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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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").

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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