Agro-ecosystem Approach to Sustainable Biofuels Production via the Pyrolysis-Biochar Platform
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Exhibit 3. Year 4 Annual Meeting Agenda


Exhibit 5. Biofuels Harvest Survey Results - 2014 Purdue University

Exhibit 6. CenUSA Extension Webinar Evaluation Instrument
LEGAL NOTICE

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

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


Project Administration

- **Project Organization and Governance**

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

- **Commercialization Objective**

  The work on the Commercialization Objective continues to progress as anticipated and is on track. Additional details are available in the Commercialization Objective update and in the Renmatix progress report “Biomass characterization: CenUSA Project #2010-05073” (Exhibit 1).

- **CenUSA Bioenergy Advisory Board**

  We continue to work closely with our Advisory Board. We anticipate an excellent Advisory Board turnout at our Year 4 annual meeting. We will once again produce a written statement from our Advisory Board documenting their thoughts after having heard each project objective’s presentation at the annual meeting. This report will be completed in September 2015.

  Advisory Board member Bryan Mellage authored an opinion piece *It's time to rethink the 'gas' in our tank* which was published in the March 2015 Nebraska Farmer Magazine (Exhibit 2). The article summarizes CenUSA’s research efforts and has been an excellent opportunity to share the CenUSA story with a wider public.

- **Executive Team Meetings and CenUSA Research Seminars**

  The Co-Project directors representing each of the ten project objectives continue to meet monthly with Ken Moore and Anne Kinzel via online meetings held in CenUSA’s dedicated Adobe Connect meeting room. The virtual meeting room allows for documents to be viewed by all participants, enhancing communications and dialogue between participants. Tom Binder (Advisory Board chair) also attends these meetings to ensure an Advisory Board presence at these important project gatherings.
• **Graduate Seminars.** We hosted a graduate seminar immediately following the March 2015 Executive Team meeting. Co-project director Raj Raman facilitated the seminar, *What are the most realistic approaches to reducing N and P exports from the Corn Belt?* which featured Co-project directors Cathy Kling (System Performance Metrics, Data Collection, Modeling, Analysis and Tools Objective) and Dermot Hayes (Markets and Distribution Objective).

The next seminar will be in June 2015 and will be specifically geared to include students participating in the 2015 summer undergraduate Internship experience. Students will participate in the on-line seminar from their assigned research sites.

• **Year 4 Annual Meeting – University of Wisconsin-Madison.** The year 4 annual meeting agenda has been finalized (Exhibit 3). At the suggestion of participants in the Year 3 we have scheduled the meeting for two days (July 28 – July 29). CenUSA CoProject Director Mike Casler (Feedstock Development) will be the meeting host.

The agenda provides significant opportunities for interaction between CenUSA Advisory Board members, CenUSA personnel and our graduate and undergraduate students.

Student participation has been favorably received at previous annual meetings and we will continue build on those past interactions.

Highlights from the agenda include:

- **Kickoff - Keynote Address.** Bill Goldner, National Program Leader USDA-NIFA Division of Bioenergy will be our kickoff keynote speaker (*Future of Biofuels: Role of USDA-NIFA in Making it Happen*).

- **Leadership Team Dinner.** Pre-meeting dinner for CenUSA Advisory Board members and CenUSA leadership (July 27). Ken Moore and Anne Kinzel will host a dinner for Advisory Board members and CenUSA Co-Project directors. The Advisory Board has provided significant input throughout the project and especially during annual meetings. This dinner will allow issues to be explored in a less structured setting than during the meeting’s formal presentations.

- **Undergraduate and Graduate Student Tour.** Mike Casler has arranged for project students, including the 2015-summer intern cohort to tour the Great Lakes Bioenergy Center research plots and the Wisconsin Energy Institute on the morning of July 28th. The tour will include a classroom presentation at the Wisconsin Energy Institute.

- **Tour for CenUSA Personnel.** CenUSA personnel will have the option of touring the US Dairy Forage Research Center Field Station on the morning of July 28th.

- **Ken Vogel Presentation.** Ken Vogel, a former CenUSA Co-Project Director will
discuss advances in switchgrass genetics from the perspective of his distinguished career at the ARS.

- **Communications**

  Our Communications Team continues to focus on the strategy we devised in early 2014 to make the project more visible among the biofuels/bio-products research community, commercial firms and the interested public. The key elements of the plan include:

  - A project website ([www.cenusa.iastate.edu](http://www.cenusa.iastate.edu)). We launched a completely redesigned website in February 2015. The change has led to significantly greater traffic at the website and appears to have driven increased traffic at our Vimeo and YouTube sites as well.

  - We produced a short recruitment video for the 2015 CenUSA Summer Bioenergy Research Internship Experience for Undergraduates which was received with significant views on our website and video sites.

  - A bimonthly newsletter, BLADES ([http://cenusa.iastate.edu/blades-newsletters](http://cenusa.iastate.edu/blades-newsletters)). In the third quarter we published two newsletters (February and April 2015). BLADES circulation has increased to 749 subscribers (up from 650 in August 2014). Our goal is to grow our mailing list to 1000 subscribers by September 2015.

  ✓ **2015 BLADES Articles**

    - **CenUSA Looks for Next Batch of Summer Interns** (February 2015) [http://blades-newsletter.blogspot.com/2015/02/cenusa-looks-for-next-batch-of-summer.html](http://blades-newsletter.blogspot.com/2015/02/cenusa-looks-for-next-batch-of-summer.html)


    - **A Producer's Viewpoint—John Weis** (February 2015) [http://blades-newsletter.blogspot.com/2015/02/a-producers-viewpointjohn-weiss.html](http://blades-newsletter.blogspot.com/2015/02/a-producers-viewpointjohn-weiss.html)

    - **How Green is Your Drive?** (February 2015) [http://blades-newsletter.blogspot.com/2015/02/how-green-is-your-drive.html](http://blades-newsletter.blogspot.com/2015/02/how-green-is-your-drive.html)


    - **CenUSA Website 101** (February 2015) [http://blades-newsletter.blogspot.com/2015/02/website-101.html](http://blades-newsletter.blogspot.com/2015/02/website-101.html)

Ø Chevrolet and Ducks Unlimited pair up for grasslands (April 2015) [http://blades-newsletter.blogspot.com/2015/04/chevrolet-and-ducks-unlimited-pair-up_2.html]


Ø The California carbon offset market: directing the changing landscape (April 2015) [http://blades-newsletter.blogspot.com/2015/04/the-california-carbon-offset-market.html]


Ø Managing carbon like coffee cups (April 2015)

• Facebook ([https://www.facebook.com/CenusaBioenergy](https://www.facebook.com/CenusaBioenergy))
  
  o Video sites Vimeo ([https://vimeo.com/cenusabioenergy](https://vimeo.com/cenusabioenergy)) and YouTube ([https://www.youtube.com/user/CenusaBioenergy](https://www.youtube.com/user/CenusaBioenergy)).

• Twitter and Facebook

  We continue to experience steady growth on both social media sites. We recently recorded our 553rd Twitter follower having gained 92 followers (19.9%) in the second quarter. Both “reach” and “engagement” are increasing in our Twitter and Facebook pages ([https://www.facebook.com/CenusaBioenergy](https://www.facebook.com/CenusaBioenergy)).

  Additional information on Communications Team activity is provided in the Extension and Outreach section (pp. 44-48).

* Financial Matters

The Administrative Team continues to monitor all project budgets and subcontracts to ensure adherence to all sponsor budgeting rules and requirements. We are working on the budgets for Year 5.

**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 is on the establishment of new breeding and evaluation trials.

1. Accomplishments Summary

   - Switchgrass, big bluestem and a low diversity mixture of grasses were successfully pelletized and their bulk density increased fourfold. Pelletizing makes it more economical to transport and store biomass. We determined that pelletizing did not adversely affect biochemical conversion of the biomasses to sugars following either hot water or alkaline pretreatments.

   - Our research provides important information on the arthropods associated with bioenergy grasses and valuable information on the host suitability of switchgrass and other bioenergy grasses to four aphids within a system that has been largely overlooked, indicating that there are genetic differences among switchgrass populations for resistance. The ultimate goal of this project is to develop effective and sustainable management strategies for the key arthropod pests affecting switchgrass.

2. Planned Activities

   - **Breeding and Genetics – ARS-Lincoln, Nebraska and Madison, Wisconsin (Mike Casler, ARS Madison and Rob Mitchell, ARS Lincoln)**
     - Grinding and scanning 2014 biomass samples.
     - Oversee data organization and sample processing from 24 field trials planted at remote locations.
     - Thresh and clean seed of all new switchgrass and big bluestem populations.

   - **Feedstock Quality Analysis (Bruce Dien, ARS Peoria and Akwasi Boateng, ARS Wyndmoor)**
     - Mike Casler and Rob Mitchell provided 88 new biomass samples to the National Center for Agricultural Utilization Research (NCAUR). These samples will be analyzed for soluble sugars, starch, and moisture contents.
     - The pelletized and unpelletized switchgrass sample set will be analyzed for enzymatic sugar release following liquid hot-water pretreatment.
✓ We will titer new commercial cellulases and hemicellulase preparations on hot-water pretreated switchgrass for preparation to screen the next group of biomass samples.

✓ We will analyze new grass samples on the py-GC/MS and perform ICP analysis for mineral content.

✓ We will perform pilot scale pyrolysis on pelletized switchgrass.

✓ We will continue to analyze data for publications.

• **Plant Pathology and Entomology - University Nebraska-Lincoln (Tiffany Heng-Moss and Gary Yuen)**

  ✓ We will collaborate with Rob Mitchell and Mike Casler to develop insect sampling plans for Year 4.

  ✓ We will begin sampling nurseries for insects and other arthropods in late May 2015.

  ✓ We will continue choice studies in the greenhouse to determine if greenbugs show a feeding or ovipositional preference among switchgrass, big bluestem and indiangrass.

  ✓ We will begin electronic feeding monitoring studies to characterize yellow sugarcane aphid feeding on big bluestem and indiangrass.

  ✓ We will complete statistical analysis of switchgrass rust severity data collected from five CenUSA varietal trial locations.

  ✓ We will derive ITS DNA sequences from Nebraska and Wisconsin strains of *Uromyces graminicola*. This information, which is critical for the genetic identification of this rust species, currently is absent from all genetic databases.

3. **Actual Accomplishments**

• **Breeding and Genetics – Lincoln, Nebraska and Madison, Wisconsin**

  ✓ We are three quarters finished grinding 2014 biomass samples.

  ✓ We have compiled about 90% of the 2014-biomass data from the field trials.

  ✓ All switchgrass and big bluestem seed has been threshed, cleaned, weighed, and germinated for 2015 trials.

  ✓ All field trials have been fertilized and staked for 2015 harvests and spring ground cover ratings completed.
• **Feedback Quality Analysis**

- New biomass samples (88) were analyzed for soluble sugars, starch and moisture contents. We are now examining the data set for outliers that will require repeat analysis.

- The pelletized and unpelletized switchgrass sample sets were analyzed for enzymatic sugar release following liquid hot-water pretreatment. Results were presented as a technical poster at a national meeting.

- Titered new commercial cellulases and hemicellulase preparations on hot-water pretreated switchgrass for preparation to screen next group of biomass samples.

- Mineral content is currently being determined for 88 new biomass samples by ICP.

- Py-GC/MS experiments are currently being conducted on all 88 new biomass samples.

- NIR calibrations for mineral content and ash content in switchgrass have been optimized. Mineral content has been determined for all STICH1 and STICH2 experiments. These data are currently being analyzed.

• **Pathology and Entomology - University Nebraska-Lincoln**

- Arthropod data have been summarized for the 2014 season. We collected similar arthropod families from Nebraska and Wisconsin and found that stage age and stand diversity had limited impact on the types and numbers of arthropods collected.

- Statistical analysis of switchgrass rust severity data collected in 2014 from five CENUSA varietal trial locations was completed.

- *Puccinia emaculata* was identified as the only rust fungus species infecting switchgrass leaf samples collected from the Columbia, MO CENUSA varietal trial.

- ITS DNA sequences were determined from Nebraska and Wisconsin strains of *Uromyces graminicola*. This information, which is critical for the genetic identification of this rust species, currently is absent from all genetic databases.

4. **Explanation of Variances**

None to report.

5. **Plans for Next Quarter**

- **Breeding and Genetics (Mike Casler and Rob Mitchell)**
- Finish grinding and scanning 2014 biomass samples.
- Finish collection of 2014 biomass data from 13 locations.

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

- Begin to process new biomass samples (88) for chemical composition.
- Process biomass samples for enzymatic sugar release.
- Finalize analysis of mineral content and pyrolysis products for the 88 grass samples.
- Complete manuscript for STICH1 experiment on the impact of harvest data on biomass yield and quality traits.

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

- A total of 160 pitfall and sticky board traps will be collected every two weeks from May to September 2015 in Nebraska and Wisconsin.
- Process samples to identify potential pests and beneficial arthropods and characterize their seasonal abundance.
- Complete choice studies in the greenhouse to determine if greenbugs show a feeding or ovipositional preference among switchgrass, big bluestem and indiangrass.
- Complete electronic feeding monitoring studies to characterize yellow sugarcane aphid feeding on big bluestem and indiangrass.
- Grasses growing in conjunction with or in the vicinity of switchgrass plots infected with Panicum mosaic virus and its satellite virus will be surveyed for the presence of the viruses and examined for virus symptoms in order to identify grass species that can serve as alternate hosts or asymptomatic reservoirs for the viruses.
- The fourth year of virus severity ratings, attributed to infection by *Panicum mosaic virus* (PMV) and Satellite *Panicum mosaic virus* (PMV+SPMV), will be collected from select switchgrass experiments and varieties will be evaluated for the severity of virus symptoms. The data will contribute information as to changes in virus severity and the relationship of virus severity to yield over multiple seasons.

6. **Publications / Presentations/Proposals Submitted**


### 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.

- **ARS-Madison Wisconsin**

  We have completed a 5-year study to quantify the impacts of harvest management on biomass yield, biomass quality, and nutrient removal rates of switchgrass. The study includes four harvest managements, ranging in harvest date from peak biomass in August to post-winter in April or May of the following year. The study includes three locations, ranging from USDA Hardiness Zones 3 to 5 (Marshfield and Arlington, Wisconsin and Urbana, Illinois). Six cultivars were included, with a range of origins. All biomass samples have been processed for minerals, neutral sugars, lignin and phenolics, ethanol yield, and pyrolysis product yields. Data analysis and manuscript preparation is currently underway.

- **Iowa State University**

  - Plant tissues samples from the switchgrass and high-input low-diversity plots were ground and shipped to Rob Mitchell for analysis.

  - **Biomass for Armstrong System Plots.** Data from the 2014-growing season suggest no consistent effects of biochar on general plant species composition, peak biomass, or end-of-season biomass. In contrast, seeding mixture seems to affect several plant community characteristics. The low input/high diversity plots have lower relative cover and biomass for sown species compared to switchgrass and high input/low diversity plots. Based on
these data, plant species choice is more important than biochar application in terms of maximizing desirable plant biomass.

**Fig. 1 Biomass for Armstrong system plots**
### Table 1. Effects of crop and biochar amendments on extractable NO$_3$ and NH$_4$ and potentially mineralization nitrogen (PMN) determine before and after a 28 day aerobic incubation using surface soil from the Armstrong system plots

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>HD</th>
<th>LD</th>
<th>SG</th>
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<tr>
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<tr>
<td><strong>Depth 0-5cm</strong></td>
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<tr>
<td>Before incubation</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>NH$_4^+$-N</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>BC</td>
<td>4.24 (0.52)*</td>
<td>3.03 (0.4)</td>
<td>3.16 (0.4)</td>
<td>2.91 (0.37)</td>
</tr>
<tr>
<td>NBC</td>
<td>3.57 (0.81)</td>
<td>2.97 (0.25)</td>
<td>2.87 (0.21)</td>
<td>3.52 (0.25)</td>
</tr>
<tr>
<td>NO$_3^-$-N</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>BC</td>
<td>3.78 (0.54)</td>
<td>1.30 (0.33)</td>
<td>3.08 (0.69)</td>
<td>2.11 (0.25)</td>
</tr>
<tr>
<td>NBC</td>
<td>3.46 (0.4)</td>
<td>1.38 (0.47)</td>
<td>2.51 (0.97)</td>
<td>3.52 (0.25)</td>
</tr>
<tr>
<td>After incubation</td>
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<tr>
<td>NH$_4^+$-N</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>BC</td>
<td>0.98 (0.04)</td>
<td>1.00 (0.10)</td>
<td>0.89 (0.012)</td>
<td>0.94 (0.035)</td>
</tr>
<tr>
<td>NBC</td>
<td>0.89 (0.08)</td>
<td>1.03 (0.10)</td>
<td>0.089 (0.04)</td>
<td>1.05 (0.08)</td>
</tr>
<tr>
<td>NO$_3^-$-N</td>
<td></td>
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<tr>
<td>BC</td>
<td>9.46 (0.62)</td>
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<td>9.61 (0.88)</td>
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<td>NBC</td>
<td>10.44 (0.69)</td>
<td>10.29 (0.82)</td>
<td>9.61 (0.67)</td>
<td>11.72 (0.55)</td>
</tr>
<tr>
<td>PMN</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>BC</td>
<td>2.92 (0.98)</td>
<td>7.52 (1.29)</td>
<td>6.44 (0.77)</td>
<td>5.52 (0.81)</td>
</tr>
<tr>
<td>NBC</td>
<td>4.34 (1.01)</td>
<td>6.97 (0.92)</td>
<td>5.12 (1.36)</td>
<td>7.14 (1.01)</td>
</tr>
</tbody>
</table>

* = Standard error; n=4

### Table 2. Effects of residue harvesting (0, 50, 90%), biochar amendments (0, C1, and C2), and wheal traffic on extractable NO$_3$ and NH$_4$ determine before a 28 day aerobic incubation using surface soil from the Field 70/71 REAP plots

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<thead>
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<tr>
<td>(Depth 0-5 cm)</td>
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<tr>
<td><strong>Residue Harvest intensity</strong></td>
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<td></td>
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<tr>
<td>0 (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 (%)</td>
<td></td>
<td></td>
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<tr>
<td>90 (%)</td>
<td></td>
<td></td>
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<tr>
<td>Char Treat</td>
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</tr>
<tr>
<td>NO$_3^-$</td>
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<tr>
<td>NH$_4^+$</td>
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<tr>
<td>NO$_3^-$</td>
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<td>mg kg$^{-1}$</td>
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<td>mg kg$^{-1}$</td>
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</tr>
<tr>
<td>0 (%)</td>
<td>3.71 (0.29)*</td>
<td>2.12 (0.38)</td>
<td>2.20 (0.33)</td>
<td>1.70 (0.38)</td>
<td>2.27 (0.58)</td>
<td>2.08 (0.72)</td>
<td>2.93 (0.85)</td>
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<td>50 (%)</td>
<td>2.12 (0.38)</td>
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<td>1.70 (0.38)</td>
<td>2.27 (0.58)</td>
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<td>2.93 (0.85)</td>
<td>2.18 (0.39)</td>
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<tr>
<td>90 (%)</td>
<td>2.20 (0.33)</td>
<td>1.70 (0.38)</td>
<td>2.27 (0.58)</td>
<td>2.08 (0.72)</td>
<td>2.93 (0.85)</td>
<td>2.18 (0.39)</td>
<td>1.98 (0.61)</td>
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</tr>
<tr>
<td>C1</td>
<td>4.12 (2.90)</td>
<td>1.99 (1.16)</td>
<td>2.36 (0.81)</td>
<td>1.46 (0.24)</td>
<td>1.83 (0.31)</td>
<td>1.91 (1.10)</td>
<td>2.97 (1.75)</td>
<td>2.18 (0.69)</td>
</tr>
<tr>
<td>C2</td>
<td>2.71 (0.66)</td>
<td>1.80 (0.43)</td>
<td>1.64 (0.63)</td>
<td>1.87 (0.72)</td>
<td>2.12 (0.40)</td>
<td>1.49 (0.43)</td>
<td>2.95 (0.73)</td>
<td>1.86 (0.15)</td>
</tr>
</tbody>
</table>

(* = Standard deviation, n=4)
Table 3. Effects of residue harvesting (0, 50, 90%), biochar amendments (0, C1, and C2), and wheel traffic on extractable NO$_3$ and NH$_4$ determine after a 28 day aerobic incubation using surface soil from the Field 70/71 REAP plots

<table>
<thead>
<tr>
<th>After incubation</th>
<th>No traffic (Depth 0-5 cm)</th>
<th>Traffic (Depth 0-5 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue Harvest intensity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 (%)</td>
<td>50 (%)</td>
<td>90 (%)</td>
</tr>
<tr>
<td>Char Treat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO$_3$</td>
<td>mg kg$^{-1}$</td>
<td>mg kg$^{-1}$</td>
</tr>
<tr>
<td>NH$_4^+$</td>
<td>mg kg$^{-1}$</td>
<td>mg kg$^{-1}$</td>
</tr>
<tr>
<td>NO$_3$</td>
<td>mg kg$^{-1}$</td>
<td>mg kg$^{-1}$</td>
</tr>
<tr>
<td>NH$_4^+$</td>
<td>mg kg$^{-1}$</td>
<td>mg kg$^{-1}$</td>
</tr>
<tr>
<td>0</td>
<td>6.64 (5.37)</td>
<td>1.65 (0.76)</td>
</tr>
<tr>
<td>C1</td>
<td>10.23 (1.89)</td>
<td>1.14 (0.20)</td>
</tr>
<tr>
<td>C2</td>
<td>9.49 (2.41)</td>
<td>1.21 (0.15)</td>
</tr>
</tbody>
</table>

(*= Standard deviation, n= 4)

Table 4. Boyd Farm (biochar rate trial on eroded soils, continuous no-till corn)

<table>
<thead>
<tr>
<th>PMN (Depth 0-5 cm)</th>
<th>PMN (Depth 0-5 cm)</th>
<th>PMN (Depth 0-5 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg kg$^{-1}$</td>
<td>mg kg$^{-1}$</td>
</tr>
<tr>
<td>0</td>
<td>0.75 (0.48)</td>
<td>0.73 (0.73)</td>
</tr>
<tr>
<td>10</td>
<td>0.67 (0.67)</td>
<td>0.71 (0.71)</td>
</tr>
<tr>
<td>20</td>
<td>0.28 (0.23)</td>
<td>0.13 (0.10)</td>
</tr>
<tr>
<td>30</td>
<td>0.21 (0.21)</td>
<td>0.71 (0.71)</td>
</tr>
<tr>
<td>40</td>
<td>0.87 (0.19)</td>
<td>1.23 (0.53)</td>
</tr>
<tr>
<td>50</td>
<td>1.65 (1.03)</td>
<td>0.88 (0.28)</td>
</tr>
</tbody>
</table>

(*= Standard error, n= 3)

- Preliminary analysis of the potentially mineralizable nitrogen study suggests a possible biochar rate effect in the results from the Boyd farm but little evidence of a biochar effect for the results from the Armstrong and Field 70/71 trials. Statistical analysis of the data is pending.

- **Update of Activities on the Long Term Rotation Plots (Sorenson Farm).** Recently completed analyses of soil chemical properties include C:N ratio, pH, and EC are shown below (Fig. 2). Ongoing analyses of chemical properties include cation exchange capacity (CEC) and anion exchange capacity (AEC). We anticipate completion of soil characterization and statistical analysis within the next quarter. Management systems for
this study include: Rotation 1 = CCCCCC, rotation 2 = CSCSCS, rotation 3 = CST/SCST/S, rotation 4 = CCCSgSgSg, Rotation 5 = SgSgSgSgSgSg; where C=corn, S=soybeans, T=triticale, and Sg=switchgrass.

![Graph](image)

**Fig. 2** Biochar treatments increase soil C:N ratio across all rotations. No difference due to the age of the biochar is seen. Statistical analysis is pending.

- **GHG Emissions.** We conducted a 140-day laboratory incubation to assess effects of interactions among biochar, temperature and moisture on GHG emissions from soil. A mixed wood gasification biochar pyrolyzed at 600°C (ICM, Inc.) was applied at a 0.5 wt% rate (equivalent to 10 Mg/ha incorporated to 15 cm) to soil obtained from a continuous corn plot at the Armstrong field site. Soil samples were pre-incubated with or without biochar for 60 days prior to the addition of NPK fertilizer (72, 22, and 27 mg/kg of N, P and K, respectively as NH₄NO₃ and KH₂PO₄) and corn stover (0.5 wt%). Samples were maintained at three temperatures (10°C, 20°C, and 30°C) and three moistures (27%, 31%, and 35%) throughout the incubation. Following fertilizer addition, CO₂ and N₂O emissions were quantified on days 0, 1, 2, 3, 7, 10, 16, 38, 52, 62 and 80 via GC.

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Fig. 3 CO₂ emissions over time, in mg of CO₂ per gram of soil per day. (blue = 10°C, green = 20°C, red = 30°C; diamonds = 27%, squares = 31%, and triangles = 35% moisture; dashes = controls, solid lines = biochar)

Fig. 4 Soil pH increased with biochar addition for rotations 1-4. (no biochar has been applied to the continuous switchgrass plots, rot 5). A substantial decrease in soil pH is visible for rotations 4 and 5 relative to rotations 1, 2, and 3. Statistical analysis is pending.
**Fig. 5**

$N_2O$ emissions during the first 10 days following fertilization, in $\mu g$ of $N_2O$ per gram of soil per day (emissions were below the detection limit after day 10).

(blue = 10°C, green = 20°C, red = 30°C; diamonds = 27%, squares = 31%, and triangles = 35% moisture; dashes = controls, solid lines = biochar)

- CO$_2$ emissions were highest immediately following fertilizer addition, and after 10 days $N_2O$ emission rates dropped below the limit of detection. For both gases, the main temperature, moisture and day effects and interactions thereof were significant ($p < 0.0001$), but the effect of biochar and interactions thereof were only significant for CO$_2$ ($p < 0.05$) and not $N_2O$. $N_2O$ emissions increased greatly with increasing temperature and moisture, whereas CO$_2$ emissions were more sensitive to temperature than moisture. Biochar impacts on CO$_2$ emissions were inconsistent over time and occurred only under select temperature-moisture combinations. For example, biochar suppressed emissions at the highest temperature and lowest moisture on days 0 and 80, but increased emissions on day 7. No significant impact of biochar was observed on cumulative CO$_2$ emissions. The lack of a biochar effect on $N_2O$ is consistent with results obtained in a previous field experiment at the Armstrong field site, wherein no significant differences in total $N_2O$ or CO$_2$ emission rates were observed between control and biochar-amended soils when biochar and fertilizer were applied at similar rates. Results are also consistent with a meta-analysis conducted by Cayuela et al (2013), in which studies using biochar application rates of $\leq 1\%$ or NH$_4$NO$_3$ fertilizer were found to suppress $N_2O$ emissions less consistently compared with studies using higher biochar application rates or other fertilizers.
- **Systems Analysis Plots at the Water Quality Field Station.** Biomass has been processed and is currently being analyzed for carbohydrates, fiber, mineral, C, and N. Plots have been fertilized for the 2015-growing season. Sensors were installed (using non-CenUSA resources) that will permit careful monitoring of soil water, and to automate the water flow data collection process. Data are being compiled for analysis.

- **Factor Analysis Plots at Three Purdue Ag Centers.** Biomass analyses are underway for samples collected in late 2014. In addition to the analyses mentioned above, tissue concentrations of N, P, and K (for fertility experiments) are being analyzed. Plots at these sites also have been fertilized and as appropriate (e.g. annuals), seed is on-site for planting at these locations as soon as weather permits. Data are being processed and prepared for statistical analysis.

- Ryan Dierking, the post-doc on this project secured full-time employment in mid-April. We have begun the process of re-hiring this position.

- We started a conversation with National Agricultural Library regarding data repositories for CenUSA data. Volene and Brouder traveled to NAL in April 2015 to participate in a one-day workshop on data. It is likely that CenUSA data will be used as a pilot to test the NAL repository.

- We continue to have a regular Skype discussion with the Iowa State team (Cathy Kling and Phil Gassman) about developing common bioenergy production scenarios that we plan to evaluate in multiple Midwest watersheds.

- The SWAT model improvements made by the Purdue team have been validated using data from watershed located in Iowa and the Upper Mississippi river watershed by the Kling and Gassman group. These include biomass production of switchgrass, miscanthus, and removal of corn stover. The group is now utilizing the improved model to evaluate impacts of various bioenergy crop production scenarios on hydrology, water quality, environmental sustainability and ecosystem services. We plan to present a series of four papers in the International SWAT conference to be held in Sardinia, Italy in June where we will discuss model improvements, validation of the improved model using data from Indiana and Iowa watersheds, and scenario analysis at various spatial (12-digit HUC to the entire Upper Mississippi River basin) and temporal scales (daily, monthly, annual and decadal).

- We have quantified impacts of perennial bioenergy crop production on marginal lands on hydrology and water quality. A manuscript in under revision based on the results obtained from this project.
• We have developed a fuzzy logic based method to delineate marginal lands that may be suitable for bioenergy crop production. We have evaluated this new method using data from Indiana watersheds. The improved method constrains our estimates of total marginal lands that may be available for perennial bioenergy crop production. We are using this method to calculate marginal land area in the Mississippi river basin and will use the improved SWAT model to evaluate biomass production potential and associated hydrologic, water quality, and environmental impacts.

- University of Illinois Urbana-Champaign

  - Factor Analysis Plots

  Biomass yield data has been analyzed and reported to the project management team. All feedstock samples have been ground and shipped to USDA-ARS Lincoln for feedstock composition analysis. Field plots were burned to remove all surface residues on March 27, 2015 and are ready for fertilization.

  ✓ Comparison and Abiotic Stress Trials. The 4-year field evaluation of dedicated energy crops on wet marginal land and salt-affected marginal land has been completed. A graduate student is currently working on data analysis and he will use the data as part of his dissertation.

- University of Minnesota

We have finished grinding our tissue samples from 2014 and are in the process of shipping them to the University of Nebraska, Lincoln for analyses. In mid-April, we sprayed for weeds at the Becker location and are monitoring the Lamberton location for weed growth.

- USDA-ARS, Lincoln

  - Factor Analysis Plots

  ✓ Plots were trimmed, treated for weeds, and fertilizer treatments applied as scheduled.

  ✓ Yield data for 2012-2014 is being summarized.

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

  - System Analysis Plots

  ✓ Samples collected in 2012, 2013, and 2014 are processed & are being scanned & predicted.
Corn plots were planted and triticale cover crop has been sampled and sprayed.

GHG samples from 2013 and 2014 are being summarized and 2015 sampling has begun.

VOM and elongated leaf height data are being summarized.

Weed control and fertilizer treatments have been applied.

Evaluated the field-scale herbaceous perennial feedstock research and demonstration site in cooperation with Vermeer Manufacturing near Pella, Iowa. Fertilizer application, stand count data collection, and seeding bare areas have been scheduled. The small-plot herbaceous perennial feedstock research and demonstration site on a floodplain in cooperation with Vermeer Manufacturing near Pella, Iowa will continue to be managed.

Continued managing the annual and perennial feedstocks to supply combined heat and power (CHP) to an advanced ethanol fermentation plant. Winter wheat and oats are growing.

The residue from the warm-season (WS) grass grazing trial was sampled then burned in preparation for grazing beginning in June 2015.

A draft decision support tool that compares the returns from row crop production to the returns for perennial grasses for bioenergy is being developed with Dr. Keri Jacobs and is progressing. Plans for the tool have been finalized and will be reported at the 2015 annual meeting.

• Plans for Next Quarter
  
  Establish factor analysis plots in two wetland sites in eastern North Dakota and one in eastern Nebraska to evaluate the potential of selected perennial grass feedstocks for multiple uses and revegetation of flooded sites.


  Collect field data during the 2015-growing season.

  Graze warm-season grass pastures.

  Analyze and summarize field data.
Present a paper titled, “Recent Advancements in Switchgrass and Other Perennial Grasses for Bioenergy” at the Advanced Bioeconomy Feedstocks Conference in June 2015.

- **Publications, Presentations and Proposals Submitted**
  - U. S. Department of Energy, Office of Science, Office of Biological and Environmental Research-Systems Biology Research to Advance Sustainable Bioenergy Crop Development. Bioenergy from genes to landscapes: developing strategies to maximize feedstock productivity while minimizing environmental impacts. Dukes, J.S. (PD), Co-PIs: Brouder, S.M., Carpita, N., Chaubey, I., Filley, T., McCann, M., Meilan, R., Turco, R., Volenc, J.J. (Purdue); Dou, F., Mullet, J. (Texas A&M); DeAngelis, K. (Univ. Massachusetts-Amherst); Dweikat, I. (Univ. Nebraska-Lincoln).

**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**

   Planned activities in this quarter included:

   Evaluation and refinement of the dry matter loss models for field conditions, and how they can be used to improve management of field harvest operations under different projected weather conditions.

2. **Actual Accomplishments**
• Analysis to estimate the impact of rainfall level and crop density on compositional and dry matter loses from switchgrass and corn stover have been completed. The leaching loss ranged from 0.2 to 2.8% for switchgrass, and losses ranged from 0.5 to 3.3% for corn stover, depending on the material density and rainfall. The total dry matter loss 48 hours after a rainfall event could be as high as 6.1 to 7.5% for switchgrass and corn stover, respectively. This level of total dry matter loss could significantly affect biomass harvest costs if there is a rainfall event between mowing and collection.

• Previous studies have shown that the dielectric properties of agricultural materials can be used to predict moisture content and bulk density of the materials under test (MUT). Using multiple superimposed high frequency signals allows for measurement of dielectric properties in a very short period. A sensing system that is capable of generating and acquiring multiple high frequency signals within 18.2 µs has been developed. The objective is to measure the dielectric properties of switchgrass, corn stover and kernel to determine the moisture content and bulk density of these materials. The sensor is being evaluated for real time measurement for biomass materials.

3. Explanation of Variance

Only minor variances in planned activities have been experienced.

4. Plans for Next Quarter

Research activities planned during next quarter include:

• Planning and preparation for field-testing of dry matter loss during fall harvest and continued evaluation of the dry matter loss models.

• Testing and evaluation of real-time biomass moisture sensor for switchgrass and corn stover.

5. Publications, Presentations, and Proposals Submitted


University of Wisconsin

1. Planned Activities

Planned activities in this quarter included:

• Lab experiments of the compaction and re-shaping system for round bales.

• Preparation of feed enhancement samples for analysis.

• Continued work on techno-economic modeling of various bale transport and processing scenarios.

• Spring harvest of grasses using single-pass, non-stop baling.

• Preparation of equipment to conduct evaluation of several alternative storage and bale processing approaches.

2. Actual Accomplishments

We have developed a process that reshapes and compacts round bales into a parallelepiped or cuboid shape to enhance transport characteristics of these bales. Bale compaction
experiments to quantify compression forces, bale density, and bale expansion rate were conducted using both switchgrass and reed canarygrass. Using appropriate instrumentation to collect force and displacement during bi-axial compression, we have identified a four-stage re-shaping and compaction process. Analytical models of the pressure-density relationship are being developed and these models will be compared with those from previously published work on large-square bales.

Experiments to improve mature grass ruminant digestion by mechanical and chemical means were started in the fall using switchgrass and corn stover (for comparison purposes). The following treatments were considered: (a) control; (b) treated with calcium hydroxide @ 5% by weight; and (c) treated with ammonium hydroxide @ 4 % by weight. All treatments were also split into two physical treatments (chopped or shredded) and DM content (45% or 82%). Treatments were removed from storage and samples prepared for analysis. The samples were then sent to co-project director Rob Mitchell (USDA Lincoln) for analysis and we are awaiting results. The results were be analyzed by a CenUSA undergraduate intern student this summer and the experiment continued during his summer work.

We have investigated numerous ways to reduce harvest, handling, storage and transport costs, including pre-cutting at baling, mega-sized round bales, film wrapping bales for storage, and re-shaping and re-compacting round bales. We have begun to analyze the economic impact – either positive or negative – of these approaches. Current efforts are focused on transport options for various bale configurations. Modifications to modules of the IBSAL model are being made to complete this analysis.

A single-pass, non-stop baler normally used to harvest grain-crop residues behind the combine harvester was modified to harvest perennial grasses while powered by a tractor. Using the baler in additional crops would help to dilute the machines fixed-costs over more area and tonnage. The modified single-pass, non-stop baler was used to harvest switchgrass and reed canarygrass that had overwintered. Continuous baling was achieved, but fuel consumption and bale density were not as favorable as compared to conventional baling approaches. However, the single-pass bales were extensively size-reduced at baling, so energy saving could ultimately occur if the downstream primary bale-grinding operation could be eliminated by harvesting in this manner.

A bale storage study was initiated in the fall of 2014 to compare several methods of bale storage of perennial grasses to that of corn stover. Half the bales will be removed from storage in mid-May and the remainder in mid-summer. We have acquired equipment to process bales as they are removed from storage so that processing energy requirements and particle-size can be compared across different crops and storage methods.

3. Explanation of Variance
None.

4. Plans for Next Quarter

Our efforts in the next quarter will include:

- Remove bales from storage and collect processing data.
- Continue work on the system to compact and re-shape round bales.
- Analyze treatments to enhance the feed value of very mature switchgrass and continue experimental work.
- Investigate alternative mower designs that would reduce losses associated with harvesting down grasses.
- Continue to assess the economic viability of the various bale harvest and configuration options previously investigated.

5. Publications, Presentations, and Proposals Submitted

None

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

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

We focus on four overarching tasks:

- Task 1. Adapt existing biophysical models to best represent data generated from field trials and other data sources.
- Task 2. Adapt existing economic land-use models to best represent cropping system production costs and returns.
- Task 3. Integrate physical and economic models to create spatially explicit simulation models representing a wide variety of biomass production options.
- Task 4. Evaluate the life cycle environmental consequences of various bioenergy landscapes.
Iowa State University

1. **Planned Activities**

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

2. **Actual Accomplishments**

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

   A paper was published in the journal of the European Agricultural Economics Association this summer. In addition, the paper formed the basis for the plenary session of the world congress of the *European Agricultural Economics Association* held in Ljubljana, Slovenia in August. That paper describes the results of baseline and a conservation practice placement to evaluate the water quality effects at the landscape level. A second set of scenarios using the extended 12-digit scenario models have been initiated using switchgrass and corn/soybean rotations as possible land-use options. We are working with a survey of Corn Belt farmers to use as a basis for developing a set of scenarios to represent how farmers indicate that they plan to respond to climate change over the next few decades. Given the potential importance of adaptation in the response to climate change, we plan to integrate these farmer indicated responses with bioenergy scenarios. We are also carrying out a series of genetic algorithm optimization runs on a calibrated watershed model to examine the tradeoffs between food, fuel, and water quality using switchgrass and/or miscanthus as biofuel feedstocks. These runs are in process.

3. **Explanation of Variance**

   No variance has been experienced.

4. **Plans for Next Quarter**

   We will continue to adapt existing biophysical models to best represent field trials and other data and to adapt existing economic land-use models to best represent cropping system production costs and returns. Continue developing scenarios of specific interest to the goals of CenUSA including the optimal placement of switchgrass to achieve a range of environmental improvements while producing energy. We will continue to work with colleagues from Purdue and plan model comparisons between watersheds at multiple locations. We have two selected small watersheds selected (one in Iowa and one in Indiana). Appropriate SWAT versions and code have now been agreed upon as have a set of scenarios.
We anticipate a complete set of comparison runs to be finished by the fourth quarter or perhaps early in the next year of the project.

5. Publications, Presentations, and Proposals Submitted


University of Minnesota

1. Planned Activities

Planned activities for this quarter include continued work on:

- **Task 1.** Adapt existing biophysical models to best represent data generated from field trials and other data sources.

- **Task 2.** Adapt existing economic land-use models to best represent cropping system production costs and returns.

- **Task 3.** Integrate physical and economic models to create spatially explicit simulation models representing a wide variety of biomass production options.

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

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

2. Actual Accomplishments

- This quarter saw the successful thesis defense of Christine Forland, a CenUSA-supported graduate master’s student, who explored the yield gaps between trial- and farm-scale production.

- We continued to update GREET for switchgrass production to explore air quality impacts of biomass and bioenergy production. Spatial and temporal descriptions of switchgrass production at different volumes are being considered.

- We submitted our manuscript *Ecosystem service provisioning and profitability in prairie grassland biomass production*, which explores farmer profitability with payment for ecosystem services.
3. **Explanation of Variance**

No variance has been experienced.

4. **Plans for Next Quarter**

Next quarter includes continued work on Tasks 1, 2, 3, 4, and 5.

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

Noe, R., Nachman, E., Heavenrich, H., Keeler, B., Hernández, D. & J. Hill. *(In review)*
Ecosystem service provisioning and profitability in prairie grassland biomass production.

**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.

**Sub-objective 1. Perform Technoeconomic Analysis**

1. **Planned Activities.**

Planned activities for the quarter included the development of AspenPlus™ models that incorporate upgrading and stabilization processes recently developed at Iowa State University to allow for more detailed analysis of pyrolysis pathways to fuels and non-fuel products.

Validation of the proposed mechanism for anisole and phenol conversion was also planned, as well as analysis of the influence of product intermediates in these conversions.

2. **Actual Accomplishments**

- **Development of AspenPlus™ Process Models.** AspenPlus™ Process models were developed for the following pyrolysis-based biorefinery scenarios:
✓ Biofuels: Products include biochar, gasoline and diesel
✓ Biochemicals: Products include biochar, calcium, acetate, asphalt binder/modifier and dextrose
✓ Alternate hydrocarbon products: Products include biochar, aromatics (primarily benzene, toluene, xylene), and olefins

These process models and combinations of the three scenarios will be the basis for future analyses.

• **Analysis of Anisole and Phenol Conversion in Catalytic Pyrolysis.** The proposed mechanisms for anisole and phenol conversion over zeolites during catalytic pyrolysis were validated by observing product distributions of the intermediates in the reactions.

The major conversion step indicated in the anisole mechanism was phenol conversion to benzene, using methylene generated from the methoxy functional group of anisole. This step was validated by co-pyrolyzing phenol with a compound that generates methylene (1,2,3-trimethoxy benzene). As expected per the proposed mechanism, methylene donation improves the conversion to benzene, indicating the influence of methylene in phenol conversion. The major conversion step indicated in the phenol mechanism was ring opening of 1,4-benzoquinone to produce benzene and naphthalene. When 1,4-benzoquinone was pyrolyzed over zeolites in an identical reaction setup, it gave similar benzene and naphthalene selectivity to phenol. These results provide strong evidence for the proposed mechanisms, validating major steps involved in these reactions.

3. **Explanation of Variance**

None to report.

4. **Plans for Next Quarter**

Update process models for biochemical and alternative hydrocarbon product scenarios with most recent data on aromatic and olefin yield, as well as acetate and dextrose recovery.

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

None.

**Sub-objective 2. Prepare and Characterize Biochar**

1. **Planned Activities**
The manuscript *Anion Exchange Capacity of Biochar* will be re-submitted for publication. Changes in the physical and chemical properties of biochars on aging in soil environments will be quantified.

2. Actual Accomplishments

The on-going biochar aging study is comparing fresh, laboratory and field aged biochars. Field aged biochars were separated from soil samples collected from various biochar field plots around the Midwest. To mimic field aging, lab aged biochars were equilibrated for 30 days with 1M HCl with weekly additions of H₂O₂. After the acid treatments, the samples were washed with 1M CaCl₂, then DI water, and finally equilibrated for 30 days with a compost aqueous extract so the biochars would adsorb DOC.

Proximate analysis indicted that most of the fresh biochars contained more fixed carbon and less volatile matter than the aged biochars (Fig. 6).

FTIR spectra showed little difference between fresh and either field or lab aged hardwood biochars (HS = hardwood biochar produced by slow pyrolysis, HF = hardwood biochar produced by fast pyrolysis, Cowboy = commercial hardwood biochar produced by slow pyrolysis) (Fig. 7). By contrast, FTIR spectra of biochars produced from herbaceous biomass (CS = corn stover slow pyrolysis, CF corn stover fast pyrolysis, SS = switchgrass slow pyrolysis, SF soybean stover fast pyrolysis) all showed evidence of increased adsorption in the carbonyl (1700 cm⁻¹) and ether (1180 cm⁻¹) regions after aging.
Fig. 6. Fixed carbon and volatile matter of fresh and aged biochars
Chemical analysis, in general, showed a decrease in pH and EC and an increase in surface area and anionic exchange capacity of aged relative to fresh biochars (Table 5). CEC of the hardwood biochars increased with aging while CEC of the herbaceous biochars (corn stover, switchgrass, soybean stover biochars) decreased with aging. Changes in chemical spectroscopic properties of the macadamia nut biochar were not consistent with the other biochars.

3. Explanation of Variance

No variance.

4. Plans for Next Quarter

Work on the biochar aging study will continue. We will obtain data for several additional field-aged biochars to provide a better comparison between the laboratory aged and field-aged biochars. A manuscript documenting inorganic and organic alkalis in biochars will be prepared for publication.

5. Publications, Presentations, and Proposals Submitted

None submitted.

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### Table 5. Comparison of physical and chemical characteristics of fresh and aged biochars

<table>
<thead>
<tr>
<th>Biochar ID</th>
<th>pH ($\text{H}_2\text{O}$; after 144 hrs)</th>
<th>EC (µS cm$^{-1}$)</th>
<th>CEC (cmol$_e$ kg$^{-1}$)</th>
<th>AEC (cmol$_c$ kg$^{-1}$)</th>
<th>Specific surface area (m$^2$ g$^{-1}$)</th>
<th>H/C atomic ratio</th>
<th>E$_2$/E$_3$ ratio</th>
<th>E$_4$/E$_6$ ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh HF</td>
<td>5.9 (0.006)</td>
<td>348 (1.2)</td>
<td>10.9 (0.7)</td>
<td>1.9 (0.14)</td>
<td>177.1 (1.1)</td>
<td>0.59 (0.004)</td>
<td>2.3 (0.07)</td>
<td>1.8 (0.05)</td>
</tr>
<tr>
<td>LA HF</td>
<td>3.1 (0.03)</td>
<td>216 (9.1)</td>
<td>14.1 (0.8)</td>
<td>3.7 (0.19)</td>
<td>638 (8.1)</td>
<td>0.57 (0.03)</td>
<td>4.3 (0.07)</td>
<td>9.02 (0.5)</td>
</tr>
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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 for the production of row crops. To create this comprehensive strategy the team focuses on two unifying approaches:

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

**1. Planned Activities**

Our team’s anticipated activities were:

- **Activity A.** Prepare an outreach piece that compares the producer survey results over two years; this will summarize findings and identify implications for our project.
• **Activity B.** Continue to interact with industry on an Iowa State University Bioeconomy project to model the use of feedstocks as a fuel source for fast pyrolysis. The business model involves a distributed system of fast pyrolysis that provides as byproducts char and bio-oil. Char will be sold as a soil amendment, and bio-oil will be sold for use in furnaces for heat. The group includes soil scientists, chemical engineers and mechanical engineers (Hayes).

• **Activity C.** Continue modeling and analysis efforts of the regional supply curve for grasses and stover using a real options framework (Hayes). Present one of these studies at conference on this subject in 2015. Publish two peer-reviewed papers in this area.

• **Activity D.** Continue a project to study the transportation economics of CRP when filter strips and grassy plantings are harvested for biomass. The expected outcome is a report describing the use of CRP for perennial grasses. The feature of this report will be an exploration of the trade-off between offering higher biomass prices to procure more product closer to the plant and lower biomass prices with increased transportation costs under various participation (harvest/yield) rates. The comparison is made to the case of corn stover and a dual crop model is considered to estimate biomass production from grasses and stover.

2. **Actual Accomplishments**

• **Planned Activity A.** Reconsidered – insufficient survey data beyond what was collected in the first round. That data was already reported to the CenUSA team and published.

• **Planned Activity B.** Ongoing.

• **Planned Activity C.** Paper published in Bioenergy.

• **Planned Activity D.** One phase of this work is completed, and another graduate student is taking over. The project was presented at the 8th Annual Berkeley Bioeconomy Conference in Berkeley, CA, April 2, 2015.

3. **Explanation of Variance**

We reconsidered the effort to prepare an outreach piece that compares the producer survey results over two years as there was insufficient survey data beyond what was collected in the first round. See “Plans for Next Quarter” for a new activity that has been added to this objective’s portfolio.

4. **Plans for Next Quarter**
During fourth quarter (Mau – July 2015), our team will continue work as outlined in the planned activities. An additional project is being added: Keri Jacobs and Rob Mitchell (Objective 2, Feedstock Production) are working on a producer decision tool based on the project’s parameters for perennial grass production. The expected output here is a decision aid to be presented at the annual meeting and training provided to extension personnel. The components of the tool have been chosen and work will begin during summer to build it and train extension educators.

5. Publications, Presentations, and Proposals Submitted


Objective 7. Health and Safety

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

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

- The risks associated with producing feedstocks; and
- The risks of air/dust exposure.

1. Task 1. Managing Risks in Producing Biofeedstocks

   - Planned Activities

   We will continue to add additional data and details necessary for the new risk assessment model. Complete calculations of risk between production systems will be accomplished and areas for model improvement will be identified. A technical paper will be submitted for peer review to the International Society of Agricultural Safety and Health professional improvement committee.

   - Actual Accomplishments

   Several injury and exposure datasets were added to the spreadsheets containing the model calculations. Refinements to the filters and adjustment techniques were made so the necessary values from injury and exposure data sets are aligned with the new probabilistic risk assessment model inputs. Refinement of processes, data, filters, and
adjustments for the new probabilistic risk assessment model for biofeedstock production were continued.

The deterministic values calculation from the new probabilistic risk assessment model with actual Midwestern related injury and exposure data was completed. This step demonstrated that the calculation algorithms were functioning as expected. The initial stochastic simulations runs were completed to calculate the change in likelihood of injury between traditional corn production and biofuel production. While these calculations yielded two numerical risk values that could be compared, these values are not the final result. These values validate the use of stochastic simulations for creating results in the probabilistic risk assessment model, an intermediary step in the process to compare the risk values.

A technical paper proposal was submitted and accepted to the International Society of Agricultural Safety and Health conference June 21-24, 2015. The technical paper 15-01 was peer reviewed and being prepared for 2015 conference proceedings.

• **Explanation of Variance**

  None to report.

• **Plans for Next Quarter**

  Data refinement and adjustments for the new probabilistic risk assessment model will continue to be added. The initial set of complete calculations of risk between production systems will be reviewed, evaluation of inputs into model will be examined, and areas for model improvement will be identified. A technical paper will be presented at the International Society of Agricultural Safety and Health conference on June 21-24, 2015 in Normal, IL. A manuscript about the model development will be submitted to the Journal of Agricultural Safety and Health.

• **Publications, Presentations, and Proposal Submitted**

  None this quarter.

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

• **Planned Activities**

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We will receive approval for modifications to the human subjects study. The air sampling equipment will prepared for use by subjects in study. Identification of human subjects to participate in the study will begin after approval.

- **Actual Accomplishments**

  The modifications to the human subjects study to include the transportation location of potential subjects is still on going. IRB approval has not yet been obtained.

- **Explanation of Variance**

  The adjustment to existing human subject approval will be resubmitted to the Institutional Review Board making the necessary adjustments to the participation, detail, and collection of data. The current human subject approval has been extended and is still enforced, but it does not provide the details necessary to collect the data needed until it has been modified.

- **Plans for Next Quarter**

  Receive approval for modifications to the human subjects study.

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


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 follow:

- To develop a shared bioenergy curriculum core for the Central Region.
- To provide interdisciplinary training and engagement opportunities for undergraduate and graduate students.

Subtask 1 is curriculum development. Subtask 2A is training undergraduates via an 8-week summer internship program modeled on the highly successful NSF REU (research experience for undergraduates) program. Subtask 2B is training graduate students via a 2-week summer intensive program modeled on a highly successful industry sponsored intensive program in biorenewables the team led in 2009. Subtask 2C is training graduate students via a monthly research webinar. The next portion of this report is broken into subtasks.

Subtask 1: Curriculum Development

1. Planned Activities

We are continuing the final edits of existing modules in feedstock development, logistics and economics areas:

- **Module 12. Biochemical Conversion of Bioenergy Feedstocks**
  
  Revise draft content and begin process to convert content to on-line module.

- **Module 13. Thermochemical Conversion of Bioenergy Feedstocks**
  
  Continue development of draft module materials.

- **Module 14. Preprocessing Operations for Bioenergy Feedstocks**
  
  Prepare draft of module outline.

- **Evaluation Tasks**
  
  Prepare presentation of evaluation case studies for module program for Innovate 365 Distance Education Conference.

2. Actual Accomplishments
• **Module 12. Perennial Grass Seed: Protection, Certification and Production**
  
  Content was revised and conversion of content on-line module has started.

• **Module 13. Thermochemical Conversion of Bioenergy Feedstocks**
  
  Continued development of draft module content.

• **Module 14: Preprocessing Operations for Bioenergy Feedstocks**
  
  Drafting of module was started. Some content in the draft of Module 12 was moved in this module.

• **Module 15: Introduction to Bioenergy Conversion Platforms**
  
  As a result of the creation of modules 12 and 13 a new module will be created that provide an overview of bioenergy conversion platforms and their relations to feedstock composition.

• **Evaluation Tasks**
  
  A presentation for the Innovate 365 Distance Education Conference was prepared which summarizes the module development and evaluation activities.

• **Creation of new online home for modules**
  
  Currently modules that are completed are made publically available through the CenUSA page in the Plants and Soils e-Library at UNL. As a result of Deana Namuth-Covert’s transition to The Ohio State University there is some uncertainty about future access to the module content. Options to move the existing modules to a more permanent home have been discussed and it has been decided that the modules should be housed with the CenUSA website structure.

3. **Explanation of Variance**

   None.

4. **Plans for Next Quarter**

   • **Module 12. Biochemical Conversion of Bioenergy Feedstocks.**
     
     Convert draft content to on-line module.

   • **Module 13. Thermochemical Conversion of Bioenergy Feedstocks.**
     
     Finish draft of module content.
• **Module 14: Preprocessing Operations for Bioenergy Feedstocks**
  Finish draft of module content.

• **Module 15: Introduction to bioenergy conversion platforms**
  Prepare outline of module content.

• **Creation of new online home for modules**
  Formalize a plan to create a repository for the modules within the CenUSA website.

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

  None to report this period.

**Subtask 2A: Training Undergraduates via Internship Program**

1. **Planned Activities**

  • Continue to promote the undergraduate internship program and encourage application submissions through the March 23, 2015 application deadline.

  • Centrally vet and rank applications based on the letters of interest, academic achievement, previous research experience, and letters of recommendation.

  • Pool of likely candidates will be given to faculty hosts for review during the week of March 30, with selections and rankings of students requested from faculty by April 3.

  • Highly ranked students, as indicated by faculty hosts, will receive telephone interviews the week of April 6 and April 13.

  • First offers to students will begin April 6, second offers to students April 13 with the cohort (20 students) finalized on April 27th.

  • Arrange travel for accepted students.

  • Secure housing for students who will be placed with faculty mentors at partner institutions.

2. **Actual Accomplishments**

  • Robust promotion of the program yielded a pool of highly qualified applications on the March 23 deadline.

  • Central vetting and ranking of the applications completed on March 27, 2015.
The pool of likely candidates was packaged and given to faculty hosts for review on March 27, and selection decisions provided back on or before April 3.

Student phone interviews with Raj Raman took place the weeks of April 6 and April 13.

First offers were extended the week of April 6, second offers extended the week of April 13, and a cohort of 19 students finalized on April 21.

The 2015 CenUSA Bioenergy Internship cohort consists of 19 students – Iowa State University placements (4 male, 3 female), University of Nebraska-Lincoln placements (4 male, 2 female), Purdue University placements (1 male, 1 female), University of Wisconsin, Madison (1 male, 1 female), USDA NCAUR Laboratory (1 female), ADM industry placement (1 male).

All non-selected candidates notified on April 24 as was publicized on the CenUSA website.

3. Explanation of Variance

None.

4. Plans for Next Quarter

Finalize all logistics; student travel, lodging at Iowa State and all five partner institutions (University of Wisconsin – Madison, University of Nebraska – Lincoln, Purdue University, USDA NCAUR Lab, and ADM), and administration of stipends.

Provide mentor training using a 15-minute video (created by Raj Raman). We will share link with the internship mentors (faculty/grad student/post doc) in mid-May, followed by a combined face-to-face (for ISU-based mentors) and virtual (via Zoom for partners) meeting to clarify any questions and concerns.

Launch the program on May 27 with the arrival of the students. Run the orientation at Iowa State from May 28 – May 31, send students to appropriate lab placements for a June 2nd start date, schedule weekly meetings (June 2 – July 22) with student interns to discuss progress, face-to-face for ISU students and virtual (via Zoom) for partner-placement students.

Iowa State University’s Research Institute for Studies in Education (RISE) administered a pre-program survey to assess students on May 28. This provided a baseline for program evaluation.

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• The ISU-based interns will participate in a team-building canoe trip on the Des Moines River on Saturday, May 30.

• All partner-placed students return to Iowa State on July 26 in preparation for travel to the CenUSA Annual Meeting at the University of Wisconsin, Madison on July 27-29.

• All undergraduate interns participate in the CenUSA annual meeting as they actively engage in the Q&A sessions following research presentations by objective program directors and faculty leaders. All interns present their research during the research poster session and dinner reception on Tuesday, July 28.

• Interns return to Iowa State University on July 29 for the close of the program. All students participate in the closing celebration brunch with faculty and graduate student mentors and ISU REU-wide poster session on Friday, July 31.

5. Publications, Presentations, and Proposals Submitted

None to report this period.

Subtask 2B – Training Graduate Students via Intensive Program

1. Planned Activities

• Continue to work with Mike Casler (Objective 1. Feedstock Development) and Iowa State University’s Conference Planning and Management staff to plan for the one-day condensed graduate intensive program add-on to the annual meeting.

✓ Plans include a tour of some Great Lakes Bioenergy Research Center (GLBRC) facilities and research plots on July 28, 2015. Consider a stop at GLBRC biomass research at the Arlington Ag Research Station and another stop at the Wisconsin Energy Institute on campus. The graduate students will see a range of biomass research that is quite different from that in CenUSA, covering a range of topics from production/sustainability all the way to conversion processes.

2. Actual Accomplishments

Worked with Dr. Mike Casler as detailed above in the planned activities.

3. Explanation of Variance

None.

4. Plans for Next Quarter

• Conduct the July 28 condensed graduate intensive program add-on to the annual meeting.
Program includes a tour of some GLBRC facilities and research plots, a stop at GLBRC biomass research at the Arlington Ag Research Station, and another stop at the Wisconsin Energy Institute on campus. The graduate students will see a range of biomass research that is quite different from that in CenUSA, covering a range of topics from production/sustainability all the way to conversion processes.

5. Publications, Presentations, and Proposals Submitted

None.

Subtask 2C – Training Graduate Students via Monthly Research Webinar

1. Planned Activities

Continue delivery of the restructured/reformatted research webinar content.

- Organize four 1-h sessions spread over the spring academic year (March and April of 2015). Each session will have several CenUSA Objective Leaders or Collaborating Faculty presenting on an issue listed below. The issues are meant to be mildly controversial so that multiple views can be presented. After the presentation of viewpoints, which should last no longer than ten minutes each, we will move to Q&A, with questions from anyone and particularly encouraged from graduate students.

Scheduled Topics

- March 27 – What are the most realistic approaches to reducing N and P export from the Corn Belt?
  - Presenters: Cathy Kling, Keri Jacobs, Raj Raman

- April 24 – Topics under consideration:
  - What kind of switchgrass yields are likely to be possible on marginal lands, and what would the cost of this material be?
    - Proposed presenters: TBA
  - How do yield increases and machinery changes impact cost and safety?
    - Proposed presenters: TBA

2. Actual Accomplishments

- Continue delivery of the restructured/reformatted research webinar content.
Organizing four 1-h sessions spread over the spring academic year (March and April of 2015). Each session will have several CenUSA Objective Leaders or Collaborating Faculty presenting on an issue listed below. The issues are meant to be mildly controversial so that multiple views can be presented. After the presentation of viewpoints, which should last no longer than ten minutes each, we will move to Q&A, with questions from anyone and particularly encouraged from graduate students.

**Scheduled Topics**

✓ March 27 – What are the most realistic approaches to reducing N and P export from the Corn Belt?

➢ Presenters: Cathy Kling, Keri Jacobs, Raj Raman

3. **Explanation of Variance**

- Keri Jacobs had a last minute schedule conflict on March 27, 2015 therefore Dermot Hayes agreed to serve on the panel in her absence.

- The originally planned April 24 research webinar was rescheduled for June 26 directly following the co-PI meeting to allow for attendance by the 19 undergraduate students participating in the CenUSA Bioenergy undergraduate research internship program.

4. **Plans for Next Quarter**

Continue delivery of the restructured/reformatted research webinar content.

- Organizing four 1-h sessions spread over the spring academic year (Each session will have several CenUSA Objective Leaders or Collaborating Faculty presenting on an issue listed below. The issues are meant to be mildly controversial so that multiple views can be presented. After the presentation of viewpoints, which should last no longer than ten minutes each, we will move to Q&A, with questions from anyone and particularly encouraged from graduate students.

**Scheduled Topics**

✓ What kind of switchgrass yields are likely to be possible on marginal lands, and what would the cost of this material be?

➢ Proposed presenters: TBA

✓ How do yield increases and machinery changes impact cost and safety?
5. **Publications, Presentations, and Proposals Submitted**

None to report.

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**Objective 9. Extension and Outreach**

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

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

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

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

  This team covers the areas of:

  - Production, harvest, storage, transportation.

  - Social and community impacts.

  - Producer and general public awareness of perennial crops and biochar agriculture.

  - Certified Crop Advisor training.

- **Economics and Decision Tools Team**

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

- **Health and Safety Team**

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

This team focuses on two separate areas:

- **Youth Development.** The emphasis is on developing a series of experiential programs for youth that introduce the topics of biofuels production, carbon and nutrient cycling, and biochar as a soil amendment.

- **Broader Public Education/Master Gardener.** These programs acquaint the non-farm community with biofuels and biochar through a series of outreach activities using the Extension Master Gardener volunteer model as the means of introducing the topics to the public.

Evaluation/Administration Team

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

1. Extension Staff Training/eXtension Team

- **Planned Activities**
  - Produce one CenUSA e-newsletter (BLADES) during the 1st quarter of 2015.
  - Begin new CenUSA Fact Sheet.
  - Begin development of one CenUSA Case Study.
  - Perform upkeep of CenUSA Index.
  - Continue social media promotion of CenUSA.

- **Actual Accomplishments**
  - Produced and published peer reviewed publication on eXtension website:
**BLADES Newsletter.** The CenUSA communications team released two newsletters this quarter (February and April). BLADES features stories related to CenUSA research activity, and other events in the perennial grass energy world, including the commercial sector. The stories were published and emailed to our list via the Constant Contact platform.

**February Issue.** The February 2015 issue was sent to 745 individuals, 6 of whom opted out. 266 individuals (36.7%) of recipients opened the newsletter and 61 (22.9%) clicked on a story ([http://blades-newsletter.blogspot.com/p/february_4.html](http://blades-newsletter.blogspot.com/p/february_4.html)). Stories included:

- **CenUSA Looks for Next Batch of Summer Interns.** Story described the 2015 internship program
- **A Producer’s Viewpoint with John Weis.** Story on biochar test plots on farm of CenUSA Advisory Board Member John Weis.
- **2015 A Turning Point in the Bioeconomy.** Story about how experts in bioeconomy see 2015 as a turning point for second-generation biofuels.
- **How Green is Your Drive?** Story about a new CenUSA paper published in the Proceedings of the National Academy of Science compared the environmental health impacts from a range of fuel types and technologies.
- **How CenUSA Uses Social Media to Spread Science – and How You Can Too.** Story discussed the use of social media in advancing research in the CenUSA project and tips for reaching a science audience.
- **CenUSA 101.** Training video on how to best view CenUSA’s new website.

**April Issue.** The April 2015 issue was sent to 761 individuals, 2 of whom opted out. Of the 761 individuals who received the newsletter, 269 (35.8%) of recipients opened the newsletter, and 62 (23%) clicked on a story ([http://blades-newsletter.blogspot.com/p/april-2015.html](http://blades-newsletter.blogspot.com/p/april-2015.html)). Stories included:

- **Toward Progress on Nutrient Reduction – An update on state-based efforts to reduce nutrient pollution from agriculture.**
o Chevrolet and Ducks Unlimited Pair Up for Grasslands – Chevrolet’s recent investment of $40 million to purchase 8 million tons of carbon credits from livestock farmers in North Dakota will protect 11,000 acres of grasslands.

o Switchgrass: Better Bedding for Broilers? The University of Delaware Extension service is working with the Nature Conservancy and Rotochopper, a manufacturer specializing in grinders for mulch, compost and animal bedding to grind switchgrass for poultry bedding.

o CenUSA releases first-ever decision support tool for switchgrass – New economic tool developed by CenUSA collaborator and Iowa State University economist Chad Hart allows farmers to compare costs when producing switchgrass.

o The California carbon offset market: directing a changing landscape – The California carbon market is changing rapidly. Biomass crops like switchgrass, that can sequester carbon, may be good future carbon offset candidates.

o Managing carbon like coffee cups – Reprinted op-ed by Dr. Robert Brown, published originally in The Hill, a daily publication covering Congressional policy issues.

✓ CenUSA eXtension Web Site. Google Analytics for CenUSA articles/Fact Sheets on the CenUSA eXtension site for this quarter reveal the following:

➢ Compared to last quarter, usage is significantly increasing – page views are up by 64%, users are up 62% and average time on page is up 41%.

➢ CenUSA eXtension site received 4,017 page views by 2,757 users, 76% of them new sessions, averaging 1.3 pages per visit. The bounce rate is 83% and average time on page is 4:31 minutes.

➢ Traffic sources are 82% search engines (i.e. Google), 14% direct traffic and 4% referring sites. Efforts continue to optimize publications for search engines.

➢ Top 10 states accessing CenUSA articles were Illinois, California, Michigan, Minnesota, Nebraska, New York, Texas, Colorado, North Carolina, and New Jersey; with use from throughout the U.S. and world.

➢ The top nine states accessing CenUSA articles were Michigan, Texas, Wisconsin, Illinois, New York, Iowa, North Carolina, Pennsylvania, and Nebraska.

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✓ **CenUSA Web Site.** The CenUSA web site had 1,970 visitors this quarter versus 790 the prior quarter. These visitors logged a total of 8,229 pageviews during 3,030 sessions (3,099 and 1,142 last quarter, respectively). We attribute the growth to the redesigned website.

✓ **Twitter.** Twitter traffic consists of followers who subscribe to our account and “follow” our tweets (announcements). Followers can “favorite” a tweet or retweet it to share with their own followers. They can also “mention” us by tagging CenUSA bioenergy’s twitter account in their own tweets. During this quarter our tweets were retweeted a total of 85 times. Followers tagged CenUSA tweets as favorite 85 times and mentioned us 59 times. CenUSA bioenergy also has 565 followers currently, up from 499 followers last quarter.

✓ **Vimeo.** During this quarter, the 41 CenUSA videos archived on Vimeo have had 430 plays or views of the videos on our Vimeo site or on a web site that embedded a CenUSA video. The 41 videos also had 3,499 loads; 3,063 of those loads came from our videos embedded on other sites. When a video is loaded, people see the video but they do not click “play.” The means the video was saved to their hard drive (users usually do this because they have limited internet connectivity which does not allow for live streaming of video). Once the video is downloaded, it is available on their computer to watch at their convenience.

✓ **YouTube.** CenUSA videos are also posted on YouTube, and those videos have been viewed 1,185 times between February 1 and April 30, 2015. Seven hundred eighty-eight views were from the United States. 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. Ninety-two percent 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 5.8% of the views and 1.8% 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 the quarter include: YouTube search, YouTube suggested videos, direct URL links, and referrals from other web sites. Thirty-four percent of our views came from users accessing videos through YouTube Search. YouTube suggested videos accounted for 25% of our views. Views from mobile apps or from direct traffic (links in an e-mail or copying/pasting the direct URL) account for 13% of video views. Finally, referrals from outside YouTube (Google search or access through external web sites) account for 12% of video views.

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1 Pageviews are the total number of pages that visitors looked at during their time on the site.
Assisted in interviewing and hiring two new CenUSA Communications Interns (undergraduate journalism students from Iowa State University).

Interviewed University of Minnesota CenUSA Extension team member Bill Lazarus and Dave Hall, Minnesota Pollution Control Agency about their nutrient decision support tool.

- **Explanation of Variance**

  The March issue of BLADES was delayed until April because the communications team needed more time to complete stories.

- **Plans for Next Quarter**

  - Continue maintenance of eXtension index: *Resources from CenUSA*.
  
  - Develop two eXtension Expert-Bio pages for CenUSA Collaborators. These pages will rotate with others bios on the eXtension Farm Energy Home Page.
  
  - Publish one fact sheet and one research summary.
  
  - Use eXtension Farm Energy Social Media sties to broadcast information from CenUSA.
  
  - Train new CenUSA communications interns.
  
  - Attend CenUSA annual meeting; capture video while at meeting if schedules allow.
  
  - Develop and release BLADES newsletters.

- **Publications, Presentations, Proposals Submitted**


  - February issue of BLADES newsletter.

  - April issue of BLADES newsletter.

**Producer Research Plots/Perennial Grass/Producer and Industry Education Team**
• **Planned Activities**

- **Indiana (Purdue University)**
  - Grind and send Indiana demonstration plot samples to CenUSA Co-Project director Rob Mitchell (USDA-ARS, Nebraska) for analysis.
  - Format 2014 plot data.
  - Remove 2014 old growth from Trafalgar and Peru plots.
  - Hire student worker for summer 2015 for on-farm plots.
  - Edit exhibit signage.
  - Re-budget for CenUSA Year 5 re-application.
  - Conduct programs for:
    - Washash County Winter Ag School
    - Midwest Bioenergy Outreach Team Meeting
    - National Association of Power Engineers Meeting
    - National Energy Extension Summit Presentation
    - Batesville Indiana Renewable Energy Expo Presentation
    - Indiana FFA and Indiana Corn Marketing Council Ethanol Training Teacher Program Development
    - Gibson County Ag School

- **Iowa**
  - Burn off grass from on-farm demonstration plots.
  - Apply N treatments to on-farm demonstration plots in April 2015.
  - Begin preparations for fall 2015 field day.

- **Minnesota**
  - Harvest plots and gather samples.
Finish grinding samples from 2014 demo plot and send to University of Nebraska, Lincoln for analysis.

Share information about CenUSA and growing switchgrass on marginal lands in lecture for upper-level undergraduate class at University of Minnesota (“Soil Nutrients in the Environment”).

Plan for June 17, 2015 field day at CenUSA Lamberton demonstration plot and for a producer field day later in the summer.

**Nebraska**

- Continue to develop plans for summer outreach activities.
- Fertilize CenUSA biomass demonstration plots.
- Dig *Liberty* and *Shawnee* switchgrass plants from demonstration plots and replant in University of Nebraska, Lincoln greenhouse for later planting at “Raising Nebraska” State Fair exhibit.
- Evaluate need for weed control at CenUSA field demonstration sites.
- Work on CenUSA budget for Year 5 of the project.
- Authorize annual land rental payments to the two CenUSA cooperating grass growers.
- Work with David and Associates to develop educational/teaching materials for Raising Nebraska Exhibit at the Nebraska State Fair and at Husker Harvest Days.

- **Actual Accomplishments**
  - **Indiana (Purdue University)**
    - Demonstration plot samples were ground and sent to Rob Mitchell at USDA-ARS, Lincoln for analysis.
    - Brittany McAdams formatted 2014 data.
    - Removed 2014 plot growth from Trafalgar and Peru plots.
    - Hired student worker for summer 2015.
    - Edited CenUSA signage several times.
    - Completed rebudgeting for CenUSA Year 5 reapplication.
Presented programs to:

- Washash County Winter Ag School.
- Midwest Bioenergy Outreach Team Meeting.
- National Association of Power Engineers Meeting.
- National Energy Extension Summit Presentation.
- Indiana FFA and Indiana Corn Marketing Council Ethanol Training Teacher Program Development.

**Iowa**

- Both plots were burned off in preparation for 2015 production (Washington County plot burned on March 31, 2015; Johnson County plot on April 14).
- N fertilizer has been purchased and will be applied in the last week of April 2015 or the first week of May as weather permits.

**Minnesota**

- 32 students (22 male and 10 female) attended a lecture about CenUSA and growing switchgrass on marginal lands.
- Began planning for summer and fall 2015 field days.

**Nebraska**

- Received final approval for planting of *Liberty* and *Shawnee* switchgrass at the Raising Nebraska Building located at the Nebraska State Fair Grounds in Grand Island, Nebraska. This is a new facility designed to enhance agricultural literacy. In addition, a similar planting will occur at the site of the three-day “Husker Harvest Days” event for growers called Grand Island, Nebraska.
- Fertilized both CenUSA on-farm demonstration plots according to CenUSA protocols.
- Dug and transplanted approximately 100 biomass switchgrass plants from the field into 5 gallon buckets and will grow them in the greenhouse until they are transplanted into the field for the Nebraska State Fair and Husker Harvest Days.
Determined application of herbicide for weed control in established CenUSA on-farm plots was not necessary at this time.

Made financial payment to both Nebraska CenUSA on-farm demonstration cooperators.

Met with David and Associates to plan exhibits.

- **Explanation of Variance**
  - Indiana: Gibson Ag School event was cancelled due to a snowstorm.
  - No variance noted in Iowa, Minnesota or Nebraska.

- **Plans for Next Quarter**
  - **Indiana**
    - We will concentrate on the following activities:
      - Indiana FFA and Indiana Corn Marketing Council Ethanol Training Program.
      - Demonstration plot development and data collection.
      - Walking tour signage installations.
      - Plan field day opportunities at the demonstration sites.
      - Contribute to Bioenergy Youth Workshop that includes the bioenergy grasses as part of the curriculum.
      - Co-lead development of CenUSA Extension team that develops a CenUSA "legacy video."
  - **Iowa**
    - Maintain plots.
    - Plan for fall field day at the Washington County plot.
  - **Minnesota**
    - Continue planning for summer and fall field days.
  - **Nebraska**
Continue to work with David and Associates on educational exhibits and materials for Raising Nebraska Exhibit and Husker Harvest Days.

Transplant greenhouse grasses to Raising Nebraska and Husker Harvest Days sites – maintain plantings at each site.

Capture biomass samples from each previously established biomass locations (Dawson/Beaver Crossing) for quality analysis.

- **Publications, Presentations, Proposals Submitted**
  - **Indiana**
    - National Energy Extension Summit presentation (Chad Martin).
    - Wabash County Winter Ag School (Chad Martin).
    - Batesville Renewable Energy Expo (Chad Martin).
    - National Association of Power Engineers Meeting (Chad Martin).

2. **Economics and Decision Tools**

- **Planned Activities**
  - Schedule and hold meeting of CenUSA Extension Economics Team with co-project directors Keri Jacobs and Rob Mitchell to discuss features to be added to the draft decision tool this summer.
  - Plan training event for CenUSA Extension team to share the *Estimated Cost of Establishment and Production of* “Liberty” *Switchgrass* decision tool and train them how to use it in workshops.

- **Actual Accomplishments**
  - Developed and published background piece for the CenUSA decision tool for perennial grasses ([http://www.extension.iastate.edu/agdm/crops/html/a1-29.html](http://www.extension.iastate.edu/agdm/crops/html/a1-29.html)).
  - Held team meeting to discuss features to be added to the tool this summer.
  - Scheduled training for CenUSA Extension team at CenUSA Annual meeting.
  - Scheduled webinar to train people about use of the tool (September 25, 2015)

- **Explanation of Variance**
None.

- **Plans for Next Quarter**
  - Add additional features to CenUSA Decision Tool.
  - Train CenUSA team members to use the tool.
  - Prepare for September 25, 2015 webinar.

- **Publications, Presentations, Proposals Submitted**

3. **Health and Safety**

   See Health and Safety Objective report, above.

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

- **Youth Development**
  - **Planned Activities**
    - **Indiana**
      - Attend 2015 HASTI (Hoosier Association of Science Teachers Inc.) conference presentation on CenUSA STEM education materials.
      - Attend 2015 NSTA (National Science Teachers Association Teachers) conference presentation on CenUSA STEM education materials.
      - Complete pilot test of high school curriculum and edit lessons for full-scale implementation in the fall of 2015.
      - Finalize CenUSA Bioenergy walking tour interpretive signage.
      - Begin planning 2015 CenUSA Indiana renewable energy Indiana 4-H science workshop.
    - **Iowa**
      - Continue development of C6 app, i-Book and related curriculum.
- Conduct training session on C6 at Iowa 4-H Volunteer Forum.
- Share C6 activities at Science Center of Iowa Earth Day celebration.

**Actual Accomplishments**

### Indiana

- Presented at 2015 HASTI conference.
- Presented at 2015 HSTA national conference.
- Presented poster at 2015 NEES conference.
- Completed pilot test of high school curriculum.
- CenUSA Bioenergy walking tour interpretive signage was finalized and approved for production and installation.
- Renewable energy 4-H science workshop schedule finalized.

### Iowa

- C6 BioFarm educational material development progressed and the programming of the C6 BioFarm game has reached a stage where the game is playable and can be piloted with youth audiences for the 2nd and 3rd quarter of 2015. The game is available using the iOS and Android operating systems and allows youth to operate an agricultural operation and make decisions that focus on the triple bottom line (economic, environmental and sociological sustainability), while producing raw materials for the bioeconomy. Iowa State University faculty have met with the CenUSA C6 team and are interested in using the game for undergraduates and graduate courses. Industrial partners have also expressed interest in supporting the C6 BioFarm project. Meetings for collaboration are planned for the second quarter.

- Eight adult 4-H volunteers (3 male; 5 female) attended the C6 session at the Iowa 4-H Volunteer Forum in Ames, Iowa. The volunteers spanned from across the state of Iowa and were interested in learning about the development of C6 BioFarm and how it could be applicable to them (February 7, 2015).

- Jay Staker (CenUSA C6 team leader) presented a session on C6 at the National Extension Educators Conference in Seattle, WA. 30 Extension Educators participated in the session (April 8, 2015).
The CenUSA C6 team traveled to the Science Center of Iowa in Des Moines for the Earth Day celebration for Iowa families. Seventy-four young people played the basic C6 game, where they learned about carbon and careers in the bioeconomy. After they completed the game and played the survey, they took home a “trading card” for them to remember what they learned (April 26, 2015).

✓ Explanation of Variance

In Indiana student workers were hired away to other positions, however, an open position has been filled for summer so curriculum editing will be completed for full-scale curriculum implementation in the fall.

✓ Plans for Next Quarter

➢ Indiana

- Complete the installation of CenUSA Bioenergy walking tour signage.
- Conduct the 2015 CenUSA renewable energy 4-H science workshop.
- Conduct CenUSA sessions at Indiana 4-H Roundup.
- Complete editing of high school curriculum and identify participants for fall implementation.

➢ Iowa

Planned activities for the fourth quarter of 2015 focus on using the C6 BioFarm educational materials for outreach events. These products will be used in the following locations to teach adults and young people about the principles related to the bioeconomy and the CenUSA educational goals of impacting knowledge relating to biorenewables and SETM Careers. These activities will serve a dual purpose as both educational outreach for CenUSA and also as pilot programming for evaluating the tools and improving the products. For the second quarter of 2015, two interns and a graduate student will work on curriculum and the games while doing outreach events.

- Polk County Extension training – June 10, 2015.
- Summer Academy Leadership Institute (SALI), session I – June 11-12, 2015.
- Iowa 4-H Center STEM Camp – July 6, 2015.
- Central Iowa Fair – July 9, 2015.
- Science Center of Iowa – July 10, 2015.
- Summer Academy for Middle School Teachers – July 13-16, 2015.
- Science Center of Iowa – July 17, 2015.
- Reiman Gardens Discovery Days – August 1, 2015.
- Iowa State Fair 4-H Building – August 13-17, 2015.

✓ **Publications, Presentations, Proposals Submitted**

- **Indiana**
  - Presentation at 2015 HASTI conference.
  - Presentation at 2015 HASTA conference.
  - Poster for 2015 NEES conference.

- **Iowa**
  

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

✓ **Planned Activities**

- **Iowa**
  
  - Order and plant seeds for CenUSA biochar demonstration gardens.
  - Hold information public meetings on Master Gardeners and the biochar project.
Minnesota

- Complete the 2014 report on the CenUSA Biochar Demonstration Garden results.
- Acquire the final results of soil moisture tests done on soil samples collected from the St. Paul Campus’ silty loam site and the Andover’s sandy site.
- Recruit approximately 12 new volunteers for the CenUSA demonstration gardens.
- Contract with grower to start demonstration garden seeds.
- Update Extension Master Gardeners applications, position descriptions, forms and garden procedures for volunteers.
- Update garden designs.
- Schedule demonstration garden leader team meeting in March 2015.
- Promote the CenUSA Biochar Research Project via a display at the Anoka County Extension Master Gardeners Home Landscaping and Garden Fair event on April 11, 2015.

✔ Actual Accomplishments

Iowa

- Seeds were received and partial planting of seeds for the biochar plots has been completed.
- Informational programs were presented about the CenUSA project, the role of CenUSA Extension Master Gardeners, and the outcomes of biochar utilization in demonstration gardens. Meetings were held in Rockwell City (Master Gardener Seminar) on March 14, 2015; Des Moines Botanical Gardens on March 21, Stanhope IA library on March 20; Story County Master Gardeners in Ames on March 16; at the Webster City High School for an FFA class on April 20; and at the Rowan Community Center in Rowan on April 14. Total participants in these sessions were 120 (45 male, 75 female; 5 Hispanic/Latino; 113 white, 2 African American).

Minnesota

- Completed the 2014 report on the CenUSA Biochar Demonstration Garden results (Exhibit 4).
- Recruited eleven new volunteers for the 2015 CenUSA project sites.
- Contracted with grower to start demonstration garden seeds.
- Updated CenUSA Master Gardener applications and position descriptions and began to update the forms and garden procedures for volunteers.
- Began update on CenUSA garden designs.
- Exhibited CenUSA Biochar garden display at the Anoka County Extension Master Gardeners Home Landscaping and Garden Fair on April 11, 2015 where we reached over 200 gardeners.

**Explanation of Variance**

- **Iowa**
  - Zinnia seeds will be planted later due to crop timing.

- **Minnesota**
  - We have not yet received an explanation of the results of the soil compaction and moisture tests.

**Plans for Next Quarter**

- **Iowa**
  - Distribute transplants to CenUSA demonstration garden sites.
  - Complete demonstration garden plantings.
  - Mentor CenUSA Master Gardeners regarding plot maintenance and data collection.
  - Hold informational meeting for Fort Dodge area gardeners.

- **Minnesota**
  - Continue with the update of the remainder of forms and procedures for CenUSA Extension Master Gardener volunteers.
  - Purchase supplies for gardens.
  - Finalize update for garden design.
o Arrange for pick-up and delivery of plants to the CenUSA demonstration garden sites.

o Plant Twin Cities Metro demonstration gardens last week of May or first week of June (weather dependent).

o Plant the demonstration garden at Fond du Lac site early-mid June (weather dependent).

o Meleah Maynard will be contacted to write new blogpost for Master Gardener eXtension website.


✓ **Publications, Presentations, Proposals Submitted**


5. **Evaluation and Administration**

• **Planned Activities**

  ✓ Collect information from CenUSA Extension teams and prepare reports.

  ✓ Write Extension/Outreach section of CenUSA Year 5 reapplication.

  ✓ Collect information to submit with Year 5 reapplication.

  ✓ Continue support for development of CenUSA C6 Youth app, videos, and iBook materials.

  ✓ Schedule meetings and meet with each CenUSA Extension work team and each state team to plan and budget for Y5 activities.

  ✓ Prepare budgets and budget justifications.

  ✓ Negotiate new contract with The Ohio State University (due to transfer of two CenUSA Extension team members).

  ✓ Complete analyses of Extension program survey results. Write reports based on results.
✓ Prepare for and present sessions related to CenUSA at the National Extension Energy Summit, University of Washington.

• **Actual Accomplishments**

  ✓ Scheduled and held meetings with each CenUSA Extension work team and each Extension state team to determine Year 5 plan of work and budgets Wrote Extension section of Year 5 reapplication.

  ✓ Collected information from CenUSA Extension team members and wrote quarterly report.

  ✓ Collected information to accompany Year 5 application (names of people trained, etc.).

  ✓ Supported for development of CenUSA C6 Youth app, videos, and iBook.

  ✓ Wrote job descriptions and recruited candidates for CenUSA Extension internships.

  ✓ Negotiated work plan and budget with The Ohio State University.

  ✓ Represented Extension Task at CenUSA co-PI meetings.

  ✓ Completed analyses of Extension program survey results. Write reports based on results.

  ✓ Prepared survey instruments for use to evaluate CenUSA Extension programs.

  ✓ Prepared for and presented sessions related to CenUSA at the National Extension Energy Summit, University of Washington

• **Explanation of Variance**

  None

• **Plans for Next Quarter**

  ✓ Coordinate/participate in CenUSA Extension work team meetings.

  ✓ Collect information from CenUSA Extension teams and prepare reports.

  ✓ Develop survey instruments, conduct analysis of surveys completed by participants, and produce reports summarizing impact of CenUSA Extension efforts.

  ✓ Support C6 team to continue development of educational materials targeting K-12 youth.
✓ Mentor CenUSA interns.
✓ Attend CenUSA Annual meeting.

• Publications, Presentations, Proposals Submitted
  ✓ Brown, S., Biofuels Harvest Survey Results. 2014 Purdue University (Exhibit 5)
  ✓ Brown, S., CenUSA Extension Webinar evaluation instrument (Exhibit 6)

Objective 10. Commercialization

Objective 10A. Archer-Daniels-Midland & Objective 10B. Renmatix

1. Planned Activities

   Plans for this quarter included tests to convert furfural derived from hemicellulose streams into value-added furan compounds such as 2-methylfuran or tetrahydrofuran and pyrolysis tests with additional lignin streams, utilizing the proprietary pretreatment method.

   Additional plans for this quarter included analysis of nine biomass samples by Renmatix to determine chemical and physical characteristics prior to testing these samples in their supercritical hydrolysis process to produce sugars. Renmatix also was scheduled to send previously produced lignin co-product from supercritical hydrolysis of hardwood.

   Finally, ADM was scheduled to send additional streams from their Acetosolv process, which fractionates biomass into pulp, lignin, xylose, and phenolic streams, to ISU for further thermochemical conversion testing to recover high value products.

2. Actual Accomplishments

   A control run was completed on the continuous flow fluidized bed pyrolysis unit using untreated lignin co-product provided by Renmatix. Similar to other lignin-rich streams, when pyrolyzed without pretreatment, agglomeration occurs in the fluidized bed after less than one hour of operation.

///
As Tables 6 and 7 show, total pyrolysis and liquid organic yields were 33.7% and 18.8% respectively, on a weight basis of the lignin feed. Analysis of the liquid product showed that phenolic monomers, carboxylic acids, and levoglucosan were the primary organic products.

Nine biomass samples were provided to Renmatix for chemical and physical characterization. The biomass includes switchgrass varieties, mixed grasses, big bluestem, corn stover, and indiangrass. Initial analysis included quantification of carbohydrates, acetyls, uronic acids, lignin, extractives, ash and metals. Porosimetry of the samples was also determined. Conclusions of the characterization and comparisons to hardwood, which is Renmatix’s typical feedstock, are as follows:

- Xylan content was found to be between 19 and 22%. This range is similar to that found in hardwoods.
- Glucan content was found to be between 31 and 34%. This range is about 10 to 20% less than that for hardwoods.
- Acetyl groups have a concentration range between 2.3 and 2.5% in the analyzed biomass samples. Acetylcs in hardwoods are typically 3-5%.
- Ash content is between 4 and 7%, or about one order of magnitude higher than that in hardwood.
- In general all elemental metal levels were higher in the analyzed biomass sample that those in hardwoods, with the greatest differences being found in silicon and potassium.
Pyrolysis of ADM’s biomass fractions has shown that several flavor compounds are present in pyrolyzed samples of the lignin waste stream and that these are actually present in the unpyrolyzed waste stream. Based on the composition of these compounds present, ADM has estimated potential value of a ton of lignocellulosic biomass (Table 8).

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Pounds per ton of biomass</th>
<th>Price per pound ($)</th>
<th>Value per ton of biomass ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp</td>
<td>1000</td>
<td>0.25</td>
<td>250</td>
</tr>
<tr>
<td>Organic Insoluble lignin</td>
<td>114</td>
<td>0.25</td>
<td>28.5</td>
</tr>
<tr>
<td>Organic Soluble lignin</td>
<td>160</td>
<td>0.25</td>
<td>40</td>
</tr>
<tr>
<td>Xylose</td>
<td>100</td>
<td>0.30</td>
<td>30</td>
</tr>
<tr>
<td>Phenolics</td>
<td>6.4</td>
<td>100</td>
<td>640</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>988.5</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. **Explanation of Variance**

None noted.

4. **Plans for Next Quarter**

- Continuous flow pyrolysis tests with Renmatix lignin streams with previously developed pretreatment
- Recently developed proprietary lignin depolymerization and stabilization process will be tested on ADM and Renmatix lignin streams
- Conversion of perennial grasses using ADM and Renmatix biorefining processes will commence

**Objective 10C. USDA-ARS, Lincoln, Nebraska**

**Alternative Uses for Native Perennial Warm-season Grasses**

- **Livestock performance on native perennial warm-season grasses.**

  Burned and fertilized pastures and have prepared water and fencing for Year 4 grazing. Cattle will go on pastures near June 10, 2015.
I. Executive Summary

This report includes chemical and physical characterizations of 9 biomass samples provided by the USDA-ARS-PA office located in Lincoln, NE. This report is part of the Project Sustainable Production and Distribution of Bioenergy for the Central USA (Award # 2010-05073), Objective 10: Commercialization.

9 samples were received and a variety of analyses have been performed on them and the present report compiles results of:

- Chemical characterization: carbohydrates (xylose, glucose, mannose, arabinose, rhamnose, and galactose), acetyl groups, uronic acids, lignin (acid insoluble plus acid soluble lignin), extractives, and ash. Metal elements were also quantified.
- Physical characterization: porosimetry (mercury intrusion).

The main conclusions from this work are as follows:

Chemical characterization

- Xylan content was found to be between 19 and 22%. This range is similar to that found for hardwoods
- Glucan content was found to be between 31 to 34%. This range is about 10 to 20% less than that for hardwoods
- Acetyl groups have a concentration range between 2.3 to 2.5% in the analyzed biomasses. Acetylts in hardwoods are about 3 to 5%
- Ash content is about one order of magnitude higher than that in hardwood, between 4 and 7%
- Extractives in the analyzed biomasses are also high; especially water extractives (6.3 to 13.4%)
- Samples for all 9 biomasses were analyzed for elemental metal composition. In general all elements have a higher concentration than that found in woody biomass; specially silicon (4,000-7,000 ppm) and potassium (4,000-9,000 ppm)
Physical characterization:

- Pore size distribution was measured by mercury intrusion porosimetry technique.
  No major differences can be noticed among all biomasses. Total Pore Area varies between 17 (m²/g) (Corn stover) and 47 (m²/g) (Switchgrass Aug-14). Major differences were found for the parameter Median Pore Diameter (Volume) which varies between 15.2 μm (Bio-energy Bigbluestem) and 149 μm (Big Bluestem - Nov 13).

II. Methods and material

2.1. Biomass material

Approximately 1 kg of different biomasses were provided by USDA-ARS-PA office located in Lincoln, NE. Samples were received dry and ground to less than 2 mm screen. Table 1 shows the 9 different biomasses being characterized.

Table 1. Biomasses being characterized for CenUSA Project.

<table>
<thead>
<tr>
<th>No.</th>
<th>Biomass</th>
<th>Harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Month</td>
</tr>
<tr>
<td>1</td>
<td>Switchgrass</td>
<td>August</td>
</tr>
<tr>
<td>2</td>
<td>Switchgrass</td>
<td>November</td>
</tr>
<tr>
<td>3</td>
<td>Low diversity mix</td>
<td>August</td>
</tr>
<tr>
<td>4</td>
<td>Low diversity mix</td>
<td>November</td>
</tr>
<tr>
<td>5</td>
<td>Big blue stem</td>
<td>August</td>
</tr>
<tr>
<td>6</td>
<td>Big blue stem</td>
<td>November</td>
</tr>
<tr>
<td>7</td>
<td>Corn stover</td>
<td>October</td>
</tr>
<tr>
<td>8</td>
<td>Indiangrass</td>
<td>November</td>
</tr>
<tr>
<td>9</td>
<td>Bio-energy big blue stem</td>
<td>November</td>
</tr>
</tbody>
</table>

2.2. Methods

Extractives
determination was performed following an internal procedure that is patterned after the Technical Report NREL/TP-510-42619 (2008). About 10-20 g of sample was placed in a 100 mL extraction cell (ASE-350-Dionex). The sample was then subjected to a sequence of extractions with three different solvents in the following order: hexane, acetone, and water. The extraction conditions for all three solvents were 100°C and 30 min (3 x 10 min). Three different extracts were produced. Extractive determination for each solvent was calculated based on total extract weight and total solids content. Residual solid was oven dried at 50°C overnight.
Polysaccharides

Close to 100 mg of extractives-free biomass samples were milled to less than 40 mesh using a Wiley Mini-Mill (Thomas Scientific). The sample follows then a standard sequential double acid hydrolysis at 72% and 4% sulfuric acid (H$_2$SO$_4$) concentration for monosaccharide determination as described by Davis (1998). After autoclaving fucose was added to all samples as an internal standard before injecting sample into the HPAEC-PAD instrument (Dionex ICS-5000) for monosugar determination. Results were an average from two sample replicates.

Lignin

The acid insoluble lignin (AIL) or Klason lignin in the extractives-free biomass was determined according to Effland (1977), while the acid soluble lignin (ASL) concentration was determined according to Tappi Method 250.

Acetyl group

The total acetyl group content was determined from the acetic acid content in the hydrolysate produced after the second hydrolysis step during sample preparation for monosaccharide determination in biomasses. The acetic acid content was determined by high performance liquid chromatography (Agilent Technologies 1260 Infinity) using a refractive index detector and Rezex column (Rezex-Organic Acid H$^+$, Phenomenex). The determination was based on a calibration curve for acetic acid.

Uronic acids

The uronic anhydride content in the extractives-free biomass was determined using the chromophoric group analysis after a two-step acid hydrolysis treatment developed by Scott (1979). Dimethylphenol was used as standard, and the content of uronic anhydride was calculated from the difference in UV absorption at 400 and 450 nm.

Ash

Ash content was determined on the extractives-free biomass. A known amount was placed in a muffle furnace at 575ºC overnight. Ash content was calculated gravimetrically on residual mass.

Metal elements

A biomass sample was subjected to a wet digestion with nitric acid for complete dissolution. The solution was analyzed by inductively coupled plasma (ICP) method for metal analysis using SPECTRO ARCOS ICP-OES.
Proteins

Protein content was calculated based on nitrogen content and using a nitrogen to protein conversion factor (CF) according the following equation:

\[
\text{Protein content} = \text{N}(\% \times CF)
\]

where, \(\text{N}\): Nitrogen content in biomass as \% on dry matter

CF: 5.5 (Mossé, 1990).

III. Results

3.1. Chemical characterization of biomass

Biomass components

Full chemical composition was performed on samples shown in Table 1. Each biomass sample was received split in 30-35 individual plastic containers (100 mL). All containers were opened and the material was mixed thoroughly to ensure homogeneity. A subsample was obtained by coning and quartering according to ASTM C702/C702M−11 procedure for further full composition analysis. Sample preparation procedure is described schematically in Appendix A.

The compositional analysis was performed on extractives-free biomass. Table 2 includes results for compositional analysis. Standard deviation is also shown. The \(\text{Total}\) value in the table does not include protein content in order to avoid double counting since some protein may have been released into the water extract fraction. Protein content was determined on “as is” biomass (not extractives-free). Water soluble components may also include inorganic material, minor sugars, starch, and sucrose (Sluiter et al, 2013). These components in the water solution will be further quantified in following reports.

Xylan content was found to be between 19 and 22%. This range is similar to that found for hardwoods (Fengel and Wegener, 2003). However, glucan content (31 to 34%) seems to be about 10 to 20% less than that for hardwoods, with a range between 38 to 50%. Acetyl groups are also found with a lower content (2.3 to 2.5%) in the analyzed biomasses. Acetys in hardwoods are about 3 to 5%. Ash content, on the other hand, is about one order of magnitude higher between 4 and 7%. Ash content is found below 1% and over 0.1% in woody biomass. In principle, the combination of lower acetyl groups and higher ash content may result in the need to adjust the auto-hydrolysis process to higher severities for the efficient release of hemicellulose during this process. Extractives in the analyzed biomasses are also higher; especially water extractives (6.3 to 13.4%). This can be explained, at least partially, since woody biomass has lower amounts of proteins, inorganics, and water soluble sugars. Dissolved ash after water extraction was between 26 and 47% of original ash.
Table 2. Chemical composition of biomass samples. Values in % b.d.w. with standard deviation.

<table>
<thead>
<tr>
<th>Component</th>
<th>Big Blue Stem-Nov13</th>
<th>Big Blue Stem-Aug14</th>
<th>Low Diversity Mix-Nov13</th>
<th>Low Diversity Mix-Aug14</th>
<th>Switchgrass-Nov13</th>
<th>Switchgrass-Aug14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arabinan</td>
<td>2.02 ± 0.02</td>
<td>2.14 ± 0.01</td>
<td>2.07 ± 0.02</td>
<td>2.30 ± 0.01</td>
<td>1.97 ± 0.01</td>
<td>2.04 ± 0.01</td>
</tr>
<tr>
<td>Galactan</td>
<td>0.54 ± 0.01</td>
<td>0.60 ± 0.01</td>
<td>0.63 ± 0.04</td>
<td>0.57 ± 0.01</td>
<td>0.58 ± 0.00</td>
<td>0.64 ± 0.01</td>
</tr>
<tr>
<td>Mannan</td>
<td>0.12 ± 0.00</td>
<td>0.08 ± 0.01</td>
<td>0.13 ± 0.02</td>
<td>0.09 ± 0.01</td>
<td>0.23 ± 0.00</td>
<td>0.19 ± 0.01</td>
</tr>
<tr>
<td>Rhamnan</td>
<td>0.06 ± 0.00</td>
<td>0.05 ± 0.00</td>
<td>0.13 ± 0.04</td>
<td>0.04 ± 0.00</td>
<td>0.14 ± 0.00</td>
<td>0.19 ± 0.00</td>
</tr>
<tr>
<td>Xylan</td>
<td>20.55 ± 0.16</td>
<td>18.88 ± 0.01</td>
<td>22.07 ± 0.08</td>
<td>19.74 ± 0.01</td>
<td>21.50 ± 0.01</td>
<td>20.52 ± 0.01</td>
</tr>
<tr>
<td>Glucan</td>
<td>33.96 ± 0.26</td>
<td>30.97 ± 0.07</td>
<td>33.34 ± 0.10</td>
<td>31.85 ± 0.30</td>
<td>33.00 ± 0.09</td>
<td>31.09 ± 0.30</td>
</tr>
<tr>
<td>Acetyls</td>
<td>2.31 ± 0.14</td>
<td>2.39 ± 0.02</td>
<td>2.42 ± 0.01</td>
<td>2.54 ± 0.03</td>
<td>2.43 ± 0.11</td>
<td>2.38 ± 0.01</td>
</tr>
<tr>
<td>Uronic acid</td>
<td>0.95 ± 0.06</td>
<td>0.92 ± 0.05</td>
<td>0.91 ± 0.01</td>
<td>1.20 ± 0.02</td>
<td>0.80 ± 0.01</td>
<td>0.58 ± 0.02</td>
</tr>
<tr>
<td>ASL</td>
<td>1.57 ± 0.06</td>
<td>1.57 ± 0.01</td>
<td>1.76 ± 0.02</td>
<td>1.70 ± 0.01</td>
<td>1.86 ± 0.03</td>
<td>1.88 ± 0.01</td>
</tr>
<tr>
<td>AIL</td>
<td>19.19 ± 0.83</td>
<td>17.96 ± 0.15</td>
<td>20.74 ± 0.45</td>
<td>18.11 ± 0.10</td>
<td>21.07 ± 0.27</td>
<td>17.26 ± 0.10</td>
</tr>
<tr>
<td>Total lignin</td>
<td>20.75</td>
<td>19.53</td>
<td>22.50</td>
<td>19.82</td>
<td>22.93</td>
<td>19.14</td>
</tr>
<tr>
<td>Ash</td>
<td>3.59 ± 0.04</td>
<td>3.69 ± 0.02</td>
<td>2.95 ± 0.01</td>
<td>4.68 ± 0.07</td>
<td>2.94 ± 0.02</td>
<td>2.66 ± 0.067</td>
</tr>
<tr>
<td>Hexane Exts.</td>
<td>0.56</td>
<td>1.70</td>
<td>0.89</td>
<td>1.30</td>
<td>0.92</td>
<td>1.09</td>
</tr>
<tr>
<td>Acetone Exts.</td>
<td>0.75</td>
<td>1.42</td>
<td>1.15</td>
<td>1.08</td>
<td>0.94</td>
<td>2.76</td>
</tr>
<tr>
<td>Water Exts.</td>
<td>7.56</td>
<td>13.43</td>
<td>6.45</td>
<td>11.23</td>
<td>6.57</td>
<td>12.17</td>
</tr>
<tr>
<td>Total</td>
<td>93.7</td>
<td>95.8</td>
<td>95.6</td>
<td>96.4</td>
<td>94.9</td>
<td>95.4</td>
</tr>
<tr>
<td>Proteins*</td>
<td>1.60</td>
<td>2.64</td>
<td>1.43</td>
<td>3.47</td>
<td>2.42</td>
<td>3.08</td>
</tr>
<tr>
<td>Ash*</td>
<td>5.20</td>
<td>6.30</td>
<td>4.00</td>
<td>6.78</td>
<td>4.47</td>
<td>4.98</td>
</tr>
</tbody>
</table>

Notes:  
ASL – Acid soluble lignin  
AIL – Acid insoluble lignin  
Total lignin = ASL + AIL  
**Ash content on original sample (non extractives-free).
Table 2. Chemical composition of biomass samples. Values in % b.d.w. with standard deviation (cont.).

<table>
<thead>
<tr>
<th>Component</th>
<th>BioEnergy Big Blue Stem-Nov14</th>
<th>Corn Stover - Oct14</th>
<th>Indiangrass-Nov14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arabinan</td>
<td>2.16 ± 0.04</td>
<td>2.04 ± 0.01</td>
<td>2.04 ± 0.00</td>
</tr>
<tr>
<td>Galactan</td>
<td>0.66 ± 0.01</td>
<td>0.82 ± 0.01</td>
<td>0.57 ± 0.01</td>
</tr>
<tr>
<td>Mannan</td>
<td>0.42 ± 0.01</td>
<td>0.38 ± 0.00</td>
<td>0.40 ± 0.00</td>
</tr>
<tr>
<td>Rhamnan</td>
<td>0.23 ± 0.01</td>
<td>0.38 ± 0.00</td>
<td>0.24 ± 0.00</td>
</tr>
<tr>
<td>Xylan</td>
<td>21.97 ± 0.18</td>
<td>20.67 ± 0.21</td>
<td>20.04 ± 0.00</td>
</tr>
<tr>
<td>Glucan</td>
<td>34.74 ± 0.41</td>
<td>36.60 ± 0.17</td>
<td>34.69 ± 0.11</td>
</tr>
<tr>
<td>Acetyls</td>
<td>2.52 ± 0.01</td>
<td>2.35 ± 0.08</td>
<td>2.49 ± 0.03</td>
</tr>
<tr>
<td>Uronic acid</td>
<td>0.63 ± 0.04</td>
<td>1.21 ± 0.01</td>
<td>0.95 ± 0.01</td>
</tr>
<tr>
<td>ASL</td>
<td>1.78 ± 0.03</td>
<td>2.31 ± 0.04</td>
<td>1.77 ± 0.00</td>
</tr>
<tr>
<td>AIL</td>
<td>19.91 ± 0.48</td>
<td>19.31 ± 0.14</td>
<td>18.30 ± 0.21</td>
</tr>
<tr>
<td>Total lignin</td>
<td>21.69</td>
<td>21.62 ± 0.04</td>
<td>20.07 ± 0.00</td>
</tr>
<tr>
<td>Ash</td>
<td>2.97 ± 0.01</td>
<td>3.69 ± 0.08</td>
<td>4.47 ± 0.02</td>
</tr>
<tr>
<td>Hexane Exts.</td>
<td>1.34</td>
<td>0.82</td>
<td>1.73</td>
</tr>
<tr>
<td>Acetone Exts.</td>
<td>0.79</td>
<td>0.76</td>
<td>0.78</td>
</tr>
<tr>
<td>Water Exts.</td>
<td>7.22</td>
<td>6.30</td>
<td>7.75</td>
</tr>
<tr>
<td>Total</td>
<td>97.3</td>
<td>97.6</td>
<td>96.2</td>
</tr>
<tr>
<td>Proteins*</td>
<td>2.50</td>
<td>4.18</td>
<td>2.56</td>
</tr>
<tr>
<td>Ash*</td>
<td>4.43</td>
<td>5.13</td>
<td>6.05</td>
</tr>
</tbody>
</table>

Notes:  
ASL – Acid soluble lignin  
AIL – Acid insoluble lignin  
Total lignin = ASL + AIL  
**Ash content on original sample (non-extractives-free).
A difference on chemical composition can be observed for species Big Bluestem, Low Diversity Mix, and Switchgrass (Table 2) for the two different harvesting seasons. Samples from late harvesting season (Nov 13) have higher sugar content than that for the early season (Aug 14); 2-3% higher glucan and 1-2% higher xylan. Lignin content was also 1-2% higher for late harvested material. On the other hand, extractives on samples from the late season decrease by almost half the amount found on those from the early season. The only exception was for acetone extractives in Low Diversity Mix, showing a slightly higher value for the late season sample. Also, switchgrass shows similar values for both seasons. Because the history of the samples provided is unknown it’s difficult to give a good explanation for the differences observed. Some explanations could be that samples come from a different ground plot (different soil quality), or maybe growing conditions, fertilization procedures, etc. were different for each pair of samples. However, harvesting season effect on biomass composition has been reported elsewhere (Lee D. et al, 2007).

*Elemental composition for biomasses*

Samples for all 9 biomasses were analyzed for elemental metal composition. The analysis was performed through an Inductively Coupled Plasma (ICP) procedure. Results for biomass samples are shown in Table 4. Table 3 shows differences for the 7 major metal components among samples with lowest and highest values found. In general all elements have a higher concentration than that found in woody biomass; specially silicon and potassium. Silicon in wood is found to have an upper-limit of 100-10 ppm while potassium has a concentration lower than 1,500 ppm (Fengel and Wegener 2003). Water soluble inorganic elements in biomass are associated to potassium, sodium, calcium, magnesium, sulfur, phosphorus, and chlorine compounds. These elements are usually found as nitrates, chlorides, phosphates, sulphate, and chloride ions (Na/KNO₃, Na/KCl, Ca/Mg(NO₃)₂, Ca/MgCl₂, CaMg₃(PO₄)₂, SO₄, PO₄) (Livingston, 2006).

<table>
<thead>
<tr>
<th>Element</th>
<th>Lowest value, ppm (species)</th>
<th>Highest value, ppm (species)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium (K)</td>
<td>3,919 (Low Div Mix-Nov13)</td>
<td>9,261 (BlueStem-Aug14)</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>4,045 (Low Div Mix-Nov13)</td>
<td>7,147 (Indiangrass-Nov14)</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>1,568 (Low Div Mix-Nov13)</td>
<td>2,851 (Indiangrass-Nov14)</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>690 (BioEnergy-Big BlueStem-Nov14)</td>
<td>1,167 (Switchgrass-Aug14)</td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>305 (Low Div Mix-Nov13)</td>
<td>1,022 (Low Div Mix-Aug14)</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>137 (Low Div Mix-Nov13)</td>
<td>837 (BioEnergy-BigBlueStem-Nov14)</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>312 (Indiangrass-Nov14)</td>
<td>593 (Switchgrass-Aug14)</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Al</td>
<td>71.9</td>
<td>36.6</td>
</tr>
<tr>
<td>As</td>
<td>&lt; 0.4</td>
<td>&lt; 0.4</td>
</tr>
<tr>
<td>Ba</td>
<td>30.4</td>
<td>26.9</td>
</tr>
<tr>
<td>Be</td>
<td>&lt; 0.006</td>
<td>&lt; 0.006</td>
</tr>
<tr>
<td>Ca</td>
<td>1989.3</td>
<td>1567.7</td>
</tr>
<tr>
<td>Cd</td>
<td>&lt; 0.006</td>
<td>0.0</td>
</tr>
<tr>
<td>Cl</td>
<td>837.0</td>
<td>259.0</td>
</tr>
<tr>
<td>Co</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Cu</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Fe</td>
<td>25.5</td>
<td>49.0</td>
</tr>
<tr>
<td>K</td>
<td>9260.8</td>
<td>4771.5</td>
</tr>
<tr>
<td>Li</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Mg</td>
<td>1050.2</td>
<td>792.4</td>
</tr>
<tr>
<td>Mn</td>
<td>81.2</td>
<td>61.5</td>
</tr>
<tr>
<td>Mo</td>
<td>&lt; 0.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Na</td>
<td>317.0</td>
<td>302.1</td>
</tr>
<tr>
<td>Ni</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>P</td>
<td>922.6</td>
<td>357.3</td>
</tr>
<tr>
<td>Pb</td>
<td>&lt; 0.7</td>
<td>&lt; 0.7</td>
</tr>
<tr>
<td>S</td>
<td>475.1</td>
<td>338.7</td>
</tr>
<tr>
<td>Se</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Si</td>
<td>5292.8</td>
<td>5240.4</td>
</tr>
<tr>
<td>Sr</td>
<td>12.0</td>
<td>9.8</td>
</tr>
<tr>
<td>Tl</td>
<td>&lt; 0.5</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Zn</td>
<td>15.5</td>
<td>10.7</td>
</tr>
</tbody>
</table>

| Total   | 20,439.1       | 13,832.0       | 32%     | 19,280.6        | 11,930.8        | 32%     | 15,403.7          | 13,027.4         | 15%     | 16,736.4                    | 17,655.7         | 18,572.9        |

Notes: Red – Highest ICP element concentration.
Δ – Difference between early and late harvesting season

Negative difference meaning concentration on early season is lower than that for late season
Differences between element’s concentrations were also observed for Big Bluestem, Low Diversity Mix, and Switchgrass (Table 4) between the two different harvesting seasons. In general, samples from late harvesting season (Nov 13) present lower concentrations than those for the early season (Aug 14). This trend is not as strong for switchgrass with only 15% lower concentration in the late harvesting season for the total concentration of elements. Big bluesteam and Low diversity mix show larger differences between the two seasons, with 32% and 38% respectively. The elements with the larger differences are chlorine and phosphorus. However, chlorine in switchgrass shows a slightly increase in concentration between the early and late harvesting seasons.

IV. Physical characterization of wood chips

4.1. Mercury intrusion porosimetry results

Pore size distribution was measured by mercury intrusion porosimetry (AutoPore IV 9500). The analysis was conducted by Micromeritics labs (Norcross, GA). Before sending samples to Micromeritics samples were dried at 60°C overnight in a convection oven. After drying, samples were size reduced using a knife mill (screen < 2.0 mm). A few grams of sample were sent for analysis.

Mercury intrusion porosimetry involves placing the sample in a special sample cup (penetrometer), then surrounding the sample with mercury. Mercury is a non-wetting liquid to most materials and resists entering voids, doing so only when pressure is applied. The pressure at which mercury enters a pore is inversely proportional to the size of the opening to the void. As mercury is forced to enter pores within the sample material, it is depleted from a capillary stem reservoir connected to the sample cup. The incremental volume depleted after each pressure change is determined by measuring the change in capacitance of the stem. This intrusion volume is recorded with the corresponding pressure or pore size.

Porosimetry properties are an important characteristic for understanding the kinetics of sugar release from cell walls to internal pore volume. In turn, the pore size is one of the factors that can help to understand differences on the release rate of hemicellulose molecules diffusing out of biomass particles.
Table 5 shows the porosity test results for biomass samples. No major differences can be noticed among all biomasses. In general, values are on the same order of magnitude for all parameters. Total Pore Area varies between 17 (m²/g) (Corn stover) and 47 (m²/g) (Switchgrass Aug-14). Median Pore Diameter (Volume) varies between 15.2 μm (Bio-energy Bigbluestem) and 149 μm (Big Bluestem -Nov 13).

Table 5. Porosity test results for biomass samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bioenergy-BigBlueStem-Nov14</th>
<th>BlueStem-Aug14</th>
<th>Blue Stem-Nov13</th>
<th>LowDivMix-Aug14</th>
<th>LowDivMix-Nov13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Intrusion Volume</td>
<td>1.73 mL/g</td>
<td>2.15 mL/g</td>
<td>2.35 mL/g</td>
<td>2.18 mL/g</td>
<td>1.49 mL/g</td>
</tr>
<tr>
<td>Total Pore Area</td>
<td>40.3 m²/g</td>
<td>41.2 m²/g</td>
<td>35.9 m²/g</td>
<td>46.9 m²/g</td>
<td>36.2 m²/g</td>
</tr>
<tr>
<td>Median Pore Diameter (Volume)</td>
<td>15.2 μm</td>
<td>123.5 μm</td>
<td>148.7 μm</td>
<td>139.1 μm</td>
<td>84.3 μm</td>
</tr>
<tr>
<td>Median Pore Diameter (Area)</td>
<td>0.0094 μm</td>
<td>0.0067 μm</td>
<td>0.0068 μm</td>
<td>0.0070 μm</td>
<td>0.0069 μm</td>
</tr>
<tr>
<td>Average Pore Diameter (4V/A)</td>
<td>0.17 μm</td>
<td>0.21 μm</td>
<td>0.26 μm</td>
<td>0.19 μm</td>
<td>0.16 μm</td>
</tr>
<tr>
<td>Bulk Density at 0.52 psia</td>
<td>0.39 g/mL</td>
<td>0.29 g/mL</td>
<td>0.32 g/mL</td>
<td>0.32 g/mL</td>
<td>0.45 g/mL</td>
</tr>
<tr>
<td>Apparent (skeletal) Density</td>
<td>1.25 g/mL</td>
<td>0.78 g/mL</td>
<td>1.34 g/mL</td>
<td>1.08 g/mL</td>
<td>1.36 g/mL</td>
</tr>
<tr>
<td>Porosity</td>
<td>68.3%</td>
<td>62.7%</td>
<td>75.9%</td>
<td>70.2%</td>
<td>66.9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Intrusion Volume</td>
<td>1.63 mL/g</td>
<td>1.48 mL/g</td>
<td>1.76 mL/g</td>
<td>2.98 mL/g</td>
</tr>
<tr>
<td>Total Pore Area</td>
<td>47.1 m²/g</td>
<td>36.9 m²/g</td>
<td>21.0 m²/g</td>
<td>17.0 m²/g</td>
</tr>
<tr>
<td>Median Pore Diameter (Volume)</td>
<td>103.7 μm</td>
<td>107.9 μm</td>
<td>106.0 μm</td>
<td>70.7 μm</td>
</tr>
<tr>
<td>Median Pore Diameter (Area)</td>
<td>0.0065 μm</td>
<td>0.0061 μm</td>
<td>0.013 μm</td>
<td>0.012 μm</td>
</tr>
<tr>
<td>Average Pore Diameter (4V/A)</td>
<td>0.14 μm</td>
<td>0.16 μm</td>
<td>0.34 μm</td>
<td>0.70 μm</td>
</tr>
<tr>
<td>Bulk Density at 0.52 psia</td>
<td>0.41 g/mL</td>
<td>0.48 g/mL</td>
<td>0.40 g/mL</td>
<td>0.27 g/mL</td>
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<tr>
<td>Apparent (skeletal) Density</td>
<td>1.22 g/mL</td>
<td>1.62 g/mL</td>
<td>1.41 g/mL</td>
<td>1.32 g/mL</td>
</tr>
<tr>
<td>Porosity</td>
<td>66.5%</td>
<td>70.5%</td>
<td>71.4%</td>
<td>79.7%</td>
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</table>

V. Conclusions

Chemical characterization

- Xylan content was found to be between 19 and 22%. This range is similar to that found for hardwoods
- Glucan content was found to be between 31 to 34%. This range is about 10 to 20% less than that for hardwoods
- Acetyl groups have a concentration range between 2.3 to 2.5% in the analyzed biomasses. Acetyl in hardwoods are about 3 to 5%
- Ash content is about one order of magnitude higher than that in hardwood, between 4 and 7%
Extractives in the analyzed biomasses are also high; especially water extractives (6.3 to 13.4%).

Samples for all 9 biomasses were analyzed for elemental metal composition. In general all elements have a higher concentration than that found in woody biomass; specially silicon (4,000-7,000 ppm) and potassium (4,000-9,000 ppm).

Physical characterization:

- Pore size distribution was measured by mercury intrusion porosimetry technique. No major differences can be noticed among all biomasses. Total Pore Area varies between 17 (m²/g) (Corn stover) and 47 (m²/g) (Switchgrass August 14). Major differences were found for the parameter Median Pore Diameter (Volume) which varies between 15.2 μm (Bio-energy Bigbluestem) and 149 μm (Big Bluestem - November 13).

VI. References


V. Revisions history

<table>
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<tr>
<th>Date</th>
<th>Revision Change</th>
<th>Revised by</th>
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<tr>
<td>04/16/2015</td>
<td>Initial Issue</td>
<td>FL</td>
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</tbody>
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Appendix

A. Sample preparation for chemical analysis

1. Mixing, coning and quartering (ASTM C702M-11)
2. Extractives determination: Hexane, Acetone, and Water. 100°C and 3 x 10 min in ASE150-Dionex.
3. Sample milled < 40 mesh (Wiley mini-mill) and mixed
4. 0.3 g of solid sample is drawn for full composition analysis
5. Carbohydrates by HPAEC-PAD
   - Acetic acid by HPLC-UV
   - Klason lignin by gravimetric
   - Acid soluble lignin by UV
   - Uronic acids by UV
   - Ash content by gravimetric
Opinion
It's time to rethink the ‘gas’ in our tank
By BRIAN MELLAGE

THE era of cheap oil has come and gone. Finite fossil fuel resources have spawned wars, deaths and environmental disasters, and this trend will continue and will even escalate as these dwindling resources become more controlled by fewer and fewer people.

While there has been a recent upturn of new ways to mine stored solar energy through fracking oil and gas, the fossil fuels lying beneath our feet are still a very finite resource. We, as a nation, and the world population as a whole, should not try to see how close to the end of oil supplies we can get.

As a stepping stone, we need a sustainable liquid transportation fuel to power our internal combustion engines as we get ready for the next big evolution in car engine technology. Biofuels can be one of those stepping stones. In Nebraska and the Midwest, in general, we are well situated to benefit from biofuels.

The first attempt at this was starch-based ethanol derived from corn. Ethanol is currently used mainly as an additive to gas, but it does not have the same equivalent of energy per unit as gasoline. Corn derived, starch-based ethanol was a good first step, but it will never become a drop-in fuel replacement for gasoline.

Another idea, using the cellulosic portions of biomass to produce ethanol, has yet to be proven as a viable, economical commercial business strategy. USDA is one of the entities working on biofuels and investing heavily into making biofuels a reality. USDA's National Institute of Food and Agriculture issued grants to several projects around the U.S. to look into making biofuels part of our transportation fuel future.

CenUSA Bioenergy was the recipient of one of the Agriculture Food Research Initiative Competitive grants, at the $25 million level. The CenUSA project will run from 2011 through 2016. CenUSA is made up of Iowa State University (lead), the University of Nebraska-Lincoln, Purdue University, the University of Wisconsin, University of Minnesota, University of Illinois, University of Vermont and the USDA Agriculture Research Service (ARS), all working to develop a holistic approach in taking biofuels to the marketplace.

CenUSA is investigating the creation of a Midwestern sustainable biofuels system using perennial grasses. The system will improve agricultural sustainability, as the perennial grasses reduce runoff of nutrients and soil from corn and soybean production, and increase carbon sequestration.
CenUSA’s project emphasis is an agroecosystem approach to sustainable biofuels production via the pyrolysis-biochar process with native grasses being used as a feedstock for biofuels production. This research is paving the way to make the biofuels marketplace-ready. One-third of total funding is required to be spent in Extension, outreach and education activities.

UNL and ARS scientists at UNL are in charge of plant genetic research in growing the feedstock varieties. Recently, the ARS team at UNL released its latest development, a new switchgrass cultivar named Liberty. Liberty switchgrass was introduced to local producers in field days across southeast Nebraska. Rob Mitchell of the ARS says that Liberty is the first switchgrass variety developed specifically for bioenergy use in the Great Plains and the Midwest, and it will help make switchgrass a much more feasible option for bioenergy use.

Pyrolysis is the thermochemical decomposition of organic matter at high temperatures in the absence of oxygen. There are several downstream products that can be derived from taking native grass biomass through this process. Bio-oil is one. It has the potential to be refined into a drop-in fuel that could go directly into your gas tank. Another product is biochar, which can be used as a soil amendment.

CenUSA is examining these steps:

- the genetics of new varieties of grass
- growing of the biomass
- logistics of harvesting, hauling, preprocessing and handling the enormous amounts of biomass
- building the brick-and-mortar energy plants that would house the pyrolysis processing facility
- exploring the feasibility of on-site pyrolysis using a mobile pyrolyzer
- laboratory work to produce the science of pyrolysis and the streams of inputs and outputs at the energy factory
- education and outreach to producers and their bankers that this is a real scenario of potentially profitable farming
- training the bioenergy workforce of tomorrow through undergraduate internships and graduate student support
- collaboration of corporate America so the product could be produced and delivered to your local gas station

Producing liquid transportation fuels in this manner would eliminate issues like the blend wall and the volatile Renewable Fuel Standard that corn-based ethanol contends with.

The plan is to take all the research and help get the technologies to the companies that will move on to the next level.

Using native grasses grown in the Midwest and putting them through the pyrolysis process to produce a drop-in biofuel will bring an income stream to producers by selling
a renewable product and engaging in sustainable farming.

Rethinking our gas tank will eventually take us to a new type of fuel altogether, but for now it can help us see through to a new type of liquid transportation fuel we can use today so we can be ready for the next step in gas tank development. It will be an economic and environmental win-win for Nebraska and the Midwest.

For more information about CenUSA, go to cenusa.iastate.edu. Mellage of Auburn has been a self-employed businessman for more than 35 years. He is on the advisory board for CenUSA. He can be reached at 402-274-8367 or via email at bryan.mellage@gmail.com.
## Tuesday - July 28

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>7:00 – 11:30am</td>
<td><strong>Undergraduate/Graduate Student Tours</strong> <em>(See p. 2)</em></td>
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</tr>
<tr>
<td>9:00 – 11:00</td>
<td><strong>Optional Tour – US Dairy Forage Research Center Field Station</strong></td>
<td><em>Prairie du Sac</em></td>
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<tr>
<td>11:30</td>
<td><strong>Registration</strong></td>
<td><em>AT&amp;T Lounge, Pyle Center</em></td>
</tr>
<tr>
<td>12:00</td>
<td><strong>Lunch &amp; Keynote Address</strong></td>
<td><em>AT&amp;T Lounge</em></td>
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<tr>
<td></td>
<td><em>Future of Biofuels: Role of USDA-NIFA in Making it Happen</em></td>
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<tr>
<td></td>
<td><em>Bill Goldner, USDA-NIFA Institute of Bioenergy, Climate, and Environment</em></td>
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<tr>
<td>1:00 – 5:00pm</td>
<td><strong>General Session</strong></td>
<td><em>Room 325/326, Pyle Center</em></td>
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<tr>
<td>1:00 – 1:45</td>
<td><strong>Obj. 1: Feedstock Development</strong></td>
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<tr>
<td></td>
<td>• Mike Casler (ARS/Madison) &amp; Rob Mitchell (ARS/Lincoln)</td>
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<td>1:45 – 2:30</td>
<td><strong>Obj. 2: Sustainable Feedstock Production</strong></td>
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<td></td>
<td>• Jeff Volenec (Purdue), David Laird (ISU) &amp; Rob Mitchell (ARS/Lincoln)</td>
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<tr>
<td>2:30 – 2:45</td>
<td><strong>Break</strong></td>
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<td>2:45 – 3:30</td>
<td><strong>Obj. 3: Feedstock Logistics</strong></td>
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<td></td>
<td>• Kevin Shinners (UW-Madison) &amp; Stuart Birrell (ISU)</td>
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<td>3:30 – 4:15</td>
<td><strong>Obj. 4: System Performance</strong></td>
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<td></td>
<td>• Cathy Kling (ISU) &amp; Jason Hill (U-Minn.)</td>
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<tr>
<td>4:15 – 5:00</td>
<td><strong>Obj. 6: Markets &amp; Distribution</strong></td>
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<td></td>
<td>• Keri Jacobs (ISU) &amp; Dermot Hayes (ISU)</td>
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<tr>
<td>5:45pm</td>
<td><strong>Poster Session &amp; Dinner Reception</strong></td>
<td><em>AT&amp;T Lounge, Pyle Center</em></td>
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## Wednesday – July 29

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<thead>
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<tr>
<td>7:00am</td>
<td><strong>Breakfast</strong></td>
<td><em>AT&amp;T Lounge, Pyle Center</em></td>
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<tr>
<td>8:15-12:00</td>
<td><strong>General Session</strong></td>
<td><em>Room 325/326, Pyle Center</em></td>
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# 2015 CenUSA Bioenergy Annual Meeting

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<th>Time</th>
<th>Objective</th>
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<tbody>
<tr>
<td>8:15 – 9:00</td>
<td><strong>Obj. 7: Health &amp; Safety</strong></td>
<td>• Chuck Schwab (ISU) &amp; Mark Hanna (ISU)</td>
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<tr>
<td>9:00 – 9:45</td>
<td><strong>Obj. 8: Education</strong></td>
<td>• Raj Raman (ISU) &amp; Patrick Murphy (ISU)</td>
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<td>9:45 – 10:15</td>
<td>Break</td>
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<tr>
<td>10:15 – 11:00</td>
<td><strong>Obj. 5: Feedstock Conversion/Refining</strong></td>
<td>• Robert Brown (ISU)</td>
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<tr>
<td>11:00 – 11:30</td>
<td>Ken Vogel, USDA-ARS Ret.</td>
<td>• The Development of Switchgrass as a Forage &amp; Bioenergy Crop</td>
</tr>
<tr>
<td>11:30pm</td>
<td>Lunch</td>
<td>AT&amp;T Lounge</td>
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<td>Extension &amp; Outreach Personnel Breakout Session &amp; Lunch</td>
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<tr>
<td>1:00 – 4:45</td>
<td><strong>General Session Objectives 9-10</strong></td>
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<tr>
<td>1:00 – 1:45</td>
<td><strong>Obj. 9: Outreach &amp; Extension</strong></td>
<td>• Jill Euken (ISU) &amp; Sorrel Brown (ISU)</td>
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<tr>
<td>1:45 – 2:30</td>
<td><strong>Obj. 10: Commercialization</strong></td>
<td>• Tom Binder (ADM) &amp; Frank Lipiecki (Renmatix)</td>
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<td>2:30 – 3:00</td>
<td><strong>Commercialization: Local Options</strong></td>
<td>• Rob Mitchell (ARS-Lincoln)</td>
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<td>3:00 – 3:15</td>
<td>Break</td>
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<tr>
<td>3:15 – 4:45</td>
<td><strong>Advisory Board and NIFA Closing Observations</strong></td>
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<td>4:45</td>
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**Tuesday – July 28: Undergraduate/Graduate Tours**

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<th>Time</th>
<th>Activity</th>
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<tr>
<td>7:00am</td>
<td>Depart Lowell Center (Brown Bag Breakfast)</td>
<td>Lowell Center</td>
</tr>
<tr>
<td>7:45</td>
<td>Tour Great Lakes Bioenergy Research Center Research Plots</td>
<td>GLBRC</td>
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<tr>
<td>9:15</td>
<td>Depart for Wisconsin Energy Institute (WEI)</td>
<td>WEI</td>
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<tr>
<td>10:00</td>
<td>Coffee &amp; Tea Break</td>
<td>WEI</td>
</tr>
<tr>
<td>Time</td>
<td>Event</td>
<td>Location</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------------</td>
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<tr>
<td>10:15</td>
<td>Tour WEI Facilities</td>
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<tr>
<td>10:45</td>
<td>Classroom presentations - Brian Fox and Trey Sato</td>
<td>WEI Rm. 1115</td>
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<tr>
<td>11:45</td>
<td>Transport to Pyle Center to join CenUSA meeting</td>
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Extension Master Gardener Biochar Demonstration Gardens
2014 Annual Report
By Lynne Hagen and Julie Weisenhorn, University of Minnesota Extension

“Is biochar a good soil amendment for home gardens?
To answer this question, University of Minnesota Extension Master Gardeners and Iowa State Master Gardeners are testing the productivity of vegetable and flower gardens amended with biochar at four Minnesota sites and three sites in Iowa from 2012-2015.

Extension Master Gardener volunteers have been participating on the Extension and Outreach objective of a 5-year national multi-state/university research project funded by the USDA National Institute for Food and Agriculture which is part of an initiative by the United States to lessen our dependence on foreign oil, to reduce greenhouse gas emission and increase local renewable energy. Information about the project can be found at http://www.cenusa.iastate.edu/.

Demonstration gardens are planted each year with typical garden plants such as tomatoes, peppers and zinnias in beds that were applied with biochar prior to the first planting in year-one on the project. No further biochar was, or will, be added during the duration of this project. These gardens are planted and maintained each season by Extension Master Gardeners and youth volunteers. Growth and yield measurements are taken on plants at designated times of the season and compared across the sites to help determine any positive or negative effects of biochar on the garden plots.

This report reflects the results from year three of the four-year study by Extension Master Gardener volunteers in Minnesota.

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

...and justice for all
The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or family status. (Not all prohibited bases apply to all programs.) Many materials can be made available in alternative formats for ADA clients. To file a complaint of discrimination, write USDA, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call 202-720-5964.
SITE ESTABLISHMENT

Originally, three sites in Minnesota and three sites in Iowa were established. In 2013, an additional site was established at the Brookston Community Center on the Fond du Lac Band of Lake Superior Chippewa Reservation located in Northeastern Minnesota adjacent to the city of Cloquet. Due to the discovery of a concrete slab under the first garden site at the Brookston Community Center, a new site was re-established in 2014.

Each site was designed to have the same varieties and numbers of plants in each location in order to draw a comparison across crops on collection dates. Each of the demonstration gardens cover 1000 ft\(^2\) and are divided into three plots of 300 ft\(^2\).

Each site has a control (CTRL) plot with no biochar added, a Treatment 1 (TRT1) plot amended with 150 pounds (1/2 lb per ft\(^2\)), of granulated biochar and a Treatment 2 plot (TRT2) amended with 300 pounds (1 lb per ft\(^2\)) of biochar. The biochar for this project was donated by the Royal Oak Enterprises, LLC. The biochar was delivered in 50 pound bags. The bags were spread evenly over the specified plots and rototilled into the soil. Protective eyewear, gloves and dust masks were worn by the applicators. The biochar was only added at establishment of the demonstration gardens in 2012 and in 2013 at the fourth Minnesota site. No additional biochar will be added during this study.

The soil structure in each site is uniquely different and it is anticipated that the results in each location will be quite different. Soil tests are conducted at the sites each spring and the gardens are amended with fertilizer one time per season based on the recommendations of the soil tests. No additional compost or other amendments are added.

Rototilling was done in the first season only when the biochar was added. By not rototilling in subsequent years, it has been more observable to determine soil compaction and ease of planting in plots with biochar compared to the control plots. It has been noted that the plots with biochar have less compaction and are easier to plant in than the control plots even if the soil is wet.

THE SITES

University of Minnesota Landscape Arboretum (ARB), 3675 Arboretum Drive, Chaska, MN 55318

The Minnesota Landscape Arboretum was selected for this study because of its reputation as a world-class arboretum that is visited by over a quarter million people per year. With that amount of visibility, it is a great location to showcase this research project. The biochar demonstration garden was established on the Three-Mile Drive next to the Dahlia Trial Gardens.

This site was amended from a previously mowed turf area. The soil at this location at the Arboretum is silt loam. The soil test analysis showed a recommendation for a nitrogen-only fertilizer with a ratio of 32-0-0.

Watering at this site is done manually with a hose and sprinkler and becomes labor intensive over the course of the season during dryer weather. An automatic timer is not an option.
University of Minnesota - St. Paul Campus (SPC),
Folwell and Gortner Avenues, St. Paul, MN 55108

The demonstration garden at the St. Paul Campus is in close proximity to the Department of Horticultural Science Display and Trial Gardens which is a popular public garden for University students, staff, faculty and the general public.

The demonstration garden site was a former low-mow turf trial plot. The soil at this site is silt loam. The area where the garden is located is irrigated regularly. The soil test in this garden recommended a nitrogen only fertilizer of 32-0-0, the same as the Arboretum site.

Bunker Hills Park (AND), Bunker Hills Activities Center,
550 Bunker Lake Blvd NW, Andover, MN 55304

The demonstration garden at Bunker Hills Park in Andover is located adjacent to a public hiking/biking trail. The park is located in the Northern metro area of the Twin Cities and is visited by thousands of people each year. This site, before it was converted to a garden, was not maintained and consisted of small trees and underbrush. The soil in this site is almost pure sand; a great place to test the theories of biochar being a benefit in poor or depleted soils. The soil test recommended a well-rounded fertilizer with a 10-0-15 ratio.

One variable in this garden, that presumably will affect the research, and that isn’t present in the other sites, is that one end of the garden gets shade in the morning hours, but full sun the rest of the day. Because of this, moisture is present in the soil longer during the day, plus the plants are less prone to heat stress.

Brookston Community Center, Fond du Lac Tribal Community (FDL), Cloquet, MN 55720

Located in Northeastern Minnesota, this demonstration garden site was established in 2013. Upon discovering a concrete slab a few inches below the surface of the garden, the garden was moved and a new site was reestablished in 2014. Extension staff and Master Gardener volunteers coached area youth and family members in developing and planting the demonstration garden. This is the only site that features a youth education component. The soil at this site is pure sand and was amended with a 10-0-12 fertilizer based on the soil test recommendations. A deer-proof fence was also required.
THE VOLUNTEERS

“The University of Minnesota Extension Master Gardener™ program is an internationally recognized volunteer program. It exists in all fifty states, in Canada and in the United Kingdom. Nationally, there are nearly 100,000 Master Gardener volunteers from all walks of life. They reach about 5 million people each year – the equivalent of more than $100 million in value to communities. In Minnesota, the Master Gardener program is coordinated by University of Minnesota Extension and has strong ties to the research and outreach of the Department of Horticultural Science.” (http://www1.extension.umn.edu/master-gardener/about/)

In Minnesota, each of the four sites has team leaders and between 8-14 additional volunteers supporting the needs of each site. All of the Master Gardeners completed a specialized training to learn about biochar and the CenUSA grant. Their hours spent teaching and caring for the sites are reported as part of their volunteer hours.

Master Gardener volunteers are involved in many facets of the study including planting and maintaining the demonstration gardens, collecting and recording data measurements and harvesting crops. Volunteers also teach the public about biochar and share their research findings at state and county fairs, horticulture field days and other community events.

THE GARDENS

The ornamental and edible crops selected at each site are typical of those grown by home gardeners. Edible crops included: green beans, tomatoes, green bell peppers, carrots, leafy kale, cucumbers, lettuce, asparagus, potatoes, and basil. The ornamental crops included zinnias, salvia, gazania, chrysanthemums and shrub roses.

Planting Day

Due to the cool and wet spring, planting was delayed in the Twin Cities Metro area until the first week of June. The Fond du Lac site was planted a week later.

The weather during the month of May and early June was in a long holding pattern of frequent rains and cold temperatures. This resulted in less than ideal conditions for planting. Regardless, the gardens were planted on schedule.

In spite of the partially wet and compacted soils, it was reported that the biochar treated areas were easier to work in compared to the control plots. This was consistent in all three established sites, even with different soil textures from sand to silt loam. Biochar appeared to improve soil texture in all of the gardens, making planting easier even when the soil was wet.
Germination and Plant Establishment

The 2014 late winter and early spring brought many cool and cloudy days. The zinnias and salvia both had a tough start in the grower’s greenhouse due to the lack of natural light, but adjusted well after transplanting.

Lettuce and carrots were planted with seed tapes but once again, germination was very spotty with over 75% failure. This was consistent over all three treatments. It is plausible that the reason for their failure could have been from inconsistent moisture during the tender germination period.

A few tomatoes and peppers had cutworm damage. The plants were replanted within a few short days and protection was added to the plants.

The perennial chrysanthemum ‘Gold Country’ had winter kill at all of the sites in 2013, with the exception of two remaining plants at the SPC site; the chrysanthemums were not replaced.

Weeds, Pests and Diseases

Rose chafers, Japanese beetles and spotted asparagus beetle nymphs were observed in the gardens in 2014. The damage was minimal on most of the plants and insects were removed by hand or tolerated. No pesticides are used in these gardens. At the scheduled times for data collection, there were no diseases to report. During the mid-season powdery mildew and a virus was spotted on some of the cucumber plants. By the end of the season there were typical tomato leaf spot diseases. Master Gardeners did a great job of providing good sanitation in the garden by removing infected plants and leaves and they kept general garden weeds under control as well. The poison ivy sightings at the AND site declined from 2012 but there were a few random sprouts that came up and were removed immediately.

Nutrient Deficiency

The demonstration gardens at the SPC and the ARB had the most vigor, most likely due primarily to the silt loam soils which holds moisture and nutrients better than their sandy counterparts. The AND and FDL sites showed early signs of nutrient deficiency which resulted in smaller plants with longer stem internodes, yellow-green colored leaves, and lower yields. Presumably, this was due to the sandy soil which is conducive to fertilizer leaching through rains and regular watering.

YOUTH EDUCATION

It became apparent when available resources and the needs of the community provided a welcome turn in the research project by offering a youth education component at the Fond du Lac site. Fond du Lac tribal community Extension Master Gardeners collaborated with the Brookston Community Center staff to deliver gardening education for elementary and middle school-aged youth in a vibrant season-long program. The volunteers engaged local youth to care for the garden and collect observational data.

The 1000 ft² CenUSA Biochar Demonstration Garden was the center of a 20-week long Junior Master Gardener (JMG) program developed and taught by the five Fond du Lac community Extension Master Gardeners.

At various times, between 10-20 children participated in an after-school JMG program focused on understanding the basics of growing healthy food and even learning about common garden weeds that are edible. Some of the topics covered included planting techniques, observation and garden care, harvesting techniques and cooking. Students
particularly enjoyed the lessons that integrated education, cooking, and tasting the vegetables. They also enjoyed seeing the variations between the different biochar test plots. Because of the change in focus, data from this garden will not be collected in the same way as the other sites in Minnesota, but the volunteers at this site will continue with their youth focus moving forward.

**Data Collection**

Since this project is a representation of a typical homeowner garden, we wanted to answer questions a homeowner would ask that would address such as, plant growth and health, vegetable yields and bloom production on flowers. The guidelines established for collecting data were based on growers’ recommended days-to-maturity. Following the growers’ optimal harvest recommendations provides a baseline for the duration of the four-year study and helps determine any long-term patterns.

Master Gardener volunteers used worksheets to record plant height and widths, weight of produce, bloom production on flowers and leaf color. Weights were measured in grams and converted to pounds and ounces. Heights and widths were measured in inches; bloom data was based on percentage of flowers open and leaf color was based on a key with a scale of 1-8 with the lowest number correlating with the lightest green and the highest number the darkest green. This key gives an indication of nitrogen and health in a plant. The lighter the green color represents lower nitrogen levels.

The cooler, wet spring conditions resulted in most crops being slightly immature based on the averages for reaching maturity per the growers’ recommendations. Regardless, the crops were harvested and measured on schedule as per the suggested days-to-maturity. Some crops such as the tomatoes, peppers, beans and cucumbers that ripen progressively had multiple data collection days and were harvested over a two-week period.

Approximately thirty five Master Gardener volunteers were involved in measuring data and recording the results. Though Extension staff provided volunteers with all possible means of training and information for proper data collection, there are notably some levels of error based on individuals’ interpretations and subjective opinions. Results from the collection of data follows.
RESULTS

1. Asparagus

Jersey Knight Hybrid asparagus (Asparagus ‘Jersey Knight Hybrid’) two-year roots were selected and are the only perennial vegetable in the gardens. This variety was chosen because of its adaptability to a variety of soils plus for their disease resistance to rust. Five crowns were planted in each treatment in year-one. There was no harvest in Year 1 or 2. In year-3, growth was very inconsistent between sites and even within plots at each site. This may be due to root dieback or other factors. As a result it will be difficult to get reliable data to determine the effect of biochar on this crop.

2. Basil

Italian Large Leaf basil (Ocimum basilicum) was the variety selected for its popularity, mild sweet flavor, high yield and tendency for slow bolting. Date to maturity is 40-65 days. Seeds were started indoors in mid-April.

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Variances:
In 2014 the basil did not like the cool start to the season, but seemed to adjust once the weather warmed up. At the time of harvest, the plants were showing early signs of bolting. Flowers were not deadheaded prior to harvest. In 2013 the original crop died and then replanted two weeks after the first planting. This resulted in smaller plants at the designated harvest date which may explain the smaller sizes and weights.

Comments:
In 2014, more growth was observed in TRT1 plots at AND and ARB. Basil performed better in the TRT2 plots. The most significant differences observed were at the AND site with nearly 2.5 times the yield in weight between TRT 1 & the CTRL plots.
3. Beans

Blue Lake Bush beans (*Phaseolus vulgaris* ‘Blue Lake 274’) were selected for this project based on their growth habit and popularity among gardeners. They typically grow a sturdy bush 15-18" tall. When mature, the pods are 6-7” and free of strings and fiber. Days-to-maturity are 52 days. Seeds were direct sown according to label directions and the scheduled harvest was within three days of July 14th, then subsequently harvested two times per week over a period of 2 weeks.

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Varians:
Approximately 60 seeds were planted in each treatment and thinned to 15 plants per treatment. There were some plant losses in both the ARB and SPC plots. The ARB lost one plant in CTRL and TRT 1. The SPC team lost one plant in CTRL and two in TRT 1. The SPC site had the best yields in the CTRL & TRT2 plots. The beans were just starting to set mature fruits for the first harvest and had average yields for the four harvest periods. In 2013, due to the early wet spring, the beans in general were not mature at the time of harvest resulting in smaller yields.

Comments:
The beans appeared to respond well to TRT 1 in both the AND and ARB sites and at the SPC the beans had the greatest yield in CTRL based on average weight per plant. Both AND and ARB sites have a sprinkler that is centered among the TRT1 plots which most likely receives more moisture than the outside plots, which may partially contribute to the higher yields in TRT 1. Overall the SPC site had much better yield results than the other sites. This could be because it has a warmer microclimate and reached maturity faster than the other two locations. The plant losses were most likely from birds and/or cutworms.
4. Carrots (Crop Failed)

Sweet Treat Hybrid carrots (*Daucus carota* var. *sativus* ‘Sweet Treat Hybrid’) were selected. At maturity, these carrots are best at 6” long. Seed tapes were used to help provide easier, more consistent direct sowing of very small seeds. They are described as sweet and crunchy. Japanese kuroda type has tapered spike shaped roots. These carrots should be mature and ready to harvest at 70 days.

**Variances:** Germination continues to be a struggle for carrots in all sites and treatments. A separate germination test was made to check viability of the seeds, and discovered they germinated well in a controlled setting. The reason for poor germination in the gardens is most likely due to a lack of consistent moisture in the soil during the time of early germination and establishment. Based on the poor germination and limited yields, the results are inconclusive.

**Comments:**
Based on the poor quality of plants, it is difficult to assess whether the biochar had any effect on plant growth. In 2015, greater efforts will be made to ensure better germination.
5. Cucumbers

The variety selected is **Tasty Green Hybrid** cucumber (*Cucumis sativus* ‘Tasty Green Hybrid’). This variety was chosen based on the description of being disease resistant, 9-10” in length and a good variety for growing on trellises. The maturity date listed was 62 days. Seeds were started in the greenhouse and transplanted.

<table>
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<tr>
<th>Cucumbers Sites &amp; Treatments</th>
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**Variance:**

Seeds were started in a greenhouse in April and three healthy plants were transplanted into each treatment. This method provided for a much healthier start than 2013 when the seeds were direct-sown. Late in the season in 2014, there were signs of powdery mildew plus a virus that resembled mosaic in all of the sites. Because it was post-harvest those diseases didn’t affect the yields. In 2013, the ARB site had a loss of cucumber plants in the CTRL plot, and SPC had a loss in TRT 1. Overall, the conditions at the ARB site seemed much more favorable to cucumbers than at the other two sites resulting in higher yields. This particular cucumber is also a very fast grower, so if the harvest at the ARB was even a few days later than the other sites, this would contribute to the greater weights as well.

**Comments:** Based on the results in 2014, there were not enough patterns of growth between the sites and treatments to determine if the biochar had any effect on the cucumbers.
6. Kale

Blue Curled Vates kale (*Brassica oleracea* ‘Blue Curled Vates’) was selected for its durability in the garden and an added bonus is its longevity of growth into the fall. Fifteen kale transplants were planted in each plot. August 1st was selected as the harvest date. Eight of the 15 plants were harvested. The remaining seven were left for aesthetic purposes until after a hard frost.

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**Variances:** The kale crops for the most part exhibited good health once they overcame transplanting and the cool start from the spring conditions. The CTRL plot at AND may have suffered more drought conditions which could have contributed to smaller plants. With the sprinkler in the middle of TRT 1 and the slight shade in TRT2 could have been why those plants were a little healthier.

**Comments:** Based on the inconsistencies in yields between treatments in 2014 and from the past year, it is difficult to determine if biochar had positive or negative effects on kale.
7. Lettuce (crop failed)

Black Seeded Simson (*Lactuca sativa* ‘Black Seeded Simson’) is a common heirloom plant that is known to have tender, buttery texture and pale green leaves. Like carrots, seed tapes were used to help provide easier, more consistent direct sowing of very small seeds. This variety has an average of 45 days-to-maturity. Because of the cool wet spring, and knowing lettuce typically performs well in those conditions, it was considered that the lettuce would be the standout crop in performance, but that wasn’t the case.

Variances: As with carrots, germination continued to be a struggle for lettuce in all sites and treatments. A separate germination test was made to check viability of the seeds, and discovered they germinated well in a controlled setting. The reason for poor germination in the gardens is most likely due to a lack of consistent moisture in the soil during the time of early germination and establishment. Based on the poor germination and limited yields, the results are inconclusive.

Comments:
Based on the poor quality of plants, it is difficult to assess whether the biochar had any effect on plant growth. In 2015, greater efforts will be made to ensure better germination.
8. Peppers

The pepper variety selected was *King Arthur Hybrid Sweet Bell* pepper (*Capsicum annuum* ‘King Arthur Hybrid’). The King Arthur peppers are large 4 1/2” bells that grow on 22” plants. The average days-to-maturity is 62. They are known for high yields and are tolerant of Tobacco Mosaic Virus (TMV) and Potato Virus Y (PVY).

<table>
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<tr>
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<th>2013 Average weight in grams per Plant</th>
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**Variance:** The peppers showed delayed growth due to the prolonged cool temperatures in the spring. Very few fruits were ripe at the designated harvest dates based on days-to-maturity.

**Comments:** The peppers were harvested twice, once per week over a two-week period and only if the fruits were of mature size. Based on the poor yields at all sites and in all treatments, there were no significant differences in the results from peppers grown in biochar.

![1st pepper harvest at the Andover site.](image)
9. Potatoes

A new variety of potato from University of Minnesota called ‘Runestone Gold’ was selected. They are a mid-to full-season variety with dark green foliage. ‘Runestone Gold’ has excellent culinary qualities and dark red skin, deep yellow flesh and a round to oval uniform tuber. The estimated days-to-maturity is 80-100 days. The date of harvest selected was 90 days after planting. Each site had three healthy eyes planted per treatment and all survived until harvest.

<table>
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<th>Plants per Treatment</th>
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**Variances:** Since potatoes typically have dieback in the vegetative portion of the plant at the time of harvest, the volunteers were only asked to measure weights on this crop.

**Comments:** There were no consistent or significant patterns of growth between plots to determine if biochar had any effect on growing potatoes.
10. Tomatoes

The **Celebrity tomato hybrid** (*Lycopersicon esculentum* 'Celebrity Hybrid'), a 1984 AAS winner, was selected for its outstanding disease resistance, determinate form and productivity. These tomatoes are determinate plants that are generally supported well by short stakes or cages. According to the growers, the fruits are large, about 8-10 oz. and are very productive with the ability to produce under a broad range of conditions. They reach maturity in 72 days and grow to a height of 3-4 feet and width of 3 feet. Seeds were started indoors and the projected date of harvest was mid-late August. Five plants were grown in each treatment.

### Sites & Treatments

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**Variances:** Within 3-5 days of the initial transplanting, a few tomatoes succumbed to cutworm damage. Those plants were immediately replaced and protective collars were placed around all plants. No further damage occurred.

**Comments:** The tomatoes in the CTRL plots outperformed those in the biochar treatments in 2014 in regards to weight. This was a surprise compared to 2013 where the TRT1 plots of tomatoes appeared to outperform the CTRL and TRT2 plots. With this inconsistency, it is difficult to determine if biochar had a positive or negative effect on tomatoes.
ORNAMENTALS

Data on flowers were collected on plant growth and leaf color. Blooms were also measured by percent of blossoms open with a ranking of 1-5, as such: 1=1-25%; 2=26-50%; 3=51-75% & 4= 76-100%. Leaf color was determined by a leaf color key ranking the colors as 1-8 with the lowest number showing the lightest green and the highest number the darkest green. The color chart gives an indication of nitrogen in the plant.

11. Gazania

*Gazania ‘Big Kiss White Flame’* was selected for its unique coloring and size, and adaptability. This particular variety has super-sized, 4 1/2 inch, pinwheel striped blooms which are nearly 50% larger than most other gazanias. They are mounded in growth habit and top-out in height and width at 8-10 inches.

<table>
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Variances: There were some height variances at the SPC site, but without other sites also showing similar growth, the reason for taller plants in the CTRL and TRT 2 plots at SPC is unknown.

Comments: Other than the anomaly in average height measurement at the SPC site in the CTRL and TRT 2 plots, there were not a lot of significant differences between treatments.
**12. Salvia**

*Salvia farinacea* ‘Victoria’ was selected for its prolific, long bloom time, dense, blue flower spikes and light gray-green foliage. This salvia can tolerate some shade or sun. Mature size is 14-24 inches high, and 12-14 inches wide.

<table>
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**Variance:** The salvia showed less vigor in 2014 when comparing to the 2013 growth data. Many factors could have contributed to that, such as temperature, moisture, nutrient retention and sunlight.

**Comments:** The CTRL plot at the AND site showed significantly poorer results in growth and leaf color. Because of the growth and leaf color, biochar may have contributed to better nutrient retention and better overall results in TRT1 and 2 compared to the control plot.
13. Zinnias

**Zinnia 'Uproar Rose Hybrid'** was selected for its large (4-6") magenta blooms, long bloom time and disease resistance. Mature size is 28-36” tall.

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</table>

**Variances:** The zinnias performed better in 2014 compared to 2013. Weather conditions between the two years most likely contributed to the differences.

**Comments:** Here we see that the biochar treated plots resulted in better growth than the CTRL plot at the AND site. Again, this could possibly be attributed to better nutrient and moisture retention.
PERENNIALS

14. Garden Chrysanthemums

There were three garden chrysanthemums selected for the demonstration gardens. All are part of the “Mums of Minnesota” series developed by the University of Minnesota. They are considered cold tolerant, prolific bloomers and disease resistant.

‘Gold Country’ was selected as a late-season variety blooming in mid-September. Mature height reaches 21” and width is also 21”. Blooms are a peachy bronze tinged with yellow and are 4.5” in width.

<table>
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</tbody>
</table>

**Variances:** Most of the ‘Gold Country’ variety had winter kill after the first season. The remaining plants at the SPC struggled initially and recovered fairly well though not with the vigor expected. The plants that died were not replanted.

**Comments:** Without the comparison across sites, plots and treatments, it is not possible to observe any benefit of biochar on this variety.
‘Betty Lou,’ was selected as an early bloomer—starting in August. The plant grows to 10-12” in the first year and 2.5-3’ when it reaches maturity. The average plant width is 30”. Blooms measure about 2.5”.

<table>
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<th>‘Betty Lou’ Sites &amp; Treatments</th>
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**Variance:** All of the mums experienced four-lined plant bug nymph damage early in the season. The damage was primarily aesthetic on the leaves and did not show long-term damage on plant growth or bloom production.

**Comments:** There appears to be some consistency in plant growth between the two years, showing slightly better results in TRT1 over the other treatments.
‘Maroon Pride’ blooms in early September and matures to a height of 15-18” with a width of up to 30”. The dark red flowers are 4.5”.

<table>
<thead>
<tr>
<th>‘Maroon Pride’ Sites &amp; Treatments</th>
<th>2014 Average Plant Height in inches</th>
<th>2013 Average Plant Height in inches</th>
<th>2014 Average Plant Width in inches</th>
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</tbody>
</table>

Variances: All of the mums experienced four-lined plant bug nymph damage early in the season. The damage was primarily aesthetic on the leaves and did not show long-term damage on plant growth or bloom production. There was an error in the 2013 report which stated that the ‘Maroon Pride’ mums had died at the ARB site, instead, data was just unavailable for this plant.

Comments: There appears to be some consistency in plant growth between the two years, showing slightly better results from biochar in TRT1 over the other treatments.
15. Northern Accent Shrub Roses
Selected for their cold-hardiness and minimal care, the Northern Accents™ Sven Rose (Rosa 'BAIsvens'), Ole Rose (Rosa 'BAIoLe') and Lena Rose (Rosa 'BAI.len') were developed by the University of Minnesota rose breeding program. These polyantha roses are prolific bloomers and require no special winter protection. Pruning is required only for removal of dieback and overall shaping for plant form.

Rose Chafers were found on all the roses at all sites. They seemed to favor the lighter colored roses at first. Chemicals are not used in the gardens, so insects were handpicked and placed in containers of soapy water. It did not appear that insects had any effect on the growth of the plants overall.

The ‘Sven’ variety grows between 2.5- 3’ height and their small 1-2” flowers are mauve in color and fragrant.

<table>
<thead>
<tr>
<th>‘Sven’- Northern Accent Rose Sites &amp; Treatments</th>
<th>2014 Average Plant Height in inches</th>
<th>2013 Average Plant Height in inches</th>
<th>2014 Average Plant Width in inches</th>
<th>2013 Average Plant Width in inches</th>
<th>2014 Average of Bloom Ranking</th>
<th>2013 Average of Bloom Ranking</th>
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</tbody>
</table>

Variance: The ‘Sven’ variety struggled to survive over the winter and succumbed to what appeared to be winter kill in the TRT2 plot. An oversight error resulted in unrecorded data at the ARB site in 2013 for all shrub roses.

Comments: There were no significant patterns of growth, color or bloom differences between treatments at all sites.
The ‘Ole’ variety is a semi-double blush pink rose that fades to white. It grows to a height of 2.5-3’.

Rose Chafers on ‘Ole’ variety at AND site

<table>
<thead>
<tr>
<th>‘Ole’ - Northern Accent Rose Sites &amp; Treatments</th>
<th>2014 Average Plant Height in inches</th>
<th>2013 Average Plant Height in inches</th>
<th>2014 Average Plant Width in inches</th>
<th>2013 Average Plant Width in inches</th>
<th>2014 Average of Bloom Ranking</th>
<th>2013 Average of Bloom Ranking</th>
<th>2014 Leaf Color Average; Scale of 1-8</th>
<th>2013 Leaf Color Average; Scale of 1-8</th>
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</table>

**Variance:** The ‘Ole’ variety struggled emerging in the TRT2 plot at the SPC site in 2013 and bounced back a little better in 2014. An oversight error resulted in unrecorded data at the ARB site in 2013 for all shrub roses.

**Comments:** There were many inconsistencies between sites and treatments in growth and bloom ranking. Without a consistent pattern it is difficult to determine if biochar had a positive or negative effect on the ‘Ole’ variety of roses.
The ‘Lena’ variety has a single-flowered blush pink blossom reminiscent of apple blossoms. It grows to 2.5’ tall and 2-3” wide.

<table>
<thead>
<tr>
<th>‘Lena’ - Northern Accent Rose Sites &amp; Treatments</th>
<th>2014 Average Plant Height in inches</th>
<th>2013 Average Plant Height in inches</th>
<th>2014 Average Plant Width in inches</th>
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</tbody>
</table>

**Variances:** The ‘Lena’ had not significant variances. An oversight error resulted in unrecorded data at the ARB site in 2013 for all shrub roses.

**Comments:** There were not any consistent patterns determine if biochar had a positive or negative effect on the ‘Lena’ variety of roses.
SUMMARY

The year-three results in the demonstration gardens were mixed. There were some notable growth differences in some plants, some responding well to biochar and others not as much. In particular the chrysanthemums seemed to respond well, while the shrub roses did not show any significant differences.

Seasonal climate factors also made significant challenges in the gardens early in the season. Biochar was a great benefit in regards to soil texture. The wet spring soils provided a good opportunity to observe that the biochar-amended plots were easy for volunteers to plant in compared to the CTRL plots, especially since no rototilling took place.

Engaging volunteers on a research project such as this has shown to have widespread benefits. Their support is not only helpful in the gathering of data, but their role as Extension Master Gardener volunteers brings a voice offering first-hand experience to the general public during the State Fair and at horticultural events.

The new online reporting system established in 2014 increased the accuracy of reporting; that process will continue in 2015.

A goal in 2015 will be to add hose splitters at both the AND and ARB sites and instead of watering from the center of the garden in the TRT1 plots with just one sprinkler, watering from two sprinklers will take place on each end. This will hopefully allow for more even watering across the gardens. The SPC site is on a timed irrigation system so watering practices will not change there.

In 2015, it is also our goal to remain as consistent as possible with our methods established in 2013 in order to have more accurate comparisons for the remainder of this project.
CenUSA Outreach and Extension educators at Purdue University held an educational field day in 2014 about harvesting biomass crops for biofuel use. The target audience represented sectors of agriculture, government, biofuels industry, as well as undergraduate/graduate students. Participants (n=16 unless otherwise noted) were surveyed using a paired sample post-test to determine their increase in understanding of the topics after the presentations.

Topics included:

- Renewable Fuels Standard and the latest EPA rulings
- The latest EPA rulings (n=15)
- Stover Removal technology
- Precision Ag methods for Biomass harvest
- Conversion of Biomass to Biofuels
- Bioenergy Grass impact on watershed management
- Warm-season Grass production practices

Results

By comparing knowledge levels ‘Before’ and ‘After’ participation in the field day, we can see the growth participants attained from the presentations.

The percentage of participants who knew None to A little about:

- the Renewable Fuels Standard and the latest EPA rulings was reduced by 50%;
- the latest EPA rulings was reduced by 46%;
- stover removal technology was reduced by 56%;
- Precision Ag methods for biomass harvest was reduced by 62%;
- the conversion of biomass to biofuels was reduced by 38%;
- the bioenergy grass impact on watershed management was reduced by 50%;
- warm-season grass production practices was reduced by 43%.

The percentage of participants who knew Some to A lot about:

- the Renewable Fuels Standard and the latest EPA rulings increased by 50%;
- the latest EPA rulings increased by 6%;
- stover removal technology increased by 62%;
- Precision Ag methods for biomass harvest increased by 75%;
- the conversion of biomass to biofuels increased by 37%;
- the bioenergy grass impact on watershed management increased by 50%;
- warm-season grass production practices increased by 44%.

Occupation (n=16)

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
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</tr>
<tr>
<td>Extension educators</td>
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<tr>
<td>Engineer</td>
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<tr>
<td>Government agencies</td>
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<tr>
<td>Business entrepreneurs</td>
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<td>Farm managers</td>
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<td>Other</td>
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</tbody>
</table>

In summary, knowledge about the topics presented at the biofuels harvest field day increased among all participants; 6.3% indicated they would like to learn more about bioenergy crop production in the future.

For more information on biomass harvest, contact:

Chad A. Martin  
Renewable Energy Extension Specialist  
Agricultural & Biological Engineering  
Purdue University  
Phone: 765-496-3964  
Email: martin95@purdue.edu
Webinar Questions

1. How much has your understanding of [insert one topic] increased as a result of today's webinar?
   a. To no extent
   b. To some extent
   c. To a great extent
   d. To a very great extent

2. How much has your interest in [insert one topic] increased as a result of today's webinar?
   a. To no extent
   b. To some extent
   c. To a great extent
   d. To a very great extent

3. How useful was the information presented in today’s webinar?
   a. Not at all useful
   b. Somewhat useful
   c. Very useful

4. After participating in this webinar, what is the most pressing issue of concern to you?

5. What topics would be of interest to you for future webinars?

6. Please select the range of acres you influence
   a. 0
   b. 1 – 50 acres
   c. 51 – 500 acres
   d. 501 – 1000 acres
   e. More than 1,000 acres

7. Please select the number of people you will share this information with.
   a. 0
   b. 1 – 10
   c. 11 – 50
   d. 51 – 100
   e. 101 - 500

8. What is your primary occupation?
   a. Higher education
   b. Extension educator
   c. Industry
   d. Agricultural producer
   e. Certified Crop Advisor
   f. Governmental agency
   g. Other: Describe _______

9. Please select your age range.
   a. 18 – 24
   b. 30 – 49
   c. 50 – 64
   d. 65 years or older
Qualtrics Survey (sent 3 months after Webinar; get email from sign-up)

1. What is your primary occupation?
   a. Higher education
   b. Extension educator
   c. Industry
   d. Agricultural producer
   e. Certified Crop Advisor
   f. Governmental agency
   g. Other: Describe _______

2. How did you use the information from the ______________ webinar presented last June?
   If select “agricultural producer”:
   a. For your operation, what are the benefits in planting perennial grasses?
   b. What are the barriers that you are facing (or would face) in planting perennial grasses?
   If do not select “agricultural producer:”
   a. What do you consider the benefits in planting perennial grasses?
   b. What do you consider the barriers to planting perennial grasses?
“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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