research-summary:-switchgrass-hay-utillization-as-roughage-in-beef-diets) - Chris Clark
- 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
- 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
- Making Business Decisions with Precision Data Can Encourage Perennial Grass Production (/pages/73918/making-business-decisions-with-precision-data-can-encourage-perennial-grass-production) - Susan Harlow
- 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
- Minnesota Watershed Nitrogen Reduction Planning Tool (/pages/67624/minnesota-watershed-nitrogen-reduction-planning-tool) - Bill Lazarus
- 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 Finds Strong Genetic Diversity in Switchgrass Gene Pools (/pages/70383/research-summary:-research-finds-strong-genetic-diversity-in-switchgrass-gene-pools) - Michael Casler
- Case Study: Renmatix Processes Biomass into Sugars for Industrial Use (/pages/73640/renmatix-processes-biomass-into-sugars-for-industrial-use)
- 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
- 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

FAQs (Frequently Asked Questions)

- Can I use my regular haying equipment to harvest switchgrass grown for biofuel? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%207)
- Can the use of conservation tillage help reduce greenhouse gas emissions from cropland soils where residues are used for biofuel? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2011)
- Can you feed switchgrass to livestock until a biofuel market develops for it? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2014)
- How can I get a switchgrass crop to dry faster in the field once it's been cut for biomass? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%208)
- How can I reduce dry matter losses to a biomass crop during storage? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%209)
- How do I grow switchgrass to provide biomass to be used in the production of biofuels? (/pages/74021/faqs-

about-perennial-grass-switchgrass-production-for-biofuels#Question%2012)

- How high should I cut switchgrass? I am growing it as a bioenergy crop. (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%206)
- Is there a market for switchgrass for biofuel and how do I get started? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2013)
- Should I begin establishing switchgrass in case they put a cellulosic ethanol plant near by? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2015)
- Should I fertilize switchgrass when I plant it? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%204)
- What effects do corn stover removal rates have on greenhouse gas emissions from cropland? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2010)
- When should I plant switchgrass? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%203)
- Why is it important to be able to grow a consistent and uniform supply of a biomass feedstock? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%201)
- Will switchgrass grow well in my region? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%202)
- Will weeds be a problem after my switchgrass stand is established? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%205)

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

- Aphid Resistance in Switchgrass CenUSA Bioenergy (http://farmenergymedia.extension.org/video/aphid-resistance-switchgrass) - Kyle Koch
- Biochar 101: An Intro to Biochar (http://farmenergymedia.extension.org/video/biochar-101-intro-biochar) - Kurt Spokas
- Biochar and Beyond with ARTi (http://farmenergymedia.extension.org/video/biochar-and-beyond-arti) - Matt Kieffer, Juan Proano and Bernardo del Campo
- 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
- Diversifying Cellulosic Feedstocks (http://farmenergymedia.extension.org/video/diversifying-cellulosic-feedstocks-native-perennial-grasses) - DK Lee
- No-Till Drill Calibration Training Video (+Captions) (http://farmenergymedia.extension.org/video/no-till-drill-calibration-training-video-captions) – Rob Mitchell
- Overview of Switchgrass Diseases (http://farmenergymedia.extension.org/video/overview-switchgrass-diseases) - 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
- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird
- Safety Issues in On-Farm Biomass Production (https://learn.extension.org/events/1406) - Douglas Schaufler
- Switchgrass and Bioenergy Crop Logistics (http://farmenergymedia.extension.org/video/switchgrass-and-bioenergy-crop-logistics) – Stuart Birrell
- 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 Cost of Production (http://farmenergymedia.extension.org/video/switchgrass-cost-production) - Marty Schmer
- Switchgrass Decision Tool (http://farmenergymedia.extension.org/video/switchgrass-decision-tool) - Keri Jacobs and Chad Hart
- 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
- Switchgrass Establishment, Weed Control, and Seed Quality (http://farmenergymedia.extension.org/video/switchgrass-establishment-weed-control-and-seed-quality) – Rob Mitchell
- 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 on the CenUSA Vimeo Site (https://vimeo.com/cenusabioenergy/videos) and on the CenUSA YouTube Site (https://www.youtube.com/user/CenusaBioenergy)

- Biochar: An Introduction to an Industry (http://farmenergymedia.extension.org/video/biochar-introduction-industry) - David Laird
- CenUSA Bioenergy-Opportunities in Biofuel (http://farmenergymedia.extension.org/video/cenusa-bioenergy-opportunities-biofuel)
- The CenUSA Legacy (http://farmenergymedia.extension.org/video/cenusa-legacy-video) - Pam Porter
- 2012 CenUSA Bioenergy Overview (http://farmenergymedia.extension.org/video/2012-cenusa-bioenergy-overview)
- 2012 CenUSA Bioenergy Farmer Focus (http://farmenergymedia.extension.org/video/2012-cenusa-bioenergy-farmer-focus) - Kevin Ross
- CenUSA Bioenergy 2015 Summer Undergraduate Research Internship (https://vimeo.com/115007243) - Raj Raman
- Commercialization Update: Opportunities for Perennial Biofeedstocks (http://farmenergymedia.extension.org/video/cenusa-commercialization-update-rob-mitchell) - Rob Mitchell
- Enhancing the Mississippi Watershed with Perennial Bioenegy Crops (http://farmenergymedia.extension.org/video/enhancing-mississippi-watershed-perennial-bioenergy-crops) - Pam Porter
- 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
- Harvesting Native Grass for Biofuel Production (+Captions) (http://farmenergymedia.extension.org/video/harvesting-native-grass-biofuel-production-captions) – Rob Mitchell
- Hazards of Biomass Production on Marginal Land (http://farmenergymedia.extension.org/video/hazards-biomass-production-marginal-land) - Douglas Schaufler
- How to Measure Stand Establishment Using a Grid (http://farmenergymedia.extension.org/video/how-measure-stand-establishment-using-grid) – John Guretzky
- Intro to No-Till Drill Calibration for Switchgrass (+Captions) (http://farmenergymedia.extension.org/video/intro-no-till-drill-calibration-switchgrass-captions) – Rob Mitchell
- Optimizing Harvest of Perennial Grasses for Biofuel (http://farmenergymedia.extension.org/video/optimizing-harvest-perennial-grasses-biofuel) – Kevin Shinners
- Plant Breeding to Improve Yield and Sustainability of Perennial Grasses (http://farmenergymedia.extension.org/video/plant-breeding-improve-yield-and-sustainability-perennial-grasses) - Michael Casler
- 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
- Switchgrass Planting Practices for Stand Establishment (http://farmenergymedia.extension.org/video/switchgrass-planting-practices-stand-establishment) – 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

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 is supported by Agriculture and Food Research Initiative (http://nifa.usda.gov/cenusa-bioenergy) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

CenUSA Models Predict Large Water Quality Improvements from Perennials

Farm Energy - March 01, 2017 (20170301) Print (http://www.printfriendly.com)

Exhibit 8

CenUSA's System Performance team research shows water quality benefits when biofuels are produced from perennial grasses; provides guidance for policymakers, farmers, and the bioenergy industry.

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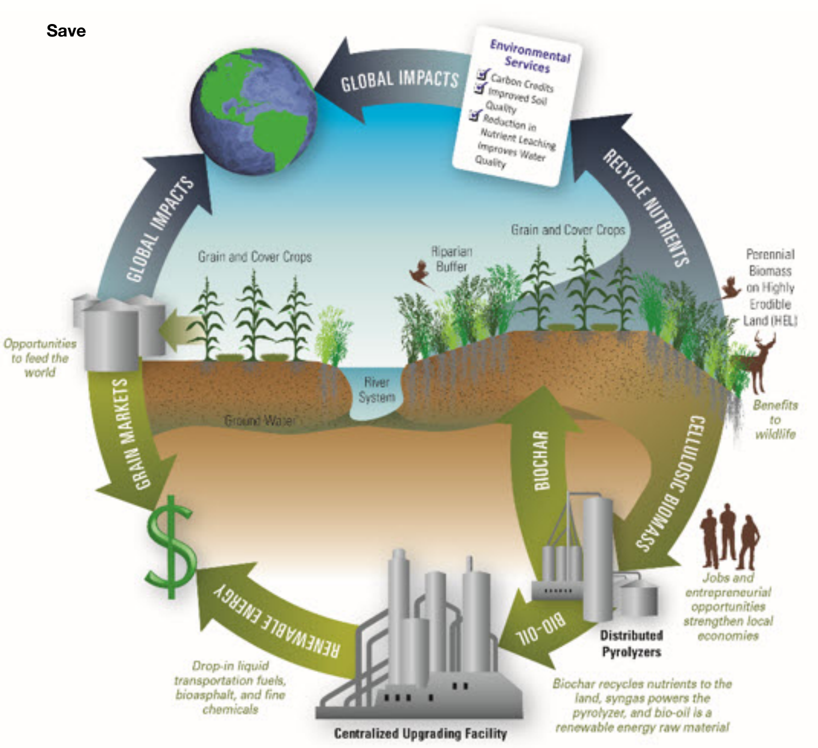
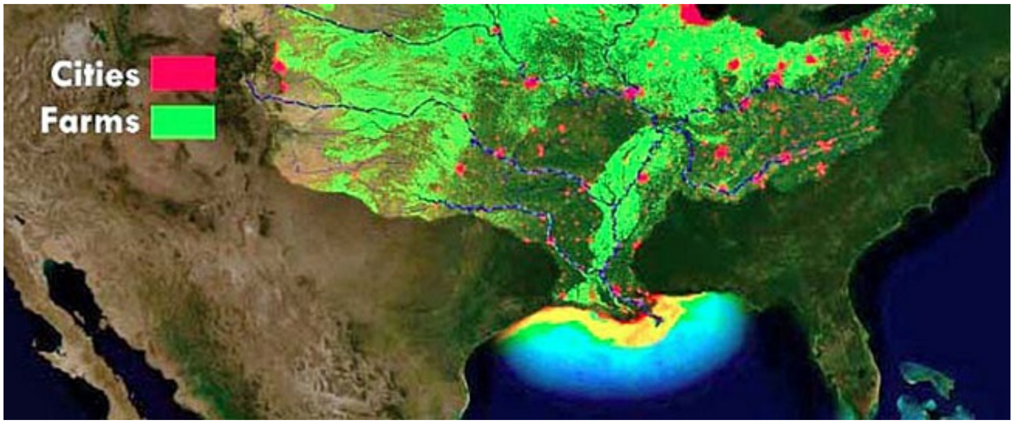


The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed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

The Team and Objectives

Despite more than 40 years of largely voluntary efforts by federal, state and local government, and tens of billions of dollars of investment in conservation, nationwide progress on nutrient control has not yet been achieved. Concentrations of nitrogen (N) and phosphorus (P) in streams and groundwater are 2-10 times higher than recommended to protect aquatic life and contamination of drinking water is still widespread. The consequences of agricultural nonpoint source pollution are particularly evident where the Mississippi River enters the Gulf of Mexico. The Gulf's hypoxic, or "dead zone" is the largest hypoxic region in the US and the second largest in the world.

The Gulf's hypoxic zone at the base of the Mississippi river is caused by nutrient runoff. *Image: NOAA's Environmental Visualization Lab*



CenUSA's System Performance team jointly led by Iowa State University's Cathy Kling and the University of Minnesota's Jason Hill has focused on water quality and biofuel production life cycle analysis. Kling's Iowa State team has worked to develop models that could evaluate what is likely to happen to water quality with various biofuel scenarios and help guide policymakers, farmers, and the bioenergy industry in designing sustainable regional biofuels systems. Their cutting edge work compared different bioenergy feedstocks, grown in both marginal and prime farmland, and how new biomass production systems are likely to impact water quality and climate change.

"CenUSA is a large project working to evaluate the production of perennial biofuels in the Corn Belt, said System Performance team collaborator Phil Gassman of Iowa State University. "We've been working with people across many institutions and have been fortunate to develop a tight collaboration with a great group of scientists."

Team Activities

Three papers co-authored by Kling and Gassman along with other team members Indrajeet Chauby (Purdue University), Raj Cibin (Penn State) and Yiannis Panagopoulus (formerly a post doc at Iowa State now at National Technical University, Athens, Greece) have recently been accepted by or are in review with the Journal of American Water Resources Association (JAWRA). A fourth overview paper, currently accepted by JAWRA, "Policy Implications from Multi-Scale Watershed Models of Biofuel Crop Adoption across the Corn Belt," compares the findings from these three studies and discusses policy impacts.

The team's research addresses one of the country's key policy questions, what are the water quality impacts of converting cropland and/or marginal lands to cellulosic biofuel systems in the upper Midwest? Uniquely, their models compared land use changes at different scales: within three smaller watersheds, the Boone River Basin in Iowa and the Wildcat Creek Basin and St Joseph River Basin in Indiana and at a larger scale, using a regional model developed across the Upper Mississippi and Ohio Tennessee watersheds (Figure 1).

Fig.1. CenUSA models contrasted the water quality impacts from biofuel

Outcomes from The Team's Work

To contrast results across the models, the team developed a set of scenarios, using the most promising biofuel feedstocks: corn stover, switchgrass and miscanthus; grown at different intensities (Corn stover harvested at 20% and 50% removal rates; and miscanthus and switchgrass grown in all cropland of the watershed versus targeted regions, environmental sensitive areas (lands greater than 2% slope) (Table 1). Results showed major environmental improvements from planting perennials, and that targeting their conversion on marginal lands can result in a disproportionately bigger impact. In general, and perhaps surprisingly, corn stover removal had small negative impacts on environmental losses. The modeled results may lead biofuel policy toward utilizing both corn stover and perennial grasses, targeted to marginal lands; something the authors state could be a potential "win-win."

Why This Work Is Important

"Our results confirmed what field studies and previous modeling studies have shown," said Gassman. "Working perennials into agricultural landscapes has big benefits. Perennial feedstocks have huge impacts in reducing pollutant losses," said Gassman.

In the latest JAWRA paper, the authors explain that, "there is a clear evidence that there are gains from targeting perennials to marginal land." Watershed scale modeling of the type done by the CenUSA team, "can provide useful information to policy makers concerning the environmental gains from adopting changes in the existing [CRP] program or develop new options in the future…"

The water quality benefits of perennials reported in these studies may encourage policy makers to reconfigure federal

Scenario	St Joseph	Wildcat Creek	Boone	Upper Mississippi and Ohio Tennessee River
	Total P (% change)			
Corn stover prime land, 20% all	---	---	2	1
Corn stover, prime land, 50%	-2	-2	5	3
Switchgrass – all land	-90	-98	-83	-58
Switchgrass, marginal - >2% slope	-51	-22	-22	-14
Miscanthus – all	-90	-94	-79	-59
Miscanthus, marginal - >2% slope	-51	-22	-22	-14

Table 1. Impact (percentage of change) of scenarios on total phosphorus.

agriculture and energy policies including the Renewable Fuel Standard (RFS) and USDA conservation programs like the Conservation Reserve Program (CRP), Environmental Quality Incentive Program (EQIP) and Conservation Security Program (CSP) to utilize corn stover on prime acres along with perennial grasses, targeted to marginal lands; something the authors state could be a potential "win-win."

Rather than paying farmers to set land aside, policy makers, particularly those looking at budget impacts, may see a benefit from programs that allow corn (grain and stover) to be harvested on prime lands while aiming perennials on marginal lands. If farmers were paid to plant perennial crops like switchgrass and the crops could be harvested, federal rental payments for conservation programs like CRP could be lowered to reflect the commercial benefit provided to growers. Similarly, the Hypoxic Task Force, with its goal of state nutrient plans reducing nutrient loads by 45% may see an opportunity in exploring the role of perennials and biofeedstock production in the Mississippi River watershed.

Contributors to This Summary

Author: Pamela Porter, Environmental Resources Center, University of Wisconsin

CenUSA Feedstock Development Team Publications

CenUSA Project Resources (/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa) - information on the opportunities and challenges in developing a sustainable system for the thermochemical production of biofuels from perennial grasses grown on land marginal for row crop production.

Case Study

- Making Business Decisions with Precision Data Can Encourage Perennial Grass Production (/pages/73918/making-business-decisions-with-precision-data-can-encourage-perennial-grass-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
- The Economics of Switchgrass for Biofuel (/pages/71073/the-economics-of-switchgrass-for-biofuel) - Richard Perrin

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
- 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
- Minnesota Watershed Nitrogen Reduction Planning Tool (/pages/67624/minnesota-watershed-nitrogen-reduction-planning-tool) - Bill Lazarus

Curriculum

- 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

Webinars

- 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
- Diversifying Cellulosic Feedstocks (http://farmenergymedia.extension.org/video/diversifying-cellulosic-feedstocks-native-perennial-grasses) - DK Lee
- 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 Cost of Production (http://farmenergymedia.extension.org/video/switchgrass-cost-production) - Marty Schmer
- 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

Instructional Video

- Enhancing the Mississippi Watershed with Perennial Bioenergy Crops (http://vimeo.com/84352256) - Pam Porter
- Role of Biochar in Achieving a Carbon Negative Economy (http://farmenergymedia.extension.org/video/role-biochar-achieving-carbon-negative-economy) – David Laird

FAQs (Frequently Asked Questions)

- What effects do corn stover removal rates have on greenhouse gas emissions from cropland? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2010)
- Can the use of conservation tillage help reduce greenhouse gas emissions from cropland soils where residues are used for biofuel? (/pages/74021/faqs-about-perennial-grass-switchgrass-production-for-biofuels#Question%2011)

Journal Publications

- Schmer MR, Vogel KP, Varvel GE, Follett RF, Mitchell RB, et al. (2014) Energy Potential and Greenhouse Gas Emissions from Bioenergy Cropping Systems on Marginally Productive Cropland. PLoS ONE 9(3): e89501. DOI: 10.1371/journal.pone.0089501 (http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0089501)
- Schilling, K., Gassman, P., Kling, C. T. Campbell, M. Jha, C. Wolter, & J. Arnold. (2103). The Potential for Agricultural Land Use Change to Reduce Flood Risk in a Large Watershed. *Hydrological Processes* (2013), wileyonlinelibrary.com, DOI: 10.1002/hyp.9865 (http://onlinelibrary.wiley.com/doi/10.1002/hyp.9865/abstract) .
- Rabotyagov, S., Kling, C.L., Gassman, P., Rabalais, N. & Turner, R. (2014). The Economics of Dead Zones: Causes, Impacts, Policy Challenges, and a Model of the Gulf of Mexico Hypoxic Zone. *Review of Environmental Economics and Policy,* published online Jan. 5, 2014 DOI:10.1093/reep/ret024 (http://reep.oxfordjournals.org/content/early/2014/01/04/reep.ret024.abstract)
- *Keeler B., Krohn, B., Nickerson, T. & Hill, J. (2014).* U.S. Federal agency models offer different visions for achieving Renewable Fuel Standard (RFS2) biofuel volumes. *Environ. Sci. Technol. (2013) 47: 10095–10101.* DOI: 10.1021/es402181y (http://pubs.acs.org/doi/abs/10.1021/es402181y) . *(Cover Feature)*
- Panagopoulos, Y., Gassman, P., Arritt, R., Herzmann, D., Campbell, T., Jha, M., Kling, C.L., Srinivasan, R., White, M. & Arnold, J. (2014). Surface Water Quality and Cropping Systems Sustainability under a Changing Climate in the Upper Mississippi River Basin. *Journal of Soil and Water Conservation* 69:483-494. DOI: 10.2489/jswc.69.6.483 (http://www.jswconline.org/content/69/6/483.refs) .
- Rabotyagov, S., Valcu, A. & Kling, C.L. (2014). Reversing the Property Rights: Practice-Based Approaches for Controlling Agricultural Nonpoint-Source Water Pollution When Emissions Aggregate Nonlinearly. *American Journal of Agricultural Economics* 96 (2): 397-419. DOI 10.1093/ajae/aat094 (http://ajae.oxfordjournals.org/content/96/2/397.abstract) .

cenusa bioenergy

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 is supported by Agriculture and Food Research Initiative (http://nifa.usda.gov/cenusa-bioenergy) Competitive Grant no. 2011-68005-30411 from the USDA National Institute of Food and Agriculture (http://www.csrees.usda.gov/) .

"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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cenusa bioenergy

Quarterly Progress Report

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

May 2017

Agriculture and Food Research Initiative Competitive Grant

No. 2011-68005-30411

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LEGAL NOTICE

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

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

3rd Quarter Report: February 1, 2017 – April 30, 2017

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. Mary Scott Hall (ISU Bioeconomy Institute) provides assistance with project financial matters.

- **CenUSA Bioenergy Advisory Board**

  Our Advisory Board continues to be engaged in the project thorough Tom Binder's participation in leadership meetings.

- **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 bimonthly 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 be submitting a request for a No Cost Extension (NCE) at the beginning of the 4th Quarter. The NCE funds will be used for expenses associated with closing the CenUSA project, including development and deployment plans to ensure CenUSA's work product remains accessible to communities of interest, as well as the public. In addition, this will allow us time to complete the final annual report.

  Specifically, NCE funds will be used for administrative support in reporting, accounting and archiving project work product (ISU library services). The major expense will be salary support for administrative employees. This will allow us to meet all reporting requirements and let us make sure CenUSA Bioenergy products remain available to anyone who wants access to them.

Germplasm to Harvest

Objective 1. Feedstock Development

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

1. Activities

The establishment and data collection from uniform field trials across the entire CenUSA region was completed at the end of Year 5. The initial analysis of biomass yield data from 65 trial-years was completed during the last quarter. Some of the findings are listed below.

- The trials confirmed the high yield of 'Liberty' switchgrass. It ranked fifth across all 65 trial-years, being beaten only by four new candidate varieties that represent highly selected lowland ecotypes, all developed after 'Liberty' was released. 'Liberty' was the highest ranked named variety for biomass yield across all 65 trial-years.
- Recent breeding efforts to develop new late-flowering switchgrasses and big bluestem for the northern USA has been extremely successful. For switchgrass, the top four rankings for biomass yield were made up of candidate lowland varieties selected in Nebraska, Illinois, or Wisconsin (three different breeding programs). For big bluestem, the top three ranks for biomass yield were contributed by the Nebraska and Wisconsin USDA breeding programs, ranking higher than all released varieties.
- These results show the incredible value of regional uniform field testing programs that are routine in annual crops, but have never been conducted on such a scale for switchgrass and big bluestem. These trials will allow intelligent decisions to be made about which selection criteria are the most successful, which environments are the best for selection, and which candidate varieties should be released to the public for seed increase.
- The results also show the regions of adaptation for these varieties, showing that there is still a need for improvement of winterhardiness in the improved lowland populations of switchgrass for USDA hardiness zones 3 and 4. Conversely, big bluestem showed no such problem, with broad adaptation across the entire region, even for the late-flowering varieties with the highest biomass yield.

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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.

- **Purdue University**

  Perennial grasses such as, Miscanthus (*Miscanthus* × *giganteus*) and switchgrass (*Panicum virgatum*), are considered superior for the bioenergy production than annual grasses such as, maize (*Zea mays*) and sorghum (*Sorghum bicolor*) because of their ability to produce high biomass with relatively low nitrogen (N), phosphorus (P), and potassium (K) fertilizer inputs.

  However, the relative contribution of these perennial and annual crops to total greenhouse gas (GHG) emissions, particularly on P- and K-deficient soils is not known. We compared GHG emissions from replicated side-by-side trials of an annual grass study (continuous maize and continuous sorghum) and three perennial grass studies (Miscanthus, switchgrass, and mixed native prairie) in 2013 and 2014. Except mixed native prairie, all crops had N treatments that included unfertilized and fertilized treatment (100 kg N ha^{-1} yr^{-1} for Miscanthus and switchgrass and 150 kg N ha^{-1} yr^{-1} for maize and sorghum). Miscanthus and switchgrass had additional P–K treatments, switchgrass was grown on plots that historically either received P–K treatment (75 kg P/ha with 400 kg K/ha per year) or were unfertilized and Miscanthus was either fertilized with a rate of 30 kg P/ha with 300 kg K/ha or were unfertilized. We conducted a weekly assessment of N_2O, CO_2, and CH_4 in situ fluxes from April to October in 2013 and 2014.

  Miscanthus was most productive followed by sorghum, switchgrass, maize and mixed native prairie with 2-yr mean biomass yield of 24.9, 12.3, 10.8, 9.5, and 6.5 Mg ha^{-1}. The PK fertilization application had no impact on biomass yield of Miscanthus and switchgrass despite low soil test levels of P and medium soil test levels of K in control plots. However, the PK application interacting effect with N treatment in both crops to increase N_2O fluxes when measured after N fertilization in 2014. There were no treatment differences among daily CO_2 and CH_4 fluxes emissions in any study. Cumulative seasonal N_2O emissions were comparable among crops except for NPK treated Miscanthus plots in 2014, however, global warming potential measured as a sum of N_2O, CO_2 and CH_4 cumulative emissions per unit of biomass produced had very low values in Miscanthus. Clearly, these results indicate that Miscanthus can produce large amount of biomass with low direct total GHG emissions per unit of biomass produced when grown on low P, medium K and moderate erosivity lands and thus could serve as a potential dedicated energy crop to meet nation's targets of produce biofuels from cellulosic feedstocks.

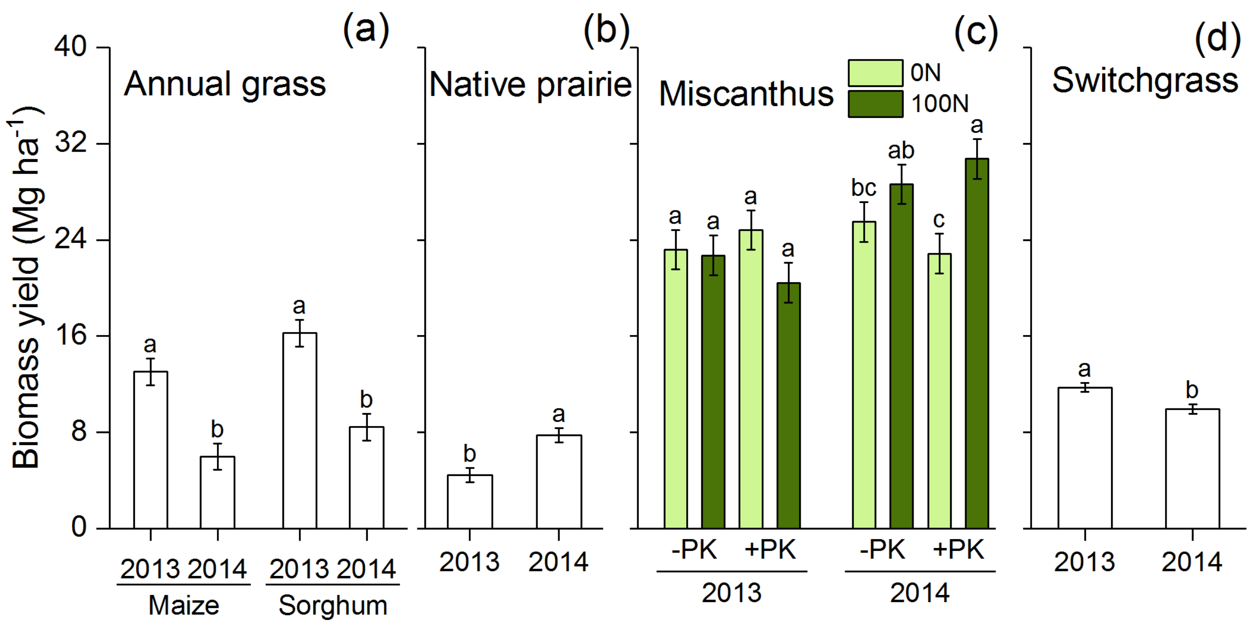

Fig. 1. Mean aboveground dry biomass yield in 2013 and 2014 of (a) annual grass (maize and sorghum), (b) native prairie, (c) Miscanthus and (d) switchgrass biomass systems. Standard errors are provided. Different lowercase letters over the vertical bars indicate there is significant difference ($P < 0.10$) between 2013 and 2014 mean dry biomass yield within a biomass system, except the Miscanthus experiment where different lowercase letters over the vertical bars identify significant differences ($P < 0.10$) between PK and N fertilizer treatments within years.

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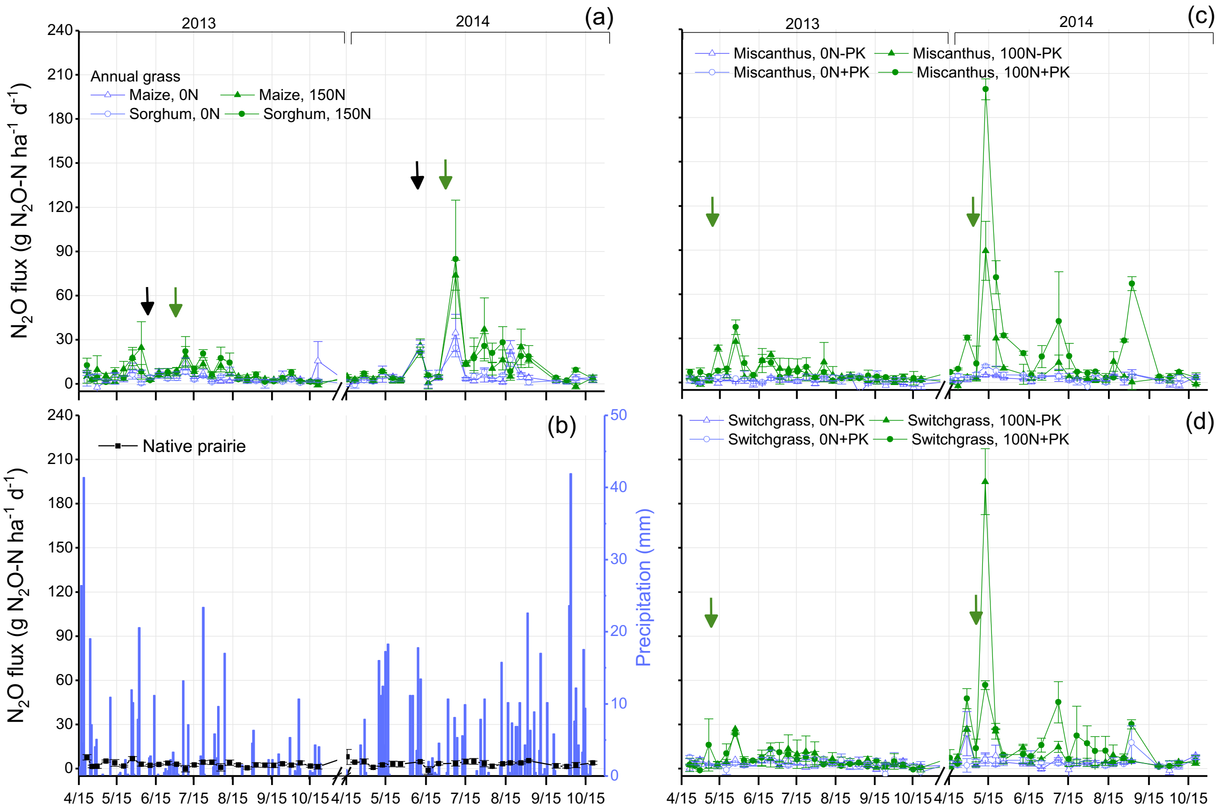

Fig. 2. Mean daily N_2O flux measured between April 22 and October 22 in 2013 and between April 16 and October 21 in 2014 by treatment in (a) annual grass, (b) native prairie, (c) Miscanthus, and (d) switchgrass study. Error bars represent standard errors of mean dry biomass yield based on replicated plots (n= 4, 4, 2, and 2 in annual grass, native prairie, Miscanthus, and switchgrass study, respectively). Downward-pointing black arrows indicate date of planting and downward-pointing green arrows indicate date of fertilizer application. Vertical bars in (b) represent daily total precipitation received from April 15 to October 30 in 2013 and 2014 at the Throckmorton Purdue Agricultural Center, Lafayette, IN.

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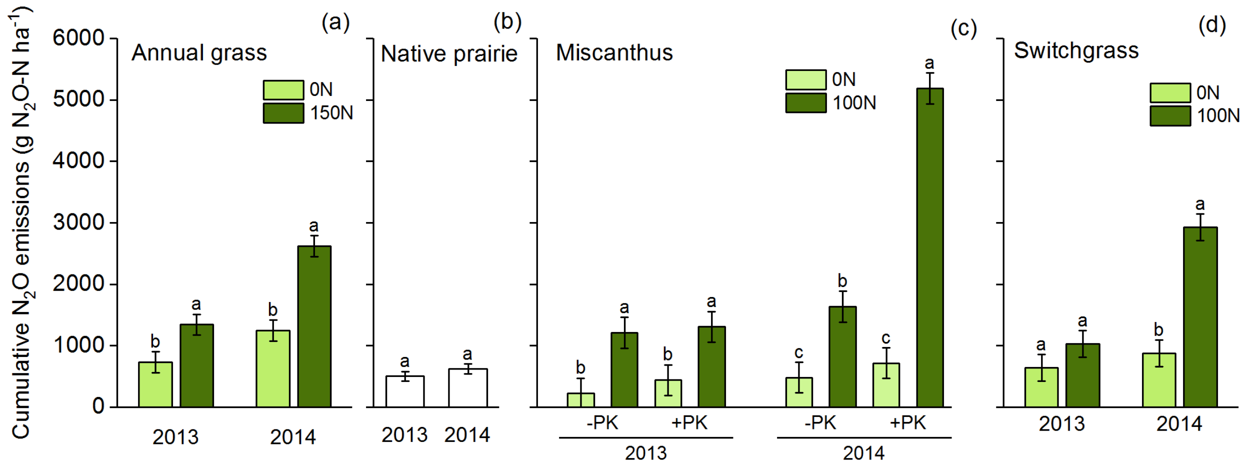

Fig. 3. Mean cumulative N_2O-N emissions calculated between April 22 and October 22 in 2013 and between April 16 and October 21 in 2014 as influenced by (a) N rate × year interaction in the annual grass study, (b) N rate × year interaction in the switchgrass study, (c) PK rate × N rate × year interaction in the Miscanthus study, and (d) by year in the native prairie study. Error bars represent standard errors of mean cumulative N_2O-N emissions based on replicated plots (n= 4, 4, 2, and 2 in annual grass, native prairie, Miscanthus, and switchgrass study, respectively). Different lowercase letters over the vertical bars indicate there is significant difference ($P < 0.10$) in mean cumulative N_2O-N emissions among two N treatments in 2013 and 2014 in annual grass and switchgrass study while in Miscanthus different lowercase letters over the vertical bars indicate there is significant difference ($P < 0.10$) between PK and N fertilizer treatments within years.

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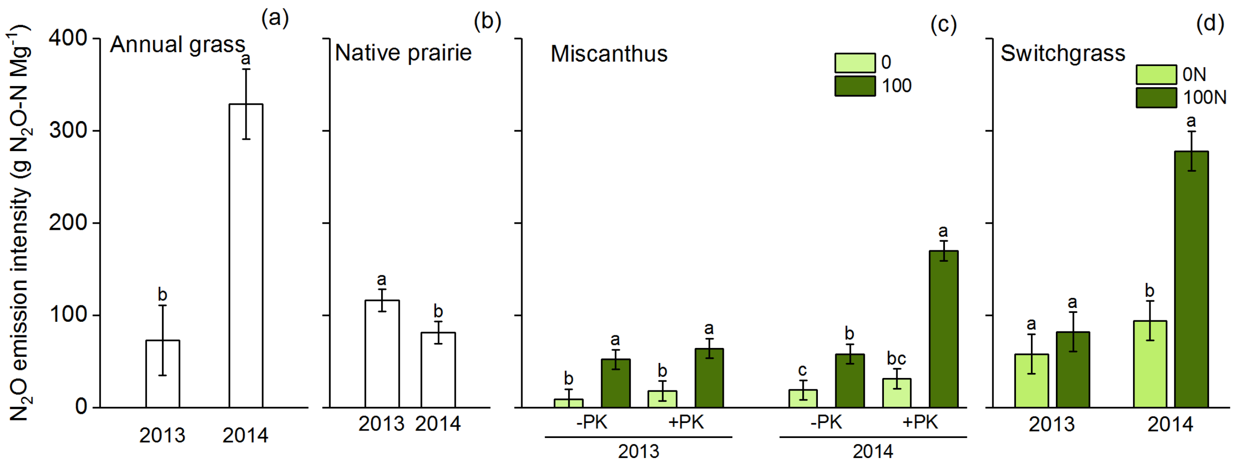

Fig. 4. Mean N_2O-N emission intensities calculated as the ratio between cumulative N_2O-N emissions (kg N_2O–N ha^{-1}) between April 22 and October 22 in 2013 and between April 16 and October 21 in 2014 and their respective aboveground biomass yield (Mg ha^{-1}) as influenced by (a) year in the annual grass, (b) year in the native prairie, (c) PK rate × N rate × year interaction in the Miscanthus, and (d) N rate × year interaction in the switchgrass study. Error bars represent standard errors of mean N_2O-N emission intensities on replicated plots (n= 4, 4, 2, and 2 in annual grass, native prairie, Miscanthus, and switchgrass study, respectively). Different lowercase letters over the vertical bars indicate there is significant difference ($P < 0.10$) in mean N_2O-N emission intensities of two years in annual grass and native prairie study and different lowercase letters over the vertical bars in the switchgrass indicate there is significant difference ($P < 0.10$) among two N treatments in 2013 and 2014 while in Miscanthus different lowercase letters over the vertical bars indicate there is significant difference ($P < 0.10$) between PK and N fertilizer treatments within years.

- **University of Illinois**

  We are currently conducting analyses of four years of data and writing manuscripts for publication in refereed journals.

- **University of Minnesota**

  - **Becker Location**

    We completed our post-frost harvest on October 13, 2016. Samples have been weighed, dried, and ground.

  - **Lamberton Location.**

    We completed our post-frost harvest on October 26, 2016. Samples have been weighed, dried, and ground.

  - **Additional Activities.**

    Anne Sawyer is making progress on her dissertation using data collected from CenUSA.

The first chapter, "Switchgrass and mixed perennial biomass production as affected by nitrogen fertility and harvest management," examines near-anthesis and post-frost yield data and N uptake/removal from three switchgrass cultivars ('Liberty,' 'Shawnee' and 'Sunburst') and three perennial polycultures at Becker (2012-2015) and Lamberton (2013-2016). We are working on internal revisions prior to submission for publication.

Chapter 2, "Rhizobacterial community structure as a function of cultivar and nitrogen in switchgrass grown on two marginal soils", explores the community of rhizosphere bacteria in unfertilized and fertilized (112 kg N ha-1) 'Liberty', 'Shawnee' and 'Sunburst' from the near-anthesis harvest in 2014 using high-throughput sequencing of the 16S rRNA gene. We will submit this chapter for publication after review by Anne's dissertation committee.

Chapter 3 "Cultivar and phosphorus fertilization effects on switchgrass biomass yield, phosphorus removal, and rhizosphere microflora." It is similar to Chapter 2 in using high-throughput sequencing of the 16S rRNA gene in bacteria, but also includes sequencing of the ITS region in fungi. Post-frost switchgrass biomass yield and P removal in 'Liberty,' "Shawnee", and 'Sunburst' was evaluated at four P rates (0, 22, 45 and 67 kg P2O5 ha-1) over three years, and near-anthesis rhizosphere microflora community structure was evaluated in all cultivars at 0 and 67 kg P2O5 ha-1. As with Chapter 2, we will submit this chapter for publication after review by Anne's dissertation committee.

Anne Sawyer's defense is scheduled for June 15, 2017, and she anticipates graduating in July 2017.

- **USDA-ARS, Lincoln**

  - **Actual Accomplishments**

    ✓ Completed all field work.

    ✓ Predicted samples from multiple locations.

    ✓ Completing equipment repair, fence repair, and field updates following field trials.

    ✓ Ground, milled, and scanning all Nebraska samples.

  - **Current Actions**

    ✓ **Demonstration Plots**

    Yield data for 2012-2016 is being summarized.

    ✓ **Factor Analysis Plots**

- ➢ Yield data for 2012-2016 is being summarized.
- ➢ Samples collected in 2012, 2013, 2014, 2015, & 2016 have been processed and are being scanned and predicted.

✓ **System Analysis Plots**

- ➢ All samples are being scanned and predicted.
- ➢ Mineral analysis samples have been completed and NIRS prediction is being developed.
- ➢ GHG samples from 2013-2015 are being summarized.
- ➢ VOM and elongated leaf height data are being summarized.
- ➢ Harvest height and harvest date data are being summarized.
- ➢ Bales were weighed and transported.
- ➢ Seed production areas were burned.
- ➢ Triticale was sampled.
- ➢ Corn was planted.

- **Plans for Next Quarter**
  - ✓ Scan and predict biomass samples forwarded from other locations.
  - ✓ Finalize mineral data and work on NIRS prediction equation.
  - ✓ Finalize the scanning and predicting of 2012, 2013, 2014, 2015, and 2016 Nebraska biomass samples.
  - ✓ Analyze and summarize field data.
  - ✓ Submit manuscripts on CenUSA projects.
- **Table 1.** Field scale yields for 'Liberty' switchgrass, big bluestem, a low diversity mixture, corn grain, and corn stover from rainfed fields near Mead, NE from 2012 through 2016. Yields represent 3 field replicates and are the mean of two fertilizer treatments (50 & 100 lb N/acre) since there was no clear response to N application. Perennial grasses were established in 2012, and grass yields from 2013-2016 represent the total dry matter that was harvested, baled, and transported from the field to the storage facility. Perennial grass means include the planting year. Herbicide damage from

glyphosate in 2014 reduced switchgrass yields in 2014 and 2015.

Table 1. Field scale yields for 'Liberty' switchgrass, big bluestem, a low diversity mixture, corn grain, and corn stover from rainfed fields near Mead, NE from 2012 through 2016.

Feedstock	2012	2013	2014	2015	2016	2017
Liberty switchgrass	3.4	5.1	4.5	4.6	5.7	4.7
Big bluestem (t/a)	1.2	4.1	4.7	4.3	5.4	3.9
LD Mixture (t/a)	1.9	5.0	5.7	5.7	6.1	4.9
Corn (bu/acre)	103.0	149.0	139.0	126.0	145.0	132.0
Stover (t/a)	1.4	1.9	1.8	1.7	1.6	1.7

- **Table 2.** Field scale yields for 'Liberty' switchgrass, big bluestem, and a low diversity mixture from rainfed demonstration fields near Humboldt, Nebraska and Beaver Crossing, Nebraska in 2016. Yields represent 2 field replicates and are the mean of three fertilizer treatments (0, 60 & 120 lb N/acre). Perennial grasses were established in 2012 at Humboldt and 2013 at Beaver Crossing and data represents the total dry matter that was harvested, baled, and weighed in the field in 2016.

Table 2. Field scale yields for 'Liberty' switchgrass, big bluestem, and a low diversity mixture from rainfed demonstration fields near Humboldt, NE and Beaver Crossing, NE in 2016.

Feedstock	Humboldt, NE	Beaver Crossing, NE	Mean
Liberty switchgrass (t/a)	3.4	5.1	4.5
Shawnee switchgrass (t/a)	1.2	4.1	4.7
LD Mixture (t/a)	1.9	5.0	5.7

- **USDA-ARS, Madison**

Currently summarizing data and writing papers. Two manuscripts are partially written. Tentative titles are:

- Nitrogen fertilization and harvest date effects on biomass yield and nutrient removal of switchgrass.
- Soil nitrogen responses to nitrogen fertilization and differential harvest dates of switchgrass.

2. Publications / Presentations/Proposals Submitted

- Participated in the DOE/USDA Bioeconomy Initiative: Action Plan Coordination Meeting, USDOE, Washington, DC, April 5-6, 2017.
- We are preparing to host Switchgrass IV, Prairie and Native Grass International Conference in Lincoln, NE, August 7-10, 2017.
- We leveraged CenUSA research sites to garner additional funding from the North-Central SunGrant on the project "Growing Bioenergy Crops on Marginally Productive Croplands: Implications on Erosion and Water Quality Parameters."
- We leveraged the Crop/Livestock/Bioenergy Production System Demonstration site in eastern Nebraska to get additional funding through the SDSU NIFA-CAP to increase sampling intensity and graze the site.
- Bonin C.L., R.B. Fidel, C. Banik, D.A. Laird, R.B. Mitchell & E. Heaton. 2017. Perennial biomass crop establishment, community characteristics, and productivity in the upper Midwest: Effects of cropping systems seed mixtures and biochar applications. Agriculture, Ecosystems and the Environment (submitted).
- Blanco-Canqui, H., R. Mitchell, V. Jin, M. Schmer & K. Eskridge. 2017. Perennial warm-season grasses for producing biofuel and enhancing soil properties: An alternative to corn residue removal. GCB Bioenergy. doi: 10.1111/gcbb.12436. Open access.
- Cibin, R., I. Chaubey, R.L. Muenich, K.A. Cherkauer, I. Panagopoulos, P.W. Gassman & C.L. Kling. 2017. Ecosystem service evaluation of futuristic bioenergy based land use change and their uncertainty from climate change and variability. J. American Water Resources Association. In Press.
- Gassman, P.W., A. Valcu, C.L. Kling, Y. Panagopoulos, R. Cibin, I. Chaubey, C.F. Volter & K.E. Schilling. 2017. Assessment of cropping scenarios for the Boone River watershed in North Central Iowa, United States. J. American Water Resources Association. In Review.
- Kling, C.L., I. Chaubey, R. Cibin, P.W. Gassman & Y. Panagopoulos. 2017. Policy implications from multi-scale watershed models of biofuel crop adoption across the Corn Belt. J. American Water Resources Association. In Press.
- Panagopoulos, Y., P.W. Gassman, C.L. Kling, R. Cibin & I. Chaubey. 2017. Assessment of large-scale bioenergy cropping scenarios for the Upper Mississippi and Ohio-Tennessee River basins. J. American Water Resources Association. Accepted.

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**

   Research activities planned included:

   - Development and validation of biomass "drying prediction models" to predict relative increase in biomass moisture levels during a rainfall event and subsequent drying profile after the re-wetting of biomass materials.

   - Continued development and evaluation of prototype real-time biomass moisture sensor for switchgrass and corn stover.

2. **Actual Accomplishments**

   During this quarter, the emphasis has been on the completion of the analysis, writing and submission of journal articles.

   An improved biomass drying prediction models has been developed. This model uses a random forest (RF) classification based algorithm, to predict moisture content (MC) of switchgrass (SW) and corn stover (CS). RF was able to predict the moisture content of switchgrass (SW) and corn stover (CS) with a coefficient of determination of 0.77 and 0.79, respectively. Hours after harvest, average solar radiation intensity, change in radiation intensity, rainfall, VPD were found to be the most important factors affecting the MC of CS. Drying CS in low density (LD) and medium density (MD) swaths facilitated quick drying even in moderate drying conditions and density were found to be higher in importance than other variables used for model development. Rainfall events ranging from 1.5 to 7.5 mm were experienced during the switchgrass drying period which delayed the crop drying by one day to several days depending on the weather conditions after rainfall. Several rewetting events were also observed due to dew at night and early morning which increased the MC in LD switchgrass and CS by 5 to 15%. The models developed in current study will help in decision making of switchgrass and CS collection after harvest based on forecasted weather conditions in lower Midwestern states.

A book chapter to be published in CRC Biomass Preprocessing Book, has been submitted and reviewed and is expected to be published in July 2017. A journal article has been submitted to Agricultural and forest meteorology Journal for review.

3. **Explanation of Variance**

No variance in planned activities has been experienced.

4. **Plans for Next Quarter**

Research activities planned during next quarter include:

Completion of all data analysis, and submission of journal articles.

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

- Khanchi, A. & S.J. Birrell. 2017. Modeling the influence of crop density and weather conditions on field drying characteristics of switchgrass and corn stover using random forest. Agricultural and Forest Meteorology Journal (Submitted).
- Khanchi, A. B Sharma, A.K. Sharma, A Kumar, J.S. Tumuluru & S.J. Birrell. 2017. Effects of Biomass Preprocessing Technologies on Gasification Performance and Economic Value of Syngas. Book Chapter submitted to CRC Biomass Preprocessing Book Chapter. (Submitted, to be published July 2017).

University of Wisconsin

1. **Planned Activities**

Our efforts in this quarter were to include:

- Re-design the experimental high-density baler to address crop flow issues.
- Continue to compress large square biomass bales to increase the dataset size.
- Continue work on twine tension for large square bales.
- Continue the outdoor storage study of large square bales covered with breathable film.
- Complete manuscripts for publication review.

2. **Actual Accomplishments**

- We have acquired a new baler pick-up and we have completed the redesign of the experimental baler to accommodate this pick-up. We have started parts fabrication and modifications. Tests are planned for early summer.

- Compression data for large-square biomass bales of biomass has been delayed until a new crop becomes available this summer. We purchased components to allow lab test of twine knot failures. We have developed samples of various restraining materials using different ways to make twine knots. We have developed a protocol to measure twine knot failure and is in the process of test and improvement before actual replicated tests begin.
- We began a storage study in the fall where the main objective is to explore cost-effective means to store large-square-bales (LSB) outdoors. These bales are being monitored for moisture content and temperature during the storage period and will be removed from storage in mid-summer.
- Two publications previously submitted for peer review have been reviewed. One has been published and the other is undergoing minor revisions. Work has shifted to two new publication dealing with biomass harvest energy requirements and LSB twine tension.

3. Explanation of Variance

Work has progressed as planned.

4. Plans for Next Quarter

Our efforts in the next quarter will include

- Finish fabrication and modifications to the experimental high-density baler.
- Continue to compress large square biomass bales to increase the dataset size.
- Continue work on twine tension for large square bales.
- Continue the outdoor storage study of large square bales covered with breathable film.
- Complete two additional manuscripts for publication review.

5. Publications, Presentations, and Proposals Submitted

- Shinners, K.J. and J.C. Friede. 2017. Enhancing switchgrass drying rate. BioEnergy Research, doi:10.1007/s12155-017-9828-5.
- Shinners. K.J., B.K. Sabrowsky; C.L. Studer & R.L. Nicholson. 2017. Switchgrass harvest progression in the North-Central US. Submitted to BioEnergy Res. (2 Feb.) Now accepted pending minor revisions.

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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**

   Our efforts remain focused on moving the set of four manuscripts submitted to the Journal of the American Water Resources Association SWAT Special Series through the review process. Abstracts are again provided for the four manuscripts as Exhibit 1 to this report.

2. **Actual Accomplishments**

   As reported previously, two of the manuscripts (Kling et al. and Cibin et al.) are now accepted (see citations below). The Panagopoulos et al. manuscript is now tentatively accepted and final acceptance of that study is expected soon. Meanwhile, the Gassman et al. manuscript has gone through a second review that resulted in more requested revisions, after the manuscript was sent to an entirely new reviewer who did not participate in the original review. Revisions are being performed to that manuscript with a goal of resubmitting it by the end of May 2017.

3. **Explanation of Variance**

   No variance has been experienced.

4. **Plans for Next Quarter**

The main goal is to complete the review and obtain final acceptance from JAWRA of the Gassman et al. manuscript.

5. Publications, Presentations, and Proposals Submitted

- Cibin, R, I. Chaubey, R.L. Muenich, K.A. Cherkauer, P. Gassman, C. Kling and Y. Panagopoulos. 2016. Ecosystem Services Evaluation of Futuristic Bioenergy-based Land Use Change and Their Uncertainty from Climate Change and Variability. J. Am. Water Resour. Assoc.(accepted).
- Gassman, P.W., A. Valcu, C.L. Kling, Y. Panagopoulos, C. Raj, I. Chaubey, C.F. Wolter, K.E. Schilling. 2016. Assessment of Bioenergy Cropping Scenarios for the Boone River Watershed in North Central Iowa, United States. J. Am. Water Resour. Assoc. (in review).
- Kling, C.L., I. Chaubey, C. Raj, P.W. Gassman, Y. Panagopoulos. 2016. Policy Implications from Multi-Scale Watershed Models of Biofuel Crop Adoption across the Corn Belt. J. Am. Water Resour. Assoc. (accepted).
- Panagopoulos, Y., P.W. Gassman, C.L. Kling, R. Cibin and I. Chaubey. 2016. Assessment of Large-scale Bioenergy Cropping Scenarios for the Upper Mississippi and Ohio-Tennessee River Basins. J. Am. Water Resour. Assoc. (first review received; revisions being performed).

University of Minnesota

1. Planned Activities

We continued submission of manuscripts from output of previous quarters.

2. Actual Accomplishments

This quarter, we resubmitted, after revision, two manuscripts related to the output of previous quarters: the first on the air quality impacts of increased switchgrass production, and the second on the output of the modeling platform developed to support air quality impact assessment. One paper, by Tessum et al. and supported in part by CenUSA, was published (See below).

3. Explanation of Variance

No variance has been experienced.

4. Plans for Next Quarter

Continued submission of manuscripts from output of previous quarters.

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

Tessum C.W., Hill J.D. & J.D. Marshall. 2017. InMAP: A model for air pollution interventions. PLoS ONE 12(4): e0176131. https://doi.org/10.1371/journal.pone.0176131 Open Access.

Post-Harvest

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

This portion of the project is complete.

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 to produce 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**

Continue work on the economic feasibility of grasses, modelling the optimization problem of a unique plant under different market structures and, using assumptions based on local commercial biomass processors, estimate input requirements and costs of grass feedstocks to meet the cellulosic mandate.

2. **Actual Accomplishments**

Graduate student Ryan Goodrich, who was previously supported by the CenUSA project, successfully completed his preliminary oral exam to become a PhD candidate in the Department of Economics at Iowa State University. Ryan's dissertation work is on the supply of biomass for bioenergy using spatially explicit models that account for crop location, distances to processing, and operational cost factors.

3. **Explanation of Variance**

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

4. **Plans for Next Quarter**

- We will develop a survey that will be used to identify the producer and land characteristics that may be used to infer optimal collection strategies for grasses from that used for stover, and

- We will finalize the work on the economic feasibility of grasses, including a summary of our findings from the CenUSA project and suggestions for future work to advance knowledge of markets and efficient distribution systems.

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

- Co-PD Jacobs presented worked funded by CenUSA at C-FARE's Conference in Washington, D.C. February 17, 2017. "American-made BioEnergy from Field to Refinery: Feedstock Logistics." The CenUSA project was the catalyst for the research on which the presentation was based.

- Co-PDs Hayes and Jacobs along with recent PhD Chao Li submitted a paper for peer-review at the American Journal of Agricultural Economics, "Competition, delivery mechanisms and market outcomes for cellulosic feedstock."

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**

The reviewers' comments will be address for the *Journal of Agricultural Safety and Health* manuscript. Page proofs are expected to be review and this journal article be completed. The authors will also address comments raised by the eXtension.org reviewer.

- **Actual Accomplishments**

The reviewers' comments were addressed for the *Journal of Agricultural Safety and Health* manuscript. The editor indicated adjustment to reviewers' comments was accepted and the manuscript was ready for publication. The final step will be reviewing page proofs before printing.

Page proofs for the *Journal of Agricultural Safety and Health* by the American Society of Agricultural and Biological Engineers have not arrived as expected. The delay in receiving page proofs are expected to be connected with American Society of Agricultural and Biological Engineers staff preparing for annual conference.

The authors addressed comments raised by the eXtension.org reviewer about the research summary posted on eXentsion.org website. Additionally, corrections were submitted that were generated by the review of the manuscript by *Journal of Agricultural Safety and Health*.

- **Explanation of Variance**

See above.

- **Plans for Next Quarter**

Page proofs are expected to be review and this journal article be completed.

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

  - ✓ Ryan, S. J., C. V. Schwab & G. A. Mosher. 2017. Agricultural worker injury comparative risk assessment methodology: assessing corn and biofuel switchgrass production systems. J. Ag Safety & Health. (In Press).
  - ✓ Ryan, S. J., C. V. Schwab & H. M. Hanna. 2017. Research summary: overview of comparative injury risk between annual corn and perennial switchgrass production. eXtension.org website http://articles.extension.org/pages/74211/research-summary:-overview-of-comparative-injury-risk-between-annual-corn-and-perennial-switchgrass-

2. Task 2 – Assessing Primary Dust Exposure

- **Planned Activities**

Have one or two pilot samples taken.

- **Actual Accomplishments**

  No samples have been taken at this time.

- **Explanation of Variance**

  None to report.

- **Plans for Next Quarter**

  Have one or two pilot samples taken and the analysis of the pilot dust exposure completed.

- **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

- Continue editing final module content.
- Determine repository location for modules at end of CenUSA project term.

- **Module 10 – Plant Breeding**

  Convert draft content to an on-line version.

- **Module 16 – Quality and Nutrient Management**

  Continue editing module content.

2. **Actual Accomplishments**

   We decided to keep Ohio State University (OSU) ATI as repository location for CenUSA module program content due to uncertainty associated with future support for maintaining and additional development work for the module program. All modules will be stored in Canvas format for use at OSU and in PDF format where appropriate.

   - **Module 10 – Plant Breeding**

     We converted the draft content to an on-line version.

   - **Module 16 – Quality and Nutrient Management**

     We suspended work on this module in lieu of work on Module 10.

   - **Module 17 – Plant Pathology for Warm-Season Grasses**

     We prepared the online lesson and are waiting the review from the technical expert.

3. **Explanation of Variance**

   We suspended work on this module in lieu of work on Module 10.

4. **Plans for Next Quarter**

   - **Module 10. Plant Breeding**

     We will review the draft on-line lesson and make edits as needed.

   - **Module 17 – Plant Pathology for Warm-Season Grasses**

     We will review the draft online lessons and make edits as needed.

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

   None to report this period.

Subtask 2A: Training Undergraduates via Internship Program

1. **Planned Activities**

   None as this was strictly a prior year activity. No forward planning is required.

2. **Actual Accomplishments**

   None as this was strictly a prior year activity. No forward planning is required.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

   None as this was strictly a prior year activity. No forward planning is required.

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**

   None.

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 public awareness of perennial crops and biochar agriculture.
  - Certified Crop Advisor training.

- **Economics and Decision Tools Team**

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

- **Health and Safety Team**

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

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

  This team focuses on two separate areas:

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

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

- **Evaluation/Administration Team**

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

  1. **Current Activities**

     Nearly all the activities of the CenUSA Extension Team wrapped up in December 2016. Below, please find descriptions of the three activities that continued into 2017:

     - Video clips for the final CenUSA video, which will feature information about pyrolysis, have been gathered and the storyboard for the video has been completed. The video will be completed and archived to the CenUSA web sites by the end of June 2017 and will be shared via social media and the CenUSA website.

     - The Iowa State University CenUSA Extension Economics team continued to promote the CenUSA Switchgrass Decision Tool at meetings with farmers and conservationists during February and March 2017. 119 people downloaded/completed the CenUSA Decision Tool (http://www.extension.iastate.edu/AgDM/crops/html/a1-29.html) this quarter. This brings total downloads and completions during the CenUSA project to 809, exceeding our project goal by 309!

     - The bulk of work in this quarter has centered on preparing for two teacher training events for the CenUSA C6 BioFarm program that will be conducted in June 2017. The first will be held in collaboration with Morningside College in Sioux City, IA on June 6, 14, 15 and 16. The course syllabus has been completed (Exhibit 2), and the class has been approved for both teacher renewal credit and graduate credit, on-line systems for teacher "homework" and course evaluation have been drafted and tours have been arranged. The class is fully subscribed.

- The second teacher training event will be held in conjunction with the National Ag in the Classroom Conference (June 20-23, see: https://naitcconference.usu.edu/). CenUSA is a sponsor for the conference. Jill Euken and Jay Staker will be providing CenUSA C6 BioFarm plenary and breakout sessions and staffing a CenUSA C6 exhibit during the conference.

2. Plans for Next Quarter

- Complete and post CenUSA pyrolysis video.
- Execute the CenUSA C6 BioFarm teacher trainings.
- Complete final quarterly report and final project for CenUSA Extension.

3. Google Analytics Data

- **CenUSA Website.** The CenUSA web site had 519 unique visitors this quarter. These visitors logged a total of 1,472 pageviews during 667 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, and the user returns, a new session is started.
- **Continuing Impact of Vimeo Channel**. During this quarter, the 54 CenUSA videos archived on Vimeo have had 211 plays or views of the videos on our Vimeo site, or on a web site that embedded a CenUSA video. The 54 videos also had 4,814 loads; 927 of those loads came from our videos embedded on other sites. This is a significant increase over last quarter's 125 views and 1,107 loads and reflects our continued efforts to publicize our video resources using social media. When a video is loaded, people see the video but they do not click "play". Vimeo videos were downloaded 8 times (0 last quarter). This 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 a video). Once the video is downloaded, it is available on their computer to watch at their convenience.
- **Continuing Impact of YouTube Channel**. CenUSA videos are also posted on

YouTube, and those videos have been viewed 1577 times between February 1, 2017 and April 30, 2017 (1385 views last quarter). 967 views were from the United States. Demographic analytics report an audience that is 84% male and 16% female. Our viewers ranged in age from 13-65+. The top 3 represented age groups were 18-24 (23%), 25-34 (23%), and 35-44 (21%).

YouTube also provides data related to how users access the videos. Videos were viewed on their associated watch page, the YouTube Channel page, or on web pages where the videos were embedded. 97% of the videos were viewed on their associated YouTube watch page (each video has a unique “watch page”). Embedded videos on another site accounted for 2.8% of the views. Our top 4 traffic sources for this quarter include: YouTube search, YouTube suggested videos, referrals from other web sites, and browse features (subscription feed, homepage navigation options, etc.). 43% of our views came from users accessing videos suggested by YouTube.

YouTube search accounted for 30% of our views. Referrals from outside YouTube (google search or access through external web sites) account for 15% of the video views. Browse features accounted for 12% 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. CenUSA bioenergy has 1049 followers currently, up from 977 followers last quarter
- **Facebook**. By the end of January 2017, CenUSA’s Facebook page had 264 likes, up from 254 the previous quarter.

Objective 10. Commercialization - Renmatix

During Q3 we conducted a number of experiments related to lignin’s ability to perform as an anti-oxidant in thermoplastics. The results from those experiments are just now coming in and being reviewed. Results will be reported during the next quarter.

Exhibit 1

Exhibit 1. Abstracts for set of four studies submitted to the Journal of the American Water Resources Association (JAWRA)

- Kling, C.L., I. Chaubey, C. Raj, P.W. Gassman & Y. Panagopoulos. 2016. Policy Implications from Multi-Scale Watershed Models of Biofuel Crop Adoption across the Corn Belt. *Journal of the American Water Resources Association* (accepted).

  Abstract: The implications and value of SWAT-based simulations of the productive potential and water quality impacts associated with switchgrass, Miscanthus or corn stover removal biofuel cropping systems are discussed. Specifically, the three accompanying studies describe the water quality implications of adopting the three biofuel cropping systems via large-scale conversion of cropland or targeting to marginal lands for three smaller watersheds located in the western or eastern Corn Belt, or across the Upper Mississippi and Ohio-Tennessee River Basins. Other results such as climate change related impacts for two eastern Corn Belt watersheds are also discussed. These studies are supported by the CenUSA Bioenergy coordinated agricultural project funded by the USDA to develop a regional system for producing cellulosic biofuels. A description of the evolving federal policy related to cellulosic biofuel production and consumption is provided as are other potential drivers for encouraging the adoption of stover removal, switchgrass, and Miscanthus as perennial feedstocks. Findings from the SWAT studies and their implications for environmental and economic performance in their respective agroecosystems are discussed, and commonalities and divergences in results are identified. The potential for policy design to improve the performance of these systems based on the findings of these modeling studies, and continuing research needs and directions for improved policy design are discussed.

- Cibin, R, I. Chaubey, R.L. Muenich, K.A. Cherkauer, P. Gassman, C. Kling & Y. Panagopoulos. 2016. Ecosystem Services Evaluation of Futuristic Bioenergy-based Land Use Change and Their Uncertainty from Climate Change and Variability. *Journal of the American Water Resources Association* (accepted).

  Abstract: Land use change can significantly affect the provision of ecosystem services and the effects could be exacerbated by projected climate change. We quantify ecosystem services of bioenergy based land use change and estimate the potential changes of ecosystem services due to climate change projections. We considered seventeen bioenergy based scenarios with Miscanthus, switchgrass, and corn stover as candidate bioenergy feedstock. Soil and Water Assessment Tool simulations of biomass/grain yield, hydrology and water quality were used to quantify ecosystem services fresh water provision (FWPI), food (FPI) and fuel provision, erosion regulation (ERI), and flood regulation (FRI). Nine climate projections from Coupled Model Intercomparison Project phase-3 were used to quantify the potential climate change variability. Overall, ecosystem services of heavily row cropped

Wildcat creek watershed were lower than St. Joseph River watershed which had more forested and perennial pasture lands. The provision of ecosystem services for both study watersheds were improved with bioenergy production scenarios. Miscanthus in marginal lands of Wildcat creek (9% of total area) increased FWPI by 27% and ERI by 14% and decreased FPI by 12% from the baseline. For St. Joseph watershed, Miscanthus in marginal lands (18% of total area) improved FWPI by 87% and ERI by 23% while decreasing FPI by 46%. The relative impacts of land use change were considerably larger than climate change impacts in this study.

- Gassman, P.W., A. Valcu, C.L. Kling, Y. Panagopoulos, C. Raj, I. Chaubey, C.F. Wolter & K.E. Schilling. 2016. Assessment of Bioenergy Cropping Scenarios for the Boone River Watershed in North Central Iowa, United States. *Journal of the American Water Resources Association* (revised and resubmitted).

Abstract: Several biofuel cropping scenarios were evaluated with an improved version of SWAT as part of the CenUSA Bioenergy consortium for the Boone River watershed (BRW), which drains about 2,370 km^2 in north central Iowa. The adoption of corn stover removal, switchgrass or Miscanthus biofuel cropping systems were simulated to assess the impact of cellulosic biofuel production on pollutant losses. The stover removal results indicate that removal of 20% or 50% of corn stover in the BRW would have negligible effects on streamflow and relatively minor or negligible effects on sediment and nutrient losses, even on higher sloped cropland. Complete cropland conversion to switchgrass or Miscanthus resulted in streamflow or sediment, nitrate and other pollutant reductions ranging between 23% to 99%. The predicted nitrate reductions due to Miscanthus adoption were over two times greater compared to switchgrass, with the largest impacts occurring for tile drained cropland. Targeting of switchgrass or Miscanthus on cropland ≥ 2% slope or ≥ 7% slope revealed that a disproportionate amount of sediment and sediment-bound nutrient reductions could be obtained by protecting these relatively small areas of higher sloped cropland. Overall, the results indicate that all biofuel cropping systems could be effectively implemented in the BRW, with the most robust approach being corn stover removal adopted on tile drained cropland in combination with a perennial biofuel crop on higher sloped landscapes.

- Panagopoulos, Y., P.W. Gassman, C.L. Kling, R. Cibin & I. Chaubey. 2016. Assessment of Large-scale Bioenergy Cropping Scenarios for the Upper Mississippi and Ohio-Tennessee River Basins. *Journal of the American Water Resources Association* (first review received; revisions being performed).

Abstract: The Upper Mississippi River Basin (UMRB) and Ohio-Tennessee River Basin (OTRB) comprise the majority of the U.S. Corn Belt Region. The combined basins are the primary U.S. food, feed and biofuel production region, resulting in degraded Mississippi River and Gulf of Mexico water quality. To address the water implications of increased biofuel production, biofuel scenarios were tested with a SWAT mode revision featuring improved biofuel crop representation. Scenarios included corn stover removal and switchgrass or Miscanthus grown on marginal lands (slopes>2% and erosion rates>2 t/ha), non-marginal lands, or both. The results reveal that stover removal is environmentally neutral, even in the most sloping and erodible marginal land and perennial bioenergy crops can reduce sediment, nitrogen (N) and phosphorus (P) yields by up to 60%. In particular, sediment and P reductions were generally twice in the marginal than in the non-marginal lands, but the highest unit area reductions of N occurred in the less sloping tile-drained lands. Productivity results showed that corn grain yield was independent from stover removal, while both switchgrass and Miscanthus yields were similar in the marginal and non-marginal lands. The study indicates that biofuel production planning in the Corn Belt may include the removal of stover in highly productive corn areas and the growth of perennials in the environmentally marginal land and in the lowland tile drained areas of the highest N pollution.

Exhibit 2

NORTHWEST AEA
NORTHWEST AREA EDUCATION AGENCY

PROFESSIONAL DEVELOPMENT PROGRAM
PROPOSED COURSE SYLLABUS

Directions: This information is **required** for activities offered for credit through the Northwest AEA Professional Development Program. This is an electronically fillable form with spaces that expand as you complete them.

All syllabi need to be submitted and approved in advance of the beginning of the course.

General Course Information - Required for all activities

Instructors/Instructors of record: *For site-based activities indicate who will evaluate participant works.*	Dr. Thomas Paulsen, PhD Associate Professor and Chair Applied Agricultural and Food Studies Morningside College paulsent@morningside.edu	Jill Euken, Deputy Director Bioeconomy Institute Iowa State University Ames, IA 50011 jeuken@iastate.edu
	C6 BioFarm Educational Game Suite and Curriculum	
Course registration:	☒ Open (show course on web) ☐ Site based (available to select group only – “hidden” registration)	
Course description: *This should be 3 to 5 sentences in length and should identify content, purpose, and/or focus of the class.*	C6 BioFarm is a game suite and curriculum designed to help middle and high school students learn about non-renewable (fossil-based) carbon, renewable carbon and agricultural production practices. Participants in this course will learn how to implement the C6 BioFarm game suite, which includes an iPad/Android tablet app, teacher curriculum, iBook, and career videos, in their classroom.	
Target audience:	Middle and High School Agricultural Education and STEM teachers	
Credit:	☒ Licensure renewal (required) ☒ Graduate credit (optional) *Requirements have changed for graduate credit. Please note the changes under participant evaluation.*	
# of credit hours requested: *15 collaborative/contact hours per credit minimum. Don't count mealtime or independent work time.*	1 License renewal credit 1 Morningside credit	

Cost Options *- Select one*

☒ **Option 1**	**No instructor fee will be paid**. **Reduced rate** requested - $35/credit hour for licensure renewal or $85/credit hour for graduate from Morningside College
☐ **Option 2**	**Instructor stipend (up to $650) paid from registrations.** (There must be a minimum of 10 registrants for this option. For fewer than 10 registrants, the stipend will be prorated.) $85/credit hour for licensure renewal or $135/credit hour for graduate from Morningside College or Briar Cliff University, $155/credit hour from Drake University or Viterbo University. (All Graduate credit is dependent on approval of syllabus by college).
☐ **Option 3**	**Other –** If other arrangements need to be made, please contact the Professional Development Office in advance for approval.

Specific Activity Information *– Required for all activities*

Location: *Be specific – course set-up requires exact location*	The course will be held on the campus of Morningside College in the Weikert Auditorium in Buhler Rohlfs Hall. Some sessions will be held in a wet lab in the Walker Science Center. Parking will be free and in the Grace Methodist Church lot on the Southeast side of campus.
Proposed meeting dates: *Be specific – course set-up requires exact dates* **Proposed meeting times:** *Be specific – course set-up requires specific times*	(see schedule below)
Proposed ending date: *Be specific – exact date that all work will be due.*	On-campus course ends June 16. Coursework due June 30.
Minimum class size: *Not required for site-based activities*	6
Maximum class size: *Not required for site-based activities*	12
Proposed registration deadline *(for site-based activities only)*	March 15

Proposed meeting dates/times schedule:

Date	
June 6:	10 am – 12:00 pm and 1:00 pm – 4:00 pm for all students via Adobe Connect; 5 hours
June 14:	at Morningside College (Weikert Auditorium – Buhler Rohlfs Hall); begin at 9:00 am; adjourn at 5 pm 7 hours
June 15:	at Morningside College (Weikert Auditorium – Buhler Rohlfs Hall); begin at 8 am; adjourn at 5 pm 8 hours
June 16:	at Morningside College (Weikert Auditorium – Buhler Rohlfs Hall); 8 am – 3 pm 6 hours

Additional group meeting work (evenings) to plan for team teaching sessions arranged by participants – 4 hours

Additional Information *- open registration activities only*

Course materials required for participants: *If a book or published materials are required, please provide name of book/material, author(s), publisher and date, ISBN, and contact information for supplier: Cost for the book will be included in the registration fee.*	Curriculum and resource materials are available on-line (http://www.extension.iastate.edu/4h/content/c6-biofarm)
Equipment needed by *instructor:* *Technology and other equipment, i.e. DVD, projector.*	LCD projector
Comments to be printed in confirmation letter regarding materials, mealtime, etc.	A printed copy of the curriculum will be provided to participants. There will be a 30-minute lunch break (food available on site) and one 15-minute break each morning and afternoon

Course Development *– Required for all activities*

List the learning goals/objectives for this activity. *What should participants know or be able to do upon completion of this activity? These should be tied to the evaluation criteria below.*	Participants will demonstrate competence in using the plans and materials in the C6 BioFarm curriculum to help students learn about: - Fossil vs renewable carbon sources - Role of carbon in the energy cycle - Environmental impacts of biomass production for fuels, chemicals, power - Impacts of different agricultural practices on soil conservation and health, biomass collection, managing air and water pollution, bioenergy production and development - Biomass conversion technologies (pyrolysis, gasification, fermentation) - Production of biorenewable products in their community - How to reduce personal carbon footprint - Impacts of climate change on food, fuel and fiber sources - STEM careers related to biorenewable energy - Economic, social and environmental impacts of food, fuel, fiber production
Activity Syllabus/Content *How will the participants achieve the stated learning goals/objectives? It should include a detailed outline of the professional development and should include theory, demonstration and practice as appropriate.*	Specific STEM concepts related to C6 will be provided throughout the sessions with just-in-time teaching. Participants will master the lessons and demonstrate teaching the lessons to their colleagues in the class to familiarize themselves with the curriculum, allow for pedagogical development and learn necessary preparation for the lessons. The schedule overview (below) is designed to focus primarily on theory on Day 1 and on demonstration and practice on Day 2-4. Assignments will also provide documentation of learnings. 1. Day 1 (June 6): 5 hours of background theory via Adobe Connect or something similar; topics will include: overview of perennial grass production for biofuels and bioproducts; thermochemical conversion of biomass to fuels and chemicals; overview of class syllabus; overview of C6 BioFarm curriculum; assignments and details regarding teaching Lessons 1-6 of the curriculum 2. Day 2 (June 14th): convene at 9:00 am; Group 1 teaches Lesson 1; Group 2 teachers Lesson 2; Field trip to producers who are implementing perennials on the landscape for water quality or other reasons; adjourn at 5pm

	3. Day 3 (June 15th): Group 3 will do Lesson 3; Group 4 will do Lesson 4; Group 5 will do lesson 5; tour to ethanol plant; adjourn at 5 pm 4. Day 4 (June 16th): Group 5 will do Lesson 5; Group 6 will do Lesson 6; discussion of additional resources, evaluation tools and plans, group activity – groups do brainstorming about implementation; wrap-up; adjourn at 3:00 pm 5. "Homework" assignments for all participants
What research supports this activity? *Please cite sources and briefly summarize the information referenced.*	The C6 BioFarm curriculum and game suite are based on a six-year (2011-2016), $25M research project called **CenUSA Bioenergy** conducted by faculty and staff from Iowa State University, University of Nebraska, Purdue University, University of Wisconsin, University of Minnesota and the USDA ARS. Research was organized around themes of biomass production, biomass logistics, biomass conversion technologies, and environmental impacts of biomass production and utilization. Research summaries, fact sheets and videos were prepared for each of the topic areas listed above and are archived at: http://articles.extension.org/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa. This site also includes a list of publications in professional journals that were produced from the CenUSA research.
How does this professional development assist teachers in planning to meet the needs of diverse learners in their classrooms?	By experiencing the lessons as teachers and learners, participants will be able to socially construct (based on the diversity complex in their own teaching situation) appropriate accommodations to meet the needs of diverse learners in their classrooms
Which of these Iowa Teaching Standards are primarily supported by this professional development?	☒ Standard 1: Demonstrates ability to **enhance academic performance** and support for implementation of school district's student achievement goals. ☒ Standard 2: Demonstrates competence in **content knowledge** appropriate to teaching position. ☒ Standard 3: Demonstrates competence in **planning and preparing for instruction**. ☒ Standard 4: Uses strategies to **deliver instruction that meets the multiple learning needs of students**. ☒ Standard 5: Uses a variety of methods to **monitor student learning**. ☐ Standard 6: Demonstrates competence in **classroom management**. ☒ Standard 7: Engages in **professional growth**. ☒ Standard 8: Fulfills **professional responsibilities** established by school district.
Which Equity Issue does this course/professional development address (mark all that apply)? *Describe how issues will be addressed during professional development.*	☐ Multi-cultural Issues ☐ Gender Fair Issues ☒ Socio-economic Issues ☐ English Language Learners ☐ Other Diverse Learners (e.g. TAG and students with special needs)

*** Additional Information** – *Site-based registration activities only*

Summarize your data and prioritized student needs. Also indicate whether this professional development is designed to address district-wide needs or attendance center needs.	

Is this a face-to-face class or a study group for collaborative action research?	☒ Face-to-face *(most or all of the time will be spent in large group instruction)* ☒ Study group for collaborative action research *(some or all of the time will be spent collaboratively in small groups reviewing student data and reflecting on practice and logs will be kept).*
What implementation and/or student data will teachers collect and how frequently will it be collected?	Reflections will be collected following each lesson
When will planned collaboration and reflection occur?	Teachers will be teamed with a colleague to plan and teach one of the lessons of the curriculum. The two-person teams will schedule their collaboration/planning meeting at a mutually agreeable time between the kick-off meeting on June 6 and the in-person meeting on June 14. Reflections will be done after each lesson and collected from each participant at the end of each day of the training
Building administrator approving this activity	William Deeds, Provost – Morningside College Thomas Paulsen, Associate Professor – Morningside College Laura Staber, Central Scheduling Coordinator – Morningside College
AEA contact *(when appropriate)*	Carolyn Smith

Participant Evaluation –For licensure renewal only course

(Do not complete this section if course is for Graduate Credit)

What are the requirements for successful course completion and how will you assess that participants have met the stated learning goals/objectives stated above? **Renewal credit is Pass/Fail.* ***Specific criteria is required.*** *"Instructor judgment" is not adequate. A rubric may be helpful.* **FYI – Attendance should not be part of your grading scale. All participants must attend 100% of the time to earn any credit.*	N/A This course is offered for graduate credit.

Participant Evaluation – Required for graduate credit course

(Requirements are the same for License Renewal credit – Pass is equal to A or B grade)

Graduate Credit offered from Morningside College, Briar Cliff University, Drake University, and Viterbo University. Participants select the institution of their choice for credit.

What are the requirements for successful course	Each participant will be responsible for preparing and teaching one lesson from the curriculum and will participate in the learning activities	Approximate out-of-class time required

completion and how will you assess that participants have met the stated learning goals/objectives stated above? **One graduate credit requires a total of 45 hours. A minimum of 15 hours must be class time: contact/collaboration with instructor/facilitator.* **You must include letter grade delineation for A, B, C, D, and F. Specific criteria is required "Instructor judgment" is not adequate.* ***A rubric is required.*** **FYI – Attendance should not be part of your grading scale. All participants must attend 100% of the time to earn any credit.*	led by their colleagues which will allow for content knowledge evaluation. Participants will also be expected to complete and turn in reflection reports following each lesson experience describing how they will utilize the knowledge gained and the materials developed in their local school district to positively impact teaching and learning in their classroom. Participants will also be asked to identify the appropriate state Teaching Standard and Criteria for their Teaching Portfolio. See Attached grading rubric and grading scale. Out of Class Work: - Read/watch/research summaries/fact sheets/videos from the CenUSA Resource list: http://articles.extension.org/pages/72584/resources-from-cenusa-sustainable-production-and-distribution-of-bioenergy-for-the-central-usa in topic areas related to the lesion plans to be developed (see below) - Develop three complete lesson plans with assessments and an implementation plan for their local curriculum from the content presented in the course - Write and submit lesson reflections - Identify and crosswalk the activities to the National Standards for Agriculture, Math and Science	to complete each activity. 2 hours 6 hours 3 hours 4 hours

Instructor of record information

***New Requirement: All instructors need to submit an official Transcript and Resume to the Professional Development Coordinator.*

Complete Personal Information if instructor has not previously taught for the Professional Development Program or Update if Information has changed.

Name: Dr. Thomas H. Paulsen Jill Euken	Title: Associate Professor – Applied Agricultural and Food Studies Department, Morningside College Title: Deputy Director, ISU Bioeconomy Institute, Iowa State University, Ames, IA 50011
Paulsen: Home address: 3004 S. Paxton St. Sioux City , IA 51106	Work address: Morningside College 1501 Morningside Ave Sioux City, IA 51106

Euken Home address: 67242 610th Street, Lewis, IA 51544	1140D BRL 617 Bissell Road Iowa State University Ames, IA 50011	
Paulsen Home phone: (712) 830-2733 Euken Home phone: (712) 769-2284	Work phone: (712) 274-5489 Work phone: (515) 249-6286	Email:paulsent@morningside.edu Email: jeuken@iastate.edu
Paulsen BA/BS institution: NWMSU Euken BS, Iowa State University	Field of study/Year completed: Agricultural Education 1987 Field of Study: Family and Consumer Sciences Education (Permanent teaching certificate for grades 7-12) 1976	
Paulsen MA/MS/MAT institution: Iowa State University Euken MS, Iowa State University	Field of study/Year completed: Agricultural Education 2001/Principal Licensure 2005 Field of Study: Rural Sociology, 1979	
Paulsen EdS and/or EdD/PhD institution: Iowa State University	Field of study/Year completed: PhD 2011	

For approval, submit to:
Carolyn Smith
Instructional Coach/Professional Development Coordinator
Northwest Area Education Agency
1520 Morningside Ave. Sioux City, IA 51106
Phone: 712-222-6033 or WATS: 800-352-9040 x 6033
Email: casmith@nwaea.org

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

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

cenusa bioenergy

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