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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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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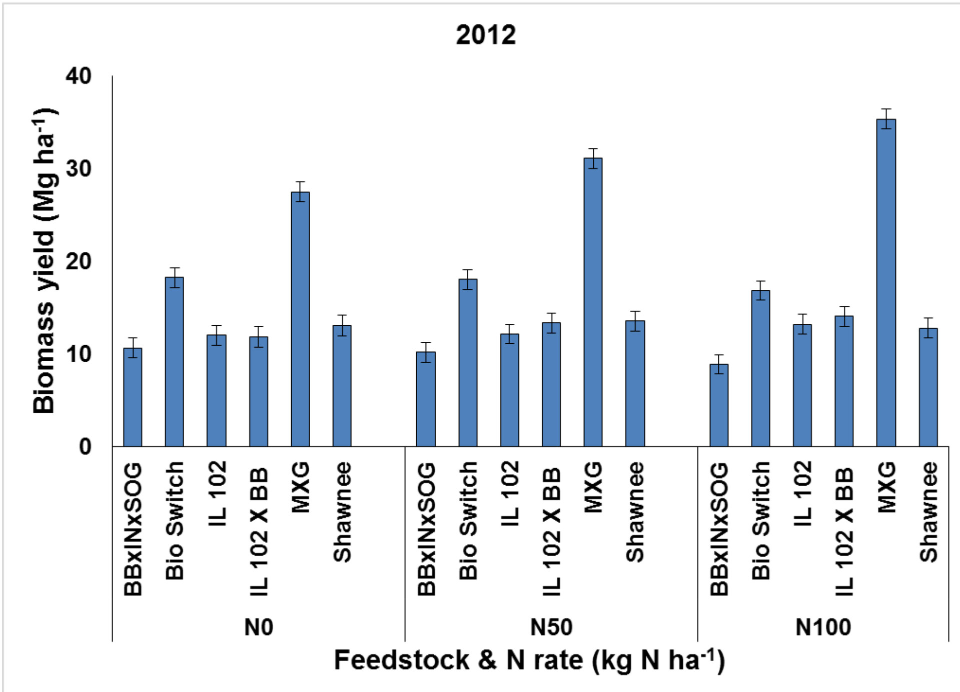

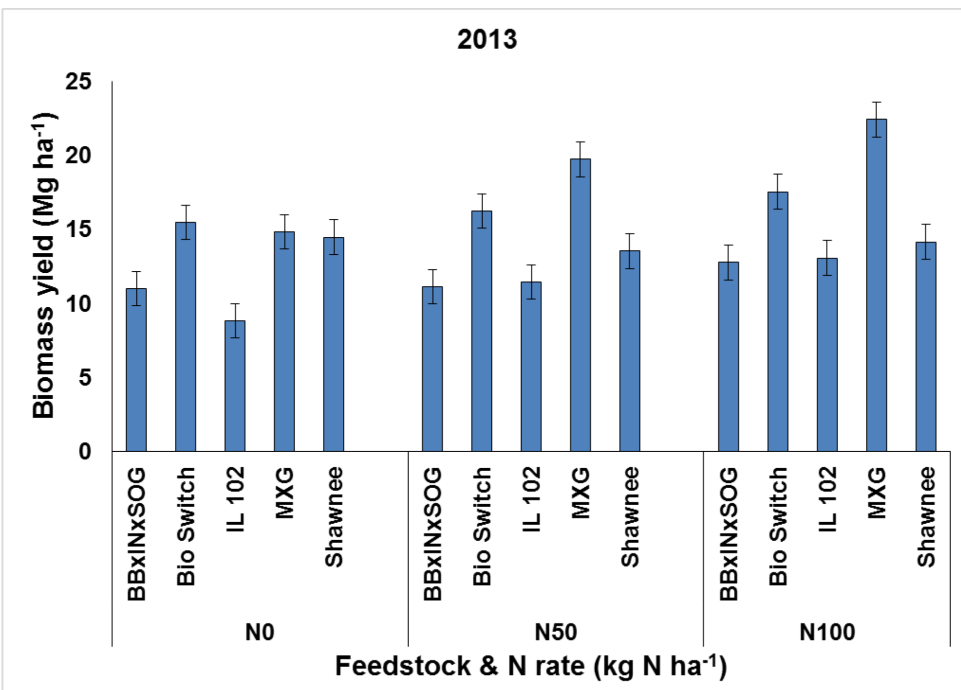

Fig 1. Effects of N rate on biomass yield of High diversity mixture (BBxINxSOG), Bioenergy switchgrass (Bio Switch), Prairie cordgrass (IL102), Miscanthus x giganteus (MXG), and switchgrass (Shawnee) and Prairie cordgrass and big bluestem mixture (IL102xBB), grown on wet marginal land during 2016. Biomass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

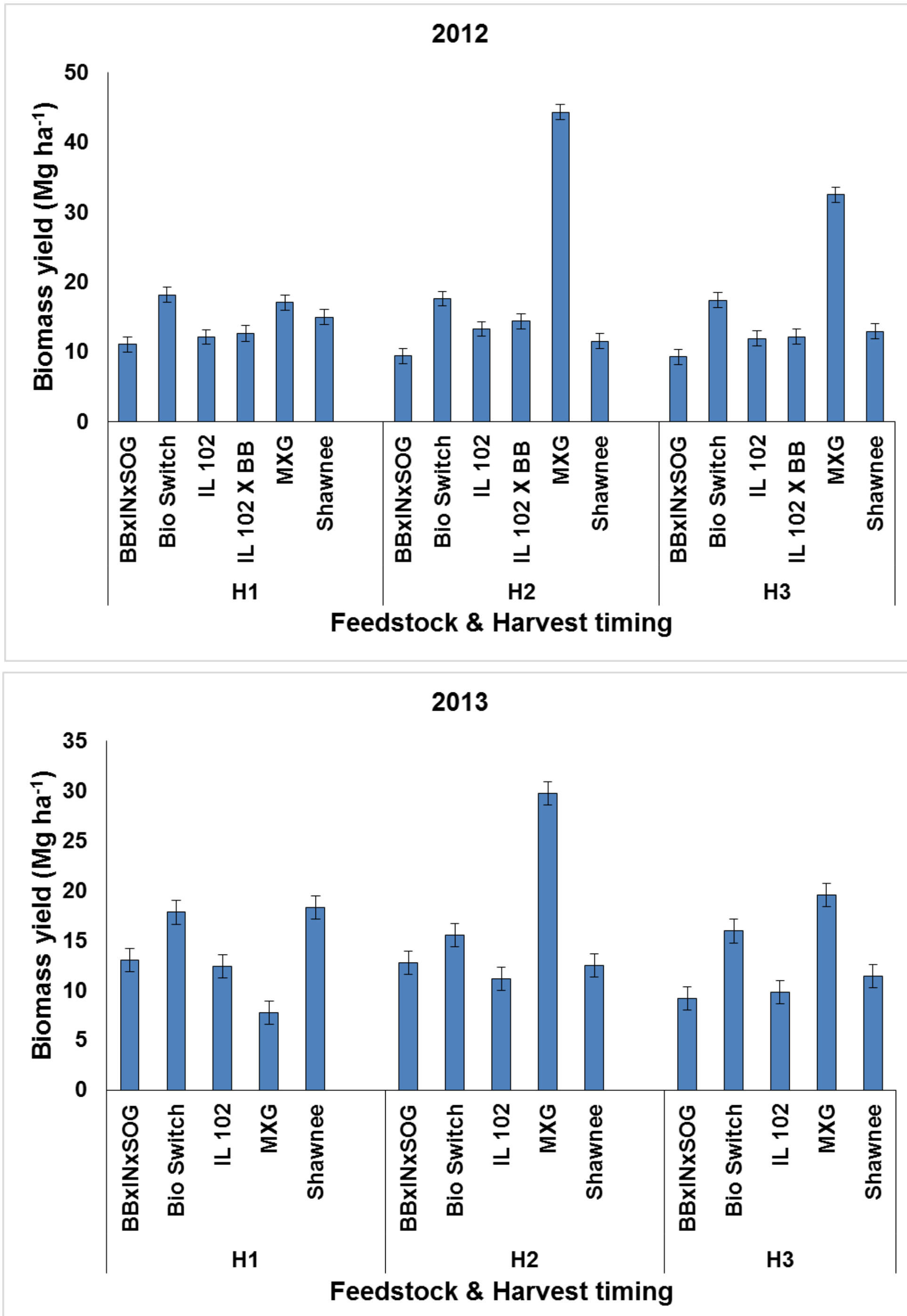

Fig 2. Effects of harvest timing (H1: post anthesis stage, H2: after killing frost, H3: alternate H1 and H2) on biomass yield of High diversity mixture (BBxINxSOG), Bioenergy switchgrass (Bio Switch), Prairie cordgrass (IL102), Miscanthus x giganteus (MXG), and Switchgrass (Shawnee) and two-way mixture (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.

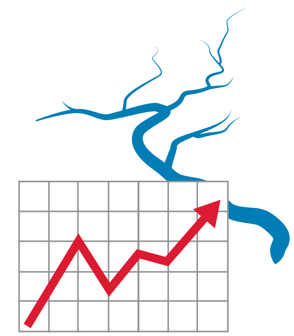
Sustainable Feedstock Production Systems

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.

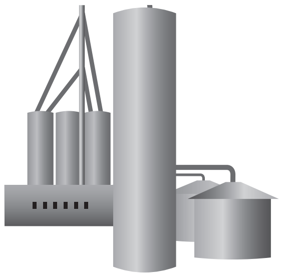
The project team developed methods to determine optimal machinery selection for switchgrass harvest and transportation, evaluated different switchgrass storage scenarios and conducted an analysis of feedstock supply costs.



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.

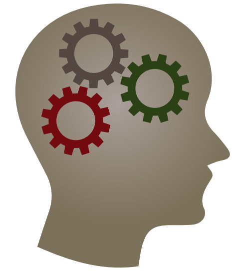
Based on market experiences of commercial cellulosic production, economists show that conventional agricultural systems do not supply enough residues to meet the cellulosic ethanol mandate, leaving room for grasses and other biomass to be competitive in that market.

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

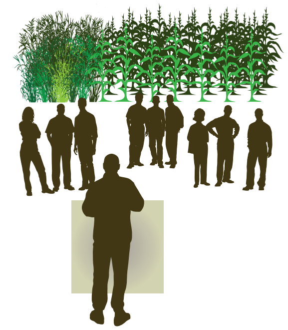


Sixty-six students went through CenUSA's undergraduate interdisciplinary internship program in which interns worked on research projects at several universities.

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.

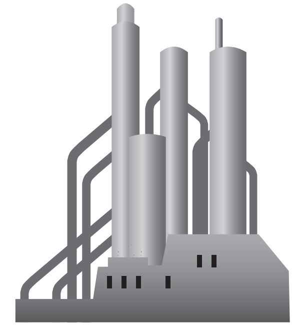
Extension and Outreach



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.

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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
- Perrin, Richard, Lilyan Fulginiti and Mustapha Alhassan. 2016. Prospects for Switchgrass as an Energy Crop (http://agecon.unl.edu/cornhusker-economics/2016/prospects-switchgrass-energy-crop) , Cornhusker Economics, University of Nebraska-Lincoln.
- Perrin, Richard, Kenneth Vogel, Marty Schmer and Rob Mitchell. 2008. Farm-Scale Production Cost of Switchgrass for Biomass (http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1130&context=agronomyfacpub) . BioEnergy Research 1(1):91-97, March, 2008.
- 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

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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*

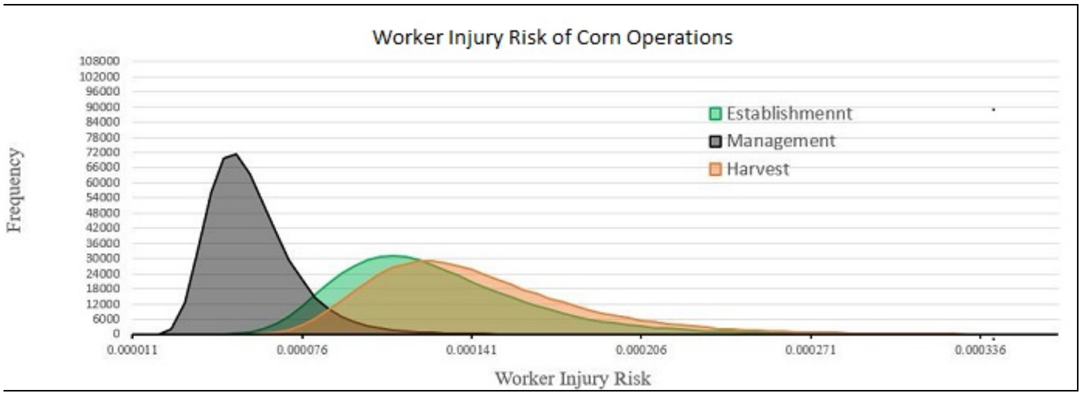
Injuries by agricultural machine type and month have been reported by Gerberich et al. (1998) for several Midwestern states. Gerberich et al. reported 83.44% of total annual injuries occurred during the March – November period, the period of interest for establishment through harvest. Distribution of 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.

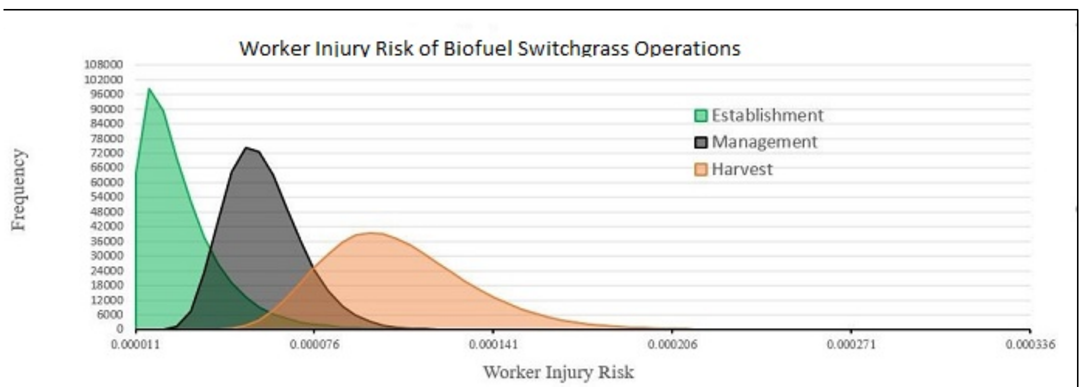
Comparing Injury Risk in Corn and Switchgrass Production Systems

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.



'ig.1. Worker injury risk frequency distributions for corn establishment, management, and harvest operations.

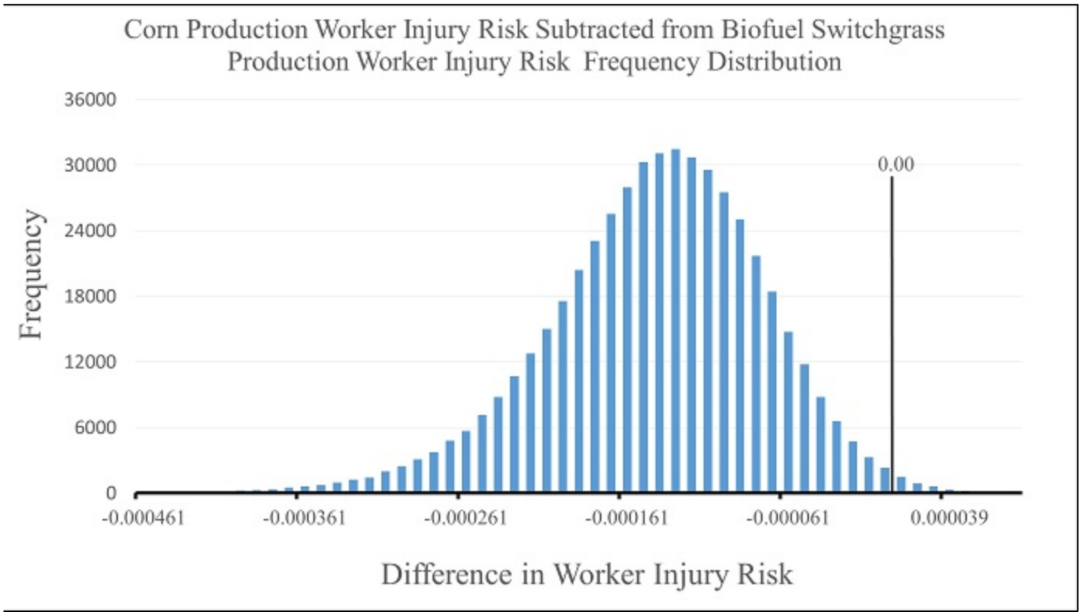


'ig.2. Worker injury risk frequency distributions for biofuel switchgrass establishment, management, and harvest operations.

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).

'ig.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.

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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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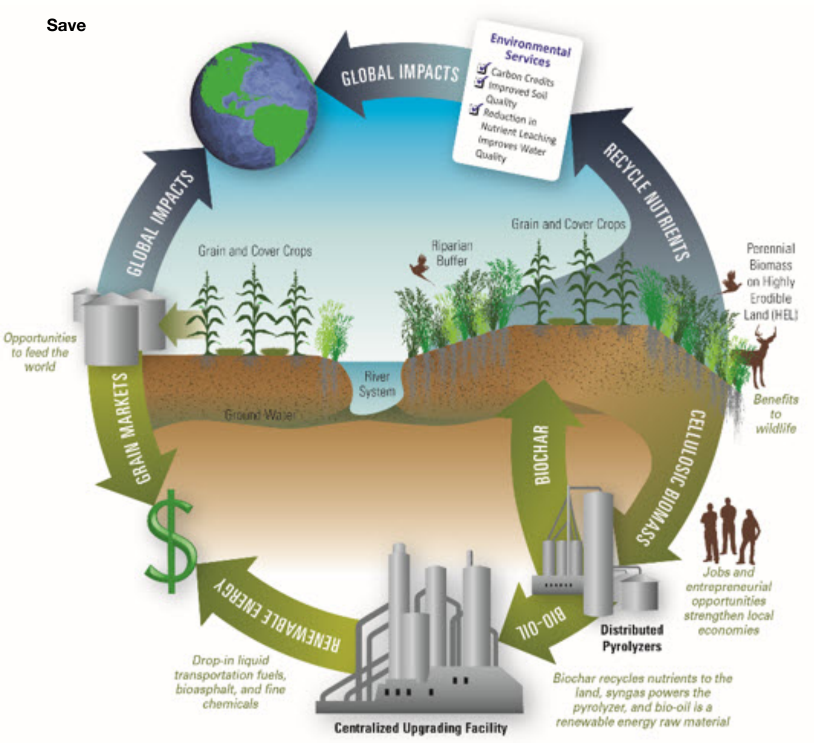

The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed 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)

Journal Publications

- Casler, M.D. (2014). Heterosis and reciprocal-cross effects in tetraploid switchgrass. Crop Sci. 54(5): 2063 .

DOI: 10.2135/cropsci2013.12.0821 (https://dl.sciencesocieties.org/publications/cs/abstracts/54/5/2063?access=0&view=pdfhttps://dl.sciencesocieties.org/publications/cs/abstracts/54/5/2063?access=0&view=pdf) .

- Casler, M.D. & Vogel, K.P. (2014). Selection for biomass yield in upland, lowland, and hybrid switchgrass. Crop Sci. 54(2):626-636. DOI: 10.2135/cropsci2013.04.0239 (https://www.ars.usda.gov/research/publications/publication/?seqNo115=289656) .
- Dien, B. S., P.J. O'Bryan, R.E. Hector, L.B. Iten, R.B. Mitchell, N. Qureshi, S. Gautum, K.P. Vogel, & M.A. Cotta. 2013. Conversion of switchgrass to ethanol using dilute ammonium hydroxide pretreatment: influence of ecotype and harvest maturity. Environ. Technol. 34:13-14. DOI: 10.1080/09593330.2013.833640 (http://www.tandfonline.com/doi/abs/10.1080/09593330.2013.833640)
- Feng, Q., I. Chaubey, G.Y. Her, R. Cibin, B. Engel, J.J. Volenec & X. Wang. 2015. Hydrologic and water quality impacts and biomass production potential on marginal land. Environmental Modelling & Software. 72:230-238. http://dx.doi.org/10.1016/j.envsoft.2015.07.004 (http://dx.doi.org/10.1016/j.envsoft.2015.07.004.)
- Jahufer, M.Z.Z. & M.D. Casler. 2014. Application of the Smith-Hazel selection index for improving biomass yield and quality of switchgrass. Crop Sci. 55(3):1212. doi: 10.2135/cropsci2014.08.0575.
- Koch, K., R. Fithian, T. Heng-Moss, J. Bradshaw, J., G. Sarath, & C. Spilker. (2014). Evaluation of tetraploid switchgrass populations (Panicum virgatum L.) for host suitability and differential resistance to four cereal aphids. J. Econ. Entomol. 107(1):424-431. 2014. DOI: http://dx.doi.org/10.1603/EC13315 (http://dx.doi.org/10.1603/EC13315)
- Koch, K., T. Heng-Moss, J. Bradshaw & G. Sarath, G. (2014). Categories of resistance to greenbug and yellow sugarcane aphid (Homoptera: Aphididae) in three tetraploid switchgrass populations. Bioenerg. Res. 7:909-918. DOI: 10.1007/s12155-014-9420-1 (http://link.springer.com/article/10.1007%2Fs12155-014-9420-1)
- Koch, K., N. Palmer, M. Stamm, J. Bradshaw, E. Blankenship, L. Baird, G. Sarath, and T. Heng-Moss. 2014. Characterization of Greenbug Feeding Behavior and Aphid (Hemiptera: Aphididae) Host Preference in Relation to Resistant and Susceptible Tetraploid Switchgrass Populations. Bioenergy Research 8: 165-174.
- Nichols, V.A., F.E. Miguez, M.E. Jarchow, M.Z. Liebman & B.S. Dien 2014. Comparison of cellulosic ethanol yields from midwestern maize and reconstructed tallgrass prairie systems managed for bioenergy. Bioenerg. Res. 7: 1550. doi: 10.1007/s12155-014-9494-9
- Price, D.L. & M.D. Casler (2014). Divergent selection for secondary traits in upland tetraploid switchgrass and effects on sward biomass yield. BioEnergy Res. 7(1):329-337. doi: 10.1007/s12155-013-9374-8
- Price, D.L. & M.D. Casler. (2014). Inheritance of secondary morphological traits for among-and-within-family selection in upland tetraploid switchgrass. Crop Sci. 54:646-653. doi: 10.2135/cropsci2013.04.0273
- Price, D.L. & M.D. Casler. (2014). Predictive relationships between plant morphological traits and biomass yield of switchgrass. Crop Sci. 54(2):637-645. doi: 10.2135/cropsci2013.04.0272
- Ramstein, G.P., J. Evans S.M. Kaeppler, R.B. Mitchell, K.P. Vogel, C.R. Buell & M.D. Casler. 2015. Accuracy of genomic prediction in switchgrass improved by accounting for linkage disequilibrium. G3: Genes, Genomes, Genet. 6(4):1049-1062. doi: 10.1534/g3.115.024950. http://g3journal.org/content/6/4/1049.full (http://g3journal.org/content/6/4/1049.full)
- Resende, R.M.S., de Resende, M.D.V. & Casler, M.D. (2013). Selection methods in forage breeding: a quantitative appraisal. Crop Sci. 53:1925-1936.
- Resende, R.M.S., Casler, M.D., & de Resende, M.D.V. (2014). Genomic selection in forage breeding: Accuracy and methods. Crop Sci. 54:143-156.
- Schaeffer, S., F. Baxendale, T. Heng-Moss, R. Sitz, G. Sarath, R. Mitchell, & R. Shearman. 2011. Characterization of the arthropod community associated with switchgrass Poales: Poaceae in Nebraska. J. Kans. Entomol. Soc. 84(2): 87-104. https://naldc.nal.usda.gov/download/54245/PDF (https://naldc.nal.usda.gov/download/54245/PDF)
- Serapiglia, M.J., A.A. Boateng, D.K. Lee & M.D. Casler. (2016). Switchgrass harvest time management can impact biomass yield and nutrient content. Crop Sci. 56(4):1970-1980. doi: 10.2135/cropsci2015.08.0527
- Serapiglia, M.J., B. Dien, A.A. Boateng & M.D. Casler. 2016. Impact of harvest time and switchgrass cultivar on sugar release through enzymatic hydrolysis. BioEnergy Res. DOI: 10.1007/s12155-016-9803-6
- Serapiglia, M.J., C.A. Mullen, A.A. Boateng, B. Dien & M.D. Casler. 2016. Impact of harvest time and cultivar on conversion of switchgrass to fast pyrolysis bio-oils. BioEnergy Res. (In review).
- Slininger, P.J., B.S. Dien, C.P. Kurtzman, B.R. Moser, E.L. Bakota, S.R. Thompson, P.J. O'Bryan, M.A. Cotta, V. Balan, M. Jin, M.D. Sousa & B.E. Dale. 2016. Comparative lipid production by oleaginous yeasts in hydrolyzates of lignocellulosic biomass and process strategy for high titers. Biotechnol. Bioeng. 113: 1676–1690. doi: 10.1002/bit.25928
- Stewart C.L., J.D. Pyle, K.P. Vogel, G.Y. Yuen & K.G. Scholthof. 2015. Multi-year pathogen survey of biofuel switchgrass breeding plots reveals high prevalence of infections by Panicum mosaic virus and its satellite virus. Phytopathology 105:1146-1154. doi:10.1094/PHYTO-03-15-0062-R (http://apsjournals.apsnet.org/doi/10.1094/PHYTO-03-15-0062-R)
- Vogel, K.P., G. Sarath & R.B. Mitchell. 2014. Micromesh fabric pollination bags for switchgrass. Crop Sci. 54(4): 1621-1623. doi: 10.2135/cropsci2013.09.0647
- Vogel, K.P., Mitchell, R.B., Casler, M.D. & G. Sarath. (2014). Registration of 'Liberty' switchgrass. J. Plant Registration 8:242–247. DOI: 10.3198/jpr2013.12.0076crc

(http://www.crops.org/publications/jpr/pdfs/8/3/242) .

- 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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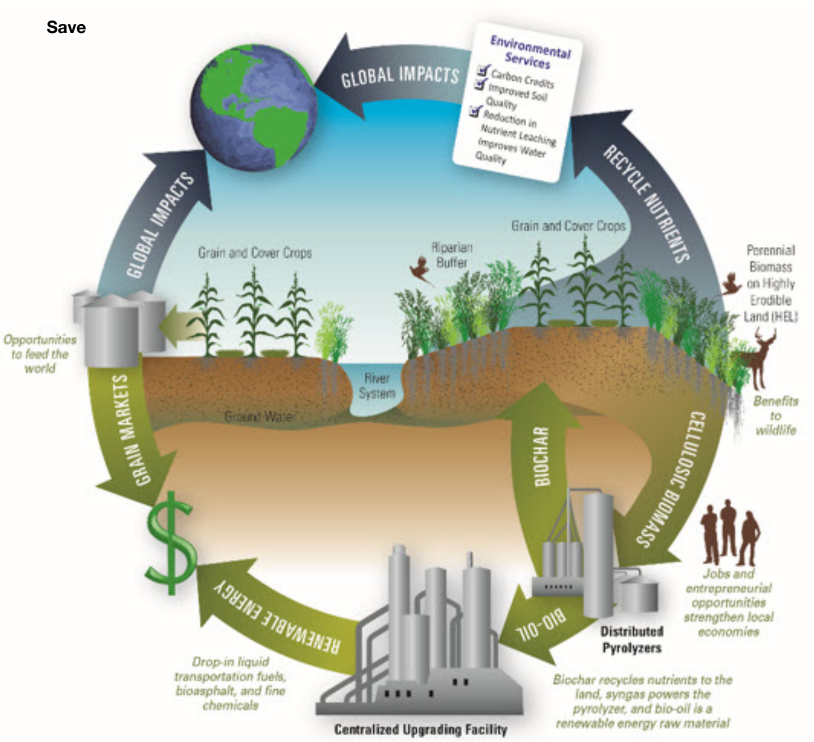

The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed 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

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.

Switchgrass harvest. *Photo: Kevin Shinners, University of Wisconsin.*

Bale Compression for Increased Density

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.

Tedding a switchgrass crop mowed in wide swaths speeds drying. *Photo: Kevin Shinners, University of Wisconsin.*

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.
- Shinners, K.J. & Friede, J.C. (2013). Energy requirements for at-harvest or on-farm size-reduction of biomass. ASABE Technical Paper No. 1591983.
- 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.

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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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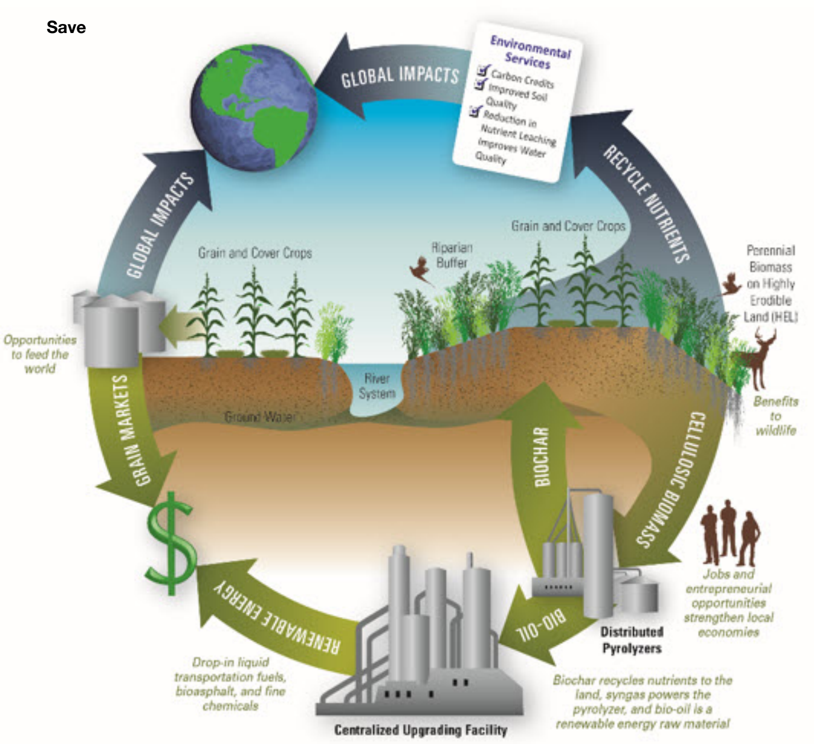


The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed 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.

Exhibit 6

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

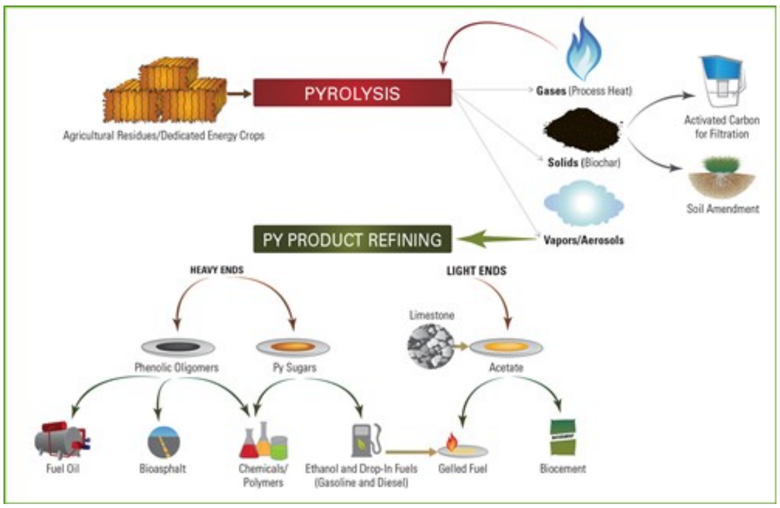
Robert Brown, director of Iowa State University's Bioeconomy Institute led CenUSA's conversion and refining projects, while David Laird has led investigations of biochar amendment impacts on soil quality and greenhouse gas emissions. In efforts aimed at commercialization, the team worked closely with 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



Concept for Pyrolysis Refinery *Photo: Bioeconomy Institute at Iowa State University.*

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.

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

- Allen, R.M. & Laird, D.A. (2013). Quantitative prediction of biochar soil amendments by near-infrared reflectance spectroscopy. Soil Science Society of America Journal. 77:1784-1794.
- Brown, T. R., Thilakaratne, R., Brown, R. C., & Hu, G. (2013). Techno-economic analysis of biomass to transportation fuels and electricity via fast pyrolysis and hydroprocessing. Fuel 106, 463–469, http://dx.doi.org/10.1016/j.fuel.2012.11.029 (http://dx.doi.org/10.1016/j.fuel.2012.11.029) .
- Brown, T. & Brown, R. C. (2013). A review of cellulosic biofuel commercial-scale projects in the United States. Biofuels, Bioproducts & Biorefineries 7, 235-245. DOI: 10.1002/bbb.1387.
- Brown, T. & Brown, R. C. (2013). Techno-economics of advanced biofuels pathways. Royal Society of

Chemistry Advances 3 (17), 5758 – 5764, DOI: 10.1039/C2RA23369J.

- Fidel, R.B., Laird, D.A. & Thompson, M.L. (2013). Evaluation of Modified Boehm Titration Methods for Use with Biochars. Journal of Environmental Quality. 42:1771-1778.
- Kauffman, N., J. Dumortier, D.J. Hayes, R.C. Brown, and D.A. Laird. 2014. Producing energy while sequestering carbon? The relationship between biochar and agricultural productivity. Biomass and Bioenergy. 63:167-176.
- Thilakaratne, R., Brown, T., Li, Y., Hu, G., & Brown R.C. (2014). Mild catalytic pyrolysis of biomass for production of transportation fuels: a techno-economic analysis. Green Chemistry, DOI: 10.1039/C3GC41314D.
- Zhang, Y., Hu, G., & Brown, R. C. (2013). Life cycle assessment of the production of hydrogen and transportation fuels from corn stover via fast pyrolysis. Environ. Res. Lett. 8, 025001 doi:10.1088/1748-9326/8/2/025001.

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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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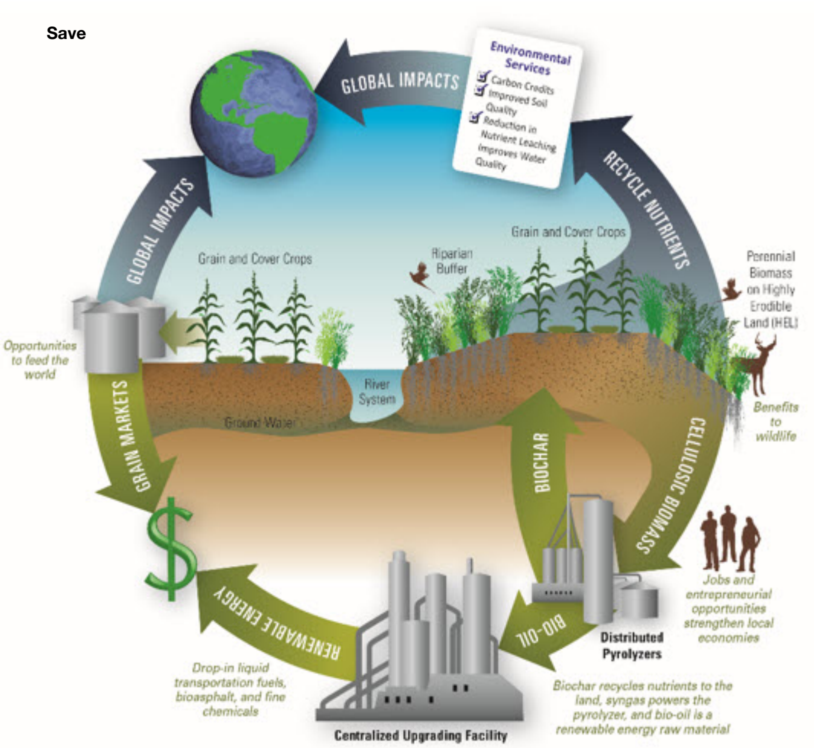
The CenUSA Extension and Outreach Team

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.

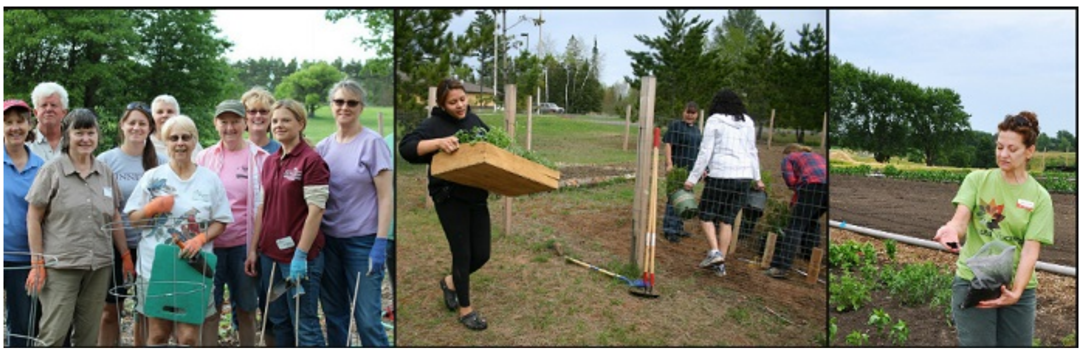
Citizen Science and Farm Research Provide Hands-On Learning

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.



Citizen Science: Master Gardeners in MN and IA conduct biocar research.

Programs for Youth

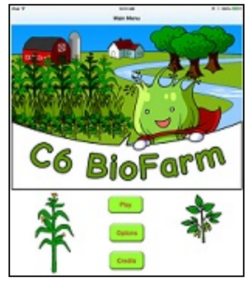
Two groups of Extension collaborators focused specifically on youth outreach programming. Purdue University Extension and outreach professionals created interactive electronic lessons and established demonstration plots of perennial grasses for STEM (science, technology, engineering, and math) career 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

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

Exhibit 8

Farm Energy - March 01, 2017 (20170301) Print (http://www.printfriendly.com)

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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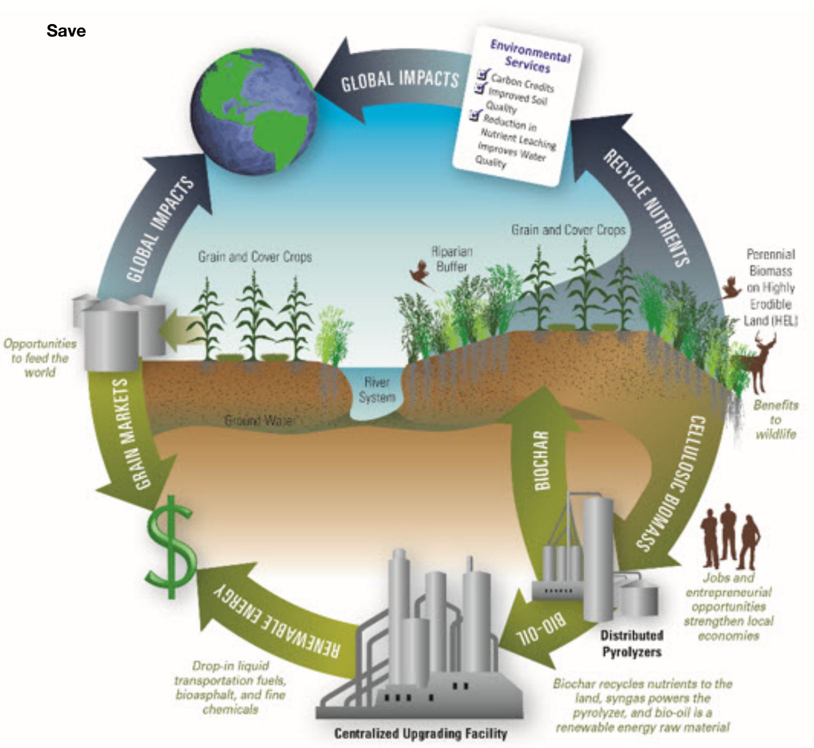
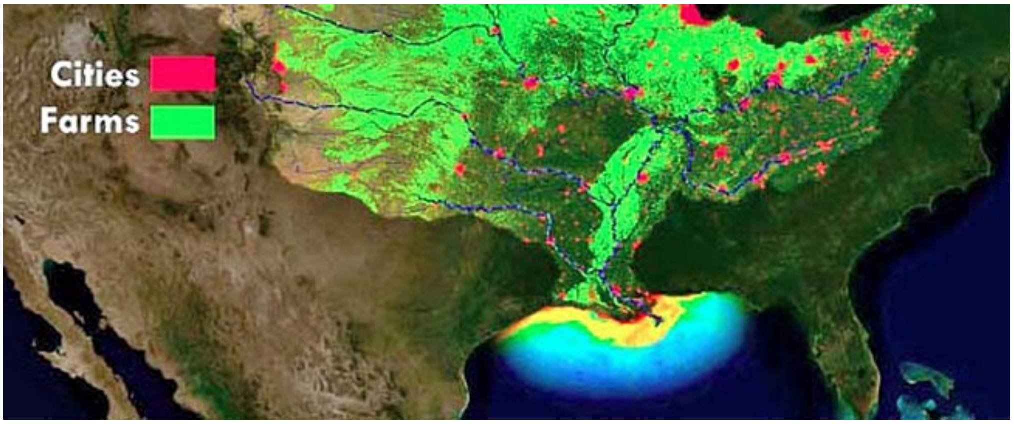


The CenUSA Vision is to create a Midwestern regional system for producing advanced transportation fuels and bioproducts derived from perennial grasses grown on land that is either unsuitable or marginal for row crop production. In addition to producing advanced biofuels and bioproducts, the proposed 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.

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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 (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.

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

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