

DOE Bioenergy Technologies Office (BETO) 2017 Project Peer Review

South Dakota State University
SGI/DOE Regional Biomass Feedstock Partnership
Competitive Grants
(Award # GO88073; WBS 7.1.2.1)



6-9 March 2017

Technology Area Review: Feedstock Supply and Logistics

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This presentation does not contain any proprietary, confidential, or otherwise restricted information

Goal Statement

- Utilize the congressionally directed DOE project at South Dakota State University and the North Central Regional Sun Grant's Competitive Grant program to address key issues and research gaps identified via the Sun Grant/DOE Regional Biomass Feedstock Partnership
- Identify and fund research projects relevant to the sustainable production, harvest, transport and delivery of cost-competitive, domestically grown biomass

Quad Chart Overview

Timeline

- Project start date: 1 June 2008
- Project end date: 30 Sep. 2016
- Percent complete: 100%

Budget (see next slide)

Barriers

- Barriers addressed
 - Ft-B Sustainable Production
 - Ft-C Feedstock Genetics and Deployment
 - Ft-H Biomass Storage Systems
 - Ft-K Biomass Physical State Alteration
 - Ft-L Biomass Material Handling and Transportation

Partners

- Land Grant Universities from 11 states (IA, IL, IN, KS, MN, MS, MT, ND, OH, TX, WI)
- Industry (see list on next slide)
- Non-profit (EcoSun Prairie Farm, Montana Wheat and Barley Committee)
- Idaho National Laboratory

Budget

	Total Costs FY08 –FY14	FY15 Costs	FY16 Costs	Total Planned Funding FY17
DOE Funded	\$9,511,392	\$601,563	\$379,045	\$0
<i>Cost Share</i>				
Awardee/sub-awardee time	\$2,210,334		Cost share met by FY14	
EcoSun Prairie Farm	\$92,833			
The Nature Conservancy	\$100,000			
Millborn Seed Co.	\$15,000			
AGCO	\$75,000			
DuPont Cellulosic Ethanol	\$47,970			
ConocoPhillips	\$107,653			
Archer Daniels Midland	\$28,064			
Hawkeye Renewables	\$28,064			
Alliant Energy	\$10,500			
John Deere	\$14,250			
Federal Machine Co.	\$135,862			
Mendel	\$11,550			
Applied Nanofilms	\$3,915			
SD Innovation Partners	\$7,585			
Thermo-Ag	\$13,201			

1 - Project Overview

- South Dakota State University agreed to employ the North Central Regional Sun Grant Center to administer a competitive grant program supporting the Regional Biomass Feedstock Partnership utilizing the Sun Grant's authorization as a guide.

2 – Approach (Technical)

- Sun Grant Authorization
 - Build local expertise and strength at the regional Sun Grant Centers (up to 25%)
 - Regional Competitive Grants (75%)
 - Integrate Federal and Regional Priorities
 - Regional Advisory Council and listening sessions
 - Federal Road Maps/Program Priorities
 - BETO Multi-Year Program Plan
 - At least 30% for
 - Technology development
 - Technology implementation

2 – Approach (Management)

- Three nationwide Request for Applications (RFA) completed (2008, 2009, and 2010)
- Two internal (SDSU) Proof of Concept RFAs completed in 2013 and 2015
- RFA Review Process: All proposals were reviewed for merit by a panel of scientific experts in the field and by the North Central Sun Grant Advisory Panel prior to selection

3 – Technical Accomplishments/Progress/Results

- 2008 Request for Applications (about \$3 million available)
 - Priority: Biomass feedstock logistics
 - 8 awards (42 pre-proposals; 20 full proposals)
 - 3 internal (SDSU) awards
- 2009 Request for Applications (about \$2.5 million available)
 - Priority: Sustainable biomass feedstock production systems/LCA
 - 6 awards (77 pre-proposals; 19 full proposals)
 - 4 internal (SDSU) awards
- 2010 Request for Applications (about \$2 million available)
 - Priority: Biomass production systems that optimize biomass yield and economic return across a diverse landscape while minimizing negative effects on the environment and food/feed production.
 - 4 awards (27 pre-proposals submitted; 14 full proposals)
 - 2 internal projects selected for funding

3 – Technical Accomplishments/Progress/Results

- 2013 and 2015 Internal Proof of Concept RFAs (about \$250,000 available)
- Project Requirements
 - 20% cash cost share from a source other than federal, state, or SDSU funds
 - Must advance economic development through commercialization of an invention discovered through SDSU research
 - Six month duration
 - Industry partner required
- Six awards (three from each request)
- Will highlight two projects today
 - EcoSun Prairie Farm (South Dakota State University)
 - Harvest, Storage, Transportation, and Technoeconomic Modeling Advances in Corn Stover Supply Chains (Iowa State University)
- One-page summary of other projects in Additional Slides section

4 - Relevance

- A portfolio of projects supporting the Sun Grant/DOE Regional Biomass Feedstock Partnership and addressing four technical barriers to producing a sustainable, cost-competitive supply of biomass feedstock
 - Ft-B Sustainable Production
 - Ft-C Feedstock Genetics and Deployment
 - Ft-H Biomass Storage Systems
 - Ft-K Biomass Physical State Alteration
 - Ft-L Biomass Material Handling and Transportation

5 - Future Work

- Project is complete

Summary

- Funding from a congressionally directed project at South Dakota State University is being utilized to support a competitive grant program through the North Central Sun Grant Center to address technical barriers identified through the Regional Feedstock partnership.
- Key barriers addressed:
 - Sustainable feedstock production systems on marginal land
 - Technologies to densify biomass to improve transportation and storage

Additional Slides

Responses to Previous Reviewers' Comments

- Comment: Suggest administrators look for ways to integrate lessons learned across many disparate projects.
 - Response: We are developing a database of projects funded under this program; part of the reason for which is to determine the ways they may connect across the bioenergy supply chain.
- Comment: Sun Grant projects continue to contribute valuable information across the intersection of agriculture production and bioenergy. Proof of concept work led to promising future work. Following up with PIs after projects ends to recognize effects or impacts of research.
 - Response: We continue to follow up with PIs who have received funding under this award. We recognize that impacts of good projects will often be seen after the actual research is completed.

Project Outputs and Industry Involvement

- Scientific and Outreach Outputs
 - 109 peer-reviewed publications
 - 2 patents
 - 4 invention disclosures
 - 5 book chapters
 - 30 conference papers
 - 224 professional presentations
 - 31 outreach publications
 - 1 website
- Industry Involvement
 - AGCO
 - Alliant Energy
 - Applied Nanofilms
 - Archer Daniels Midland
 - ConocoPhillips
 - DuPont-Danisco Cellulosic Ethanol
 - EcoSun Prairie Farm
 - Federal Machine Co.
 - Hawkeye Renewables
 - John Deere
 - Mendel
 - SD Innovation Partners
 - Thermo-Ag

A one page highlight of each project follows
this slide

2008 Funded Project: Evaluation of In-field Corn Stover Densification and Interaction with Storage Quality, Logistics, and Production Costs; Matthew Darr, Iowa State Univ. (DOE award: \$699,557)

- In-field bale production costs of \$12 per ton.
- Found a 20% improvement in bale collection efficiency when using an intelligent bale staging system.
- Tarped stacks offered best balance of cost and quality.
- Road quality a key criterion in selecting a satellite storage location
- Tube wrapping a viable preservation option for early season, high moisture corn stover.
- Dry matter loss the most influential economic driver to storage methods
- Partners included DuPont-Danisco Cellulosic Ethanol, AGCO, ConocoPhillips, Archer Daniels Midland, Hawkeye Renewables, Alliant Energy, Idaho National Lab
- Key project in DuPont siting decisions for cellulosic ethanol facility



2008 Funded Project: In-Field Cubing of Cellulosic Biomass; Kevin Shinnars,
University of Wisconsin (DOE award: \$159,276)

- Most important variables for successful formation of biomass (corn stover, switchgrass, reed canarygrass) cubes were, in order of importance
 - low moisture content (< 16% w.b.)
 - die block temperature at or below ~ 50°C
 - addition of lime at ~1% of DM as a binding amendment
 - steam conditioning
- Cube density was often greater than 500 kg/m³ but fraction cubed and durability were often less than the desired targets of 90% and 75%, respectively



2008 Funded Project: The Logistics of Herbaceous Crop Residue-Based Ethanol Production under Uncertainty; David Lambert, Kansas State University
(DOE award: \$116,063)

- Results indicated HCR-based cellulosic ethanol production is profitable under the cost, price, and technical assumptions used to model plant investment decisions
- Local cropping patterns influence likely locations of pretreatment and refinery operations
- Potential crop residue-based ethanol plants favor the more productive agricultural areas of the three states (MN, SD, ND) modeled
- In these models, Ammonium Fiber Expansion pretreatment (AFEX) yields feedstock for ethanol production yet also can provide high value cattle feed for local feedlots

2008 Funded Project: Strategies for Concurrent Wet Storage and Pretreatment of Corn Stover; Yebo Li, The Ohio State University (DOE award: \$79,688)

- Adding NaOH (up to 50 g/kg DM) enhanced the enzymatic degradability of corn stover by 2-3 fold after 90-d wet storage
- Treatment with white rot fungus (*Ceriporiopsis subvermispora*) also reduced recalcitrance of corn stover during storage

2008 Funded Project: Improving Handling Characteristics of Herbaceous Biomass; Vance Morey, University of Minnesota (DOE award: \$154,242)

- Optimum tub-grinding and roll press compaction variables were obtained to produce compacted biomass materials with a bulk density of at least 240 kg/m³ (15 lb/ft³) for transport
- Roll press compacts could be handled in belt conveyors without significant dust formation
- Estimates show that as a fuel for heat and power applications, coarse ground/roll compacted corn stover reduced life-cycle GHG emissions by factors of approximately 7 and 11 compared to natural gas and coal, respectively
- Industry partners: Kolbeck, Inc.; Bepex International LLC



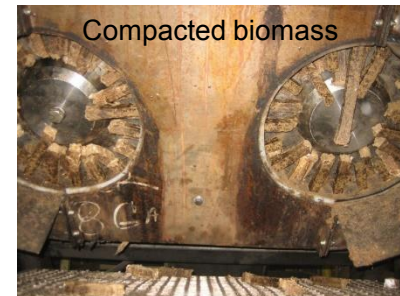
2008 Funded Project: Optimizing the Logistics of a Mobile Fast Pyrolysis System for Sustainable Bio-crude Oil Production; Sergio Capareda, Texas A&M University (DOE award: \$700,000)

- A mobile fast pyrolysis system was developed and tested for biofuel production from corn stover, sorghum, and switchgrass
- GIS analyses revealed that railroads and pipelines were generally not useful in optimizing feedstock logistics in the NC Region. Instead, roads and highways were the preferred means of transportation
- Bio-char incorporation negatively affected major plant nutrient availability, and caused changes in soil pH and soil salinity
- Proper incorporation of biochar critical to prevent derogatory soil environment
- Company in Dallas, TX has licensed TAMU gasifier technology utilizing MSW for power generation
- One provisional patent issued (see additional slides)



2008 Funded Project: Transforming and Densifying Biomass in Regional Biomass Processing Centers; K. Muthukumarappan, South Dakota State University (DOE award: \$689,553)

- Optimized AFEX pretreatment conditions for bioethanol production from corn stover, switchgrass, and prairie cordgrass
- AFEX pretreatment permitted effective pelletization at lower temperatures and pressures than is possible for untreated biomass using the ComPakco process



- 2008 Funded Project: Prioritizing Corn Harvest and Biomass Collection
- Corn grain only option—Farmers are able to complete harvesting corn grain and achieve profit maximization in a fairly short amount of time with existing combine harvest capacity
 - Corn grain and cob one-pass option—grain harvest capacity diminishes due to the attachment of cob harvester to the back of combine which results in harvest slowdown
 - Corn grain and stover two-pass option—Time allocation will be the main challenge when farmers consider this system especially as farm size increases



2008 Internally Funded Project: Landscape Scale Biomass Production, Economics, and Environmental Quality; Carter Johnson, SDSU (DOW award: \$400,000)

- Biomass production varied by species, mixture, and landscape position
- Perennial grass production provided year round cover to all parts of the landscape thus minimizing erosion and sedimentation
- Perennial grasses can slowly improve the soil over time; significant improvement was seen in wet aggregate stability, a key indicator of management impacts on soil quality
- Improvements in soil quality can be made on cultivated land
- Economics: Input costs of grass farming were about one-third the costs of conventional farms; however, grass farm income and profits were considerably lower than those of comparable corn-soybean farms

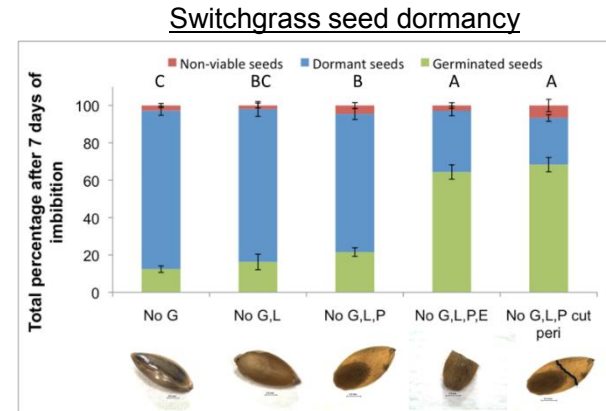


2008 Internally Funded Project: Interactions of Biochar/Bio-ash Source/Properties Impacts on Soil Properties, C Sequestration Potential, and Crop Management; Doug Malo, SDSU (DOE award: \$78,000)

- Addition of biochar to the soil (10%) reduced plant available N and increased P and K
- Biochar additions from the optimal production conditions significantly increased soil salinity
- Biochar pH values varied greatly depending on processing temperature and residence time; highest pH at 650oC and >16 minute residence time, lowest pH at 550oC. These differences impact biochar suitability as a soil amendment.
- Led to USDA-NIFA successful grant application

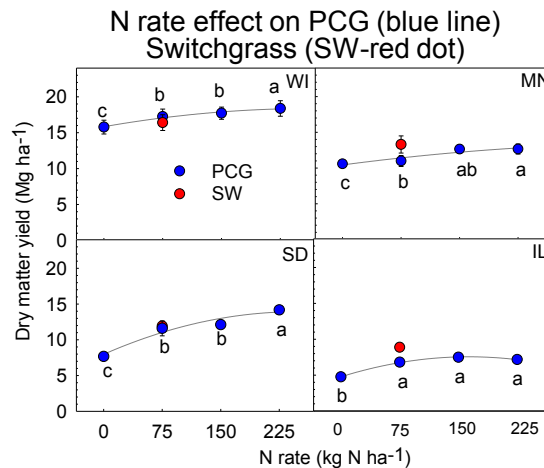
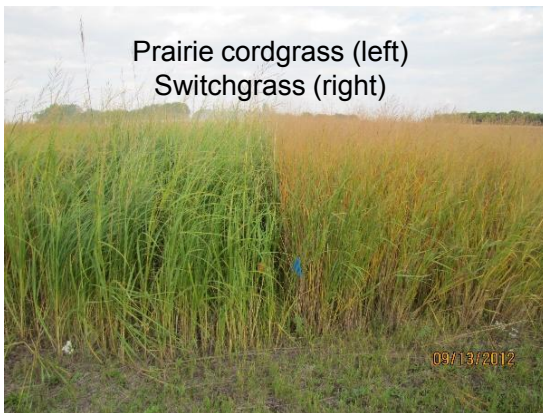
2009 Funded Project: Seed Technologies to Secure Rapid and Complete Switchgrass Establishment; Brian Baldwin, Mississippi State University (DOE award: \$378,049)

- Seed dormancy in these switchgrass cultivars lies primarily with permeability of the pericarp, and to a lesser extent the inner glumes
- Seed safeners (to protect against metolachlor) improved switchgrass seedling establishment and resulted in greater crop yields
- The use of the herbicide metolachlor in controlling weeds for the first months of establishment may enable a harvest in the establishment year



2009 Funded Project: Sustainable Biomass Production on Marginal Lands using a Novel Legume/Grass Mixture; Vance Owens, South Dakota State University (DOE award: \$644,021)

- Cultivar adaptation: Prairie cordgrass (PCG) yields increased with N application up to 225 kg/ha in WI, SD and MN and with urea application up to 75 kg/ha in IL
- By year three (2013) there was a N value associated with PCG grown with KC
- N was important in increasing theoretical ethanol yield because of biomass yield

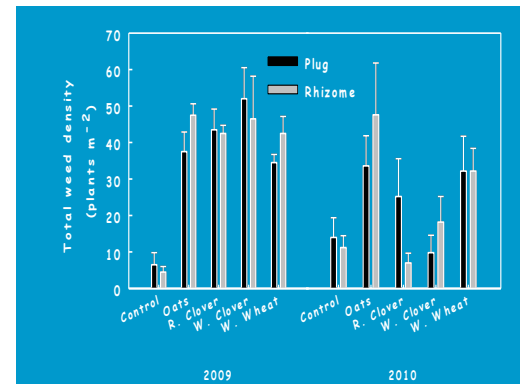


State	FNRV* kg/ha
WI	25
SD	60
MN	82
IL	44

*FNRV: fertilizer N replacement value

2009 Funded Project: Do Nurse Crops Make *Miscanthus x giganteus* Establishment More Sustainable?; Emily Heaton, Iowa State University (DOE award: \$180,969)

- Nurse crops had no clear effect on *M. giganteus* winter survival. Survival was near 100%, except in 2010, when ~30 % of plugs were lost due to severe heat-stress during shipping
- Nurse crops suppressed weeds, especially when combined with timely herbicide application, allowing fewer applications and/or less mechanical weed control.
- Nurse crops reduced *M. giganteus* yields in the first year after growth.

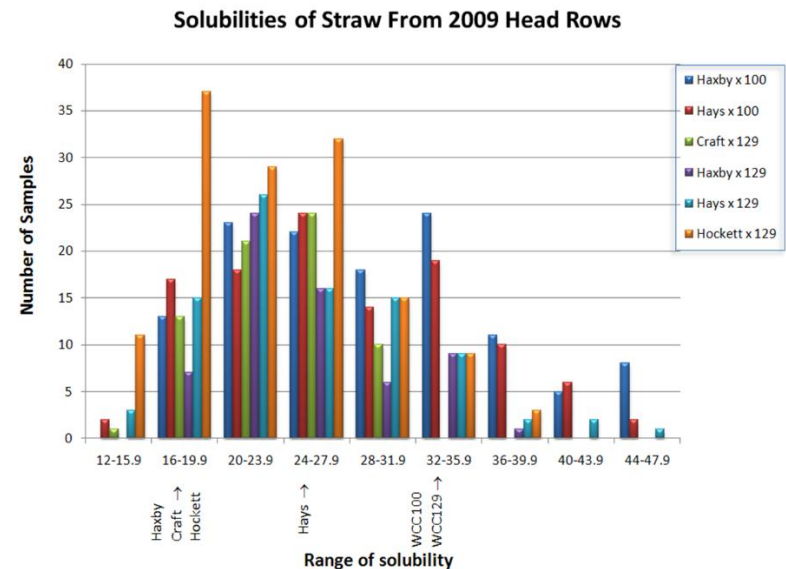


2009 Funded Project: Optimization of biomass productivity and environmental sustainability for cellulosic feedstocks: Land capability and life cycle analysis; Sylvie Brouder, Purdue University (DOE award: \$700,000)

- Average yields of sweet and photoperiod sensitive sorghums were higher than corn
- Yields of the perennial crops (*Miscanthus x giganteus*, switchgrass, and low diversity prairie mix) were variable depending on location and establishment success (up to 3 years)
- Once established, *Miscanthus x giganteus* produced the greatest biomass across all locations followed by switchgrass, then the low diversity prairie
- Switchgrass and prairie mix less variable across locations
- LCAs to evaluate environmental sustainability of bioenergy crops as compared to liquid petroleum
- Led to successful grant applications to DOE, USDA, and IPNI (International Plant Nutrition Institute)

2009 Funded Project: Barley Straw Fructanose Ethanol for On-Farm Biofuel Production; Victoria Blake, Montana State University (DOE award: \$77,868)

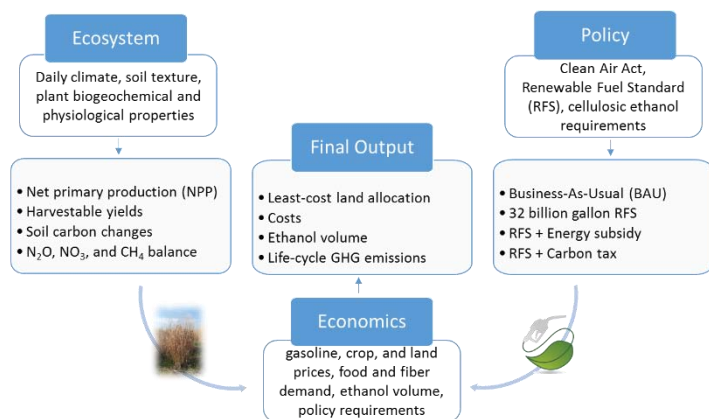
- Evaluation of straw yield and composition from high-fructan barley lines
- Utilization of recombinant inbred barley lines to improve grain and straw yield characteristics in high straw fructan barley lines
- Found 22 lines with 35% straw solubles and competitive grain and straw yield



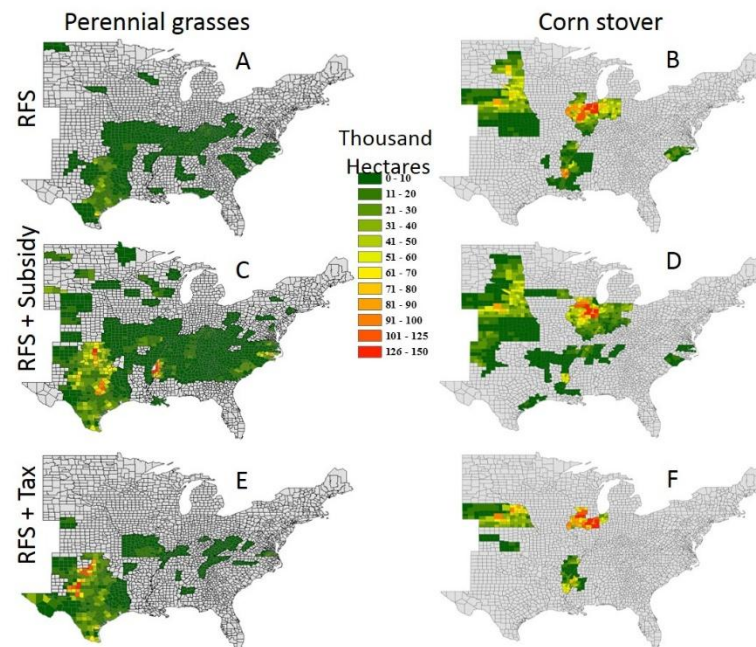
- 2009 Funded Project: Evaluation of Bioenergy Crop Production on Marginal Land in Wisconsin; Stephen Ventura, University of Wisconsin-Madison (DOE award: \$667,299)
- Cropping scenarios that converted sensitive lands currently in low crop production to perennial crops such as switchgrass generated greater ecosystem benefits in terms of water quality, soil erosion, greenhouse gas sequestration, and wildlife (pollinator) habitat.
 - Mail surveys: Getting farmers to switch to bioenergy crops would require a substantial subsidy or increase in current market prices, particularly farmers with integrated crop-livestock systems. Fewer than one-third of farmers would even consider including bioenergy crops in their cropping systems.
 - Mail surveys: Identified characteristics of farms and farmers associated with likelihood of adopting bioenergy crops including amount of marginal land (slight positive association), type of cropping system (negative for integrated crop-livestock systems), age (younger is more likely) and education of farmer (more educated is more likely), familiarity with bioenergy crops (more familiar is more likely), and non-farm family income (more non-farm income is more likely).
 - Farm gate price was the main determinant of willingness to adopt bioenergy crops.
 - Developed a manual on safe and sustainable production of bioenergy crops on sensitive landscapes, now distributed by the Wisconsin Bioenergy Council.

2010 Funded Project: Using Second-Generation Biofuel Feedstocks to Improve the Carbon Economy of US Agriculture; Evan DeLucia, Univ. of Illinois (DOE award: \$644,517)

- Improved DayCENT modeling through data collection, and projected yields for the central and eastern US.
- Calculated GHG emissions for potential bioethanol crop scenarios.
- Calculated abatement costs and associated GHG balance for the least-cost land allocation scenario.



Integrated modeling scheme. The DayCENT ecosystem model is used to produce maps of yield and GHG balance for different crops. The economic model uses the DayCENT model output combined with different policy scenarios to produce land allocation, LCA, and abatement costs.



Land allocation in thousand hectares for each scenario for the crop yield and GHG balance modeled in DayCENT, perennial grasses (A, C, E) and corn stover removals (B, D, F). Corn stover removals are 30% if the baseline system is conventional till and 50% if the baseline system is no-till. Perennial grasses include miscanthus and switchgrass.

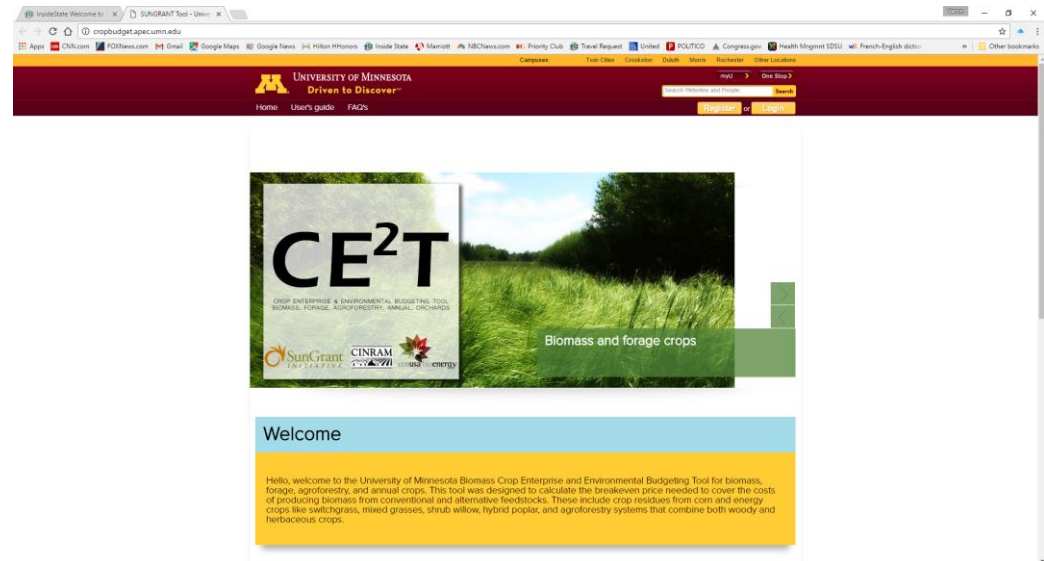
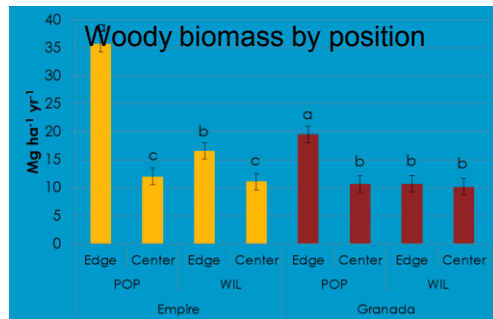
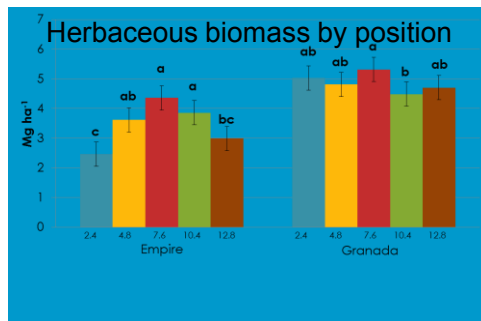
2010 Funded Project: Improving production, resilience, and biodiversity of perennial grass mixtures and monocultures as biofuel feedstocks across environmentally heterogeneous landscapes; Carter Johnson, South Dakota State Univ. (DOE award: \$671,506)

- Reliance on switchgrass monocultures for biofuel feedstock may miss opportunities for higher biomass and more ecosystem services.
- Certain native species, such as little bluestem, prairie cordgrass, and cup plant out-produce switchgrass on more extreme sites in heterogeneous fields.
- Tailoring mixtures of plants including forbs (flowers) to soils where they are best adapted for growth increases whole field biomass and numbers of insect pollinators, butterflies, and wildlife.



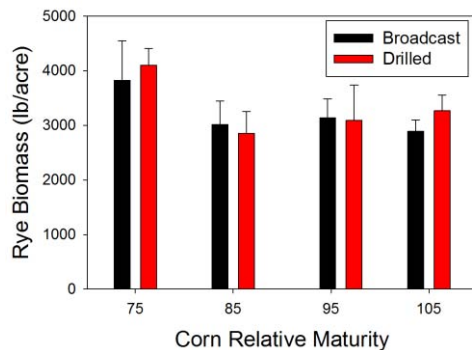
2010 Funded Project: Production and Economics of Perennial-based Woody and Herbaceous Biomass Crops under Alley-Cropping Systems; Gregg Johnson, University of Minnesota (DOE award: \$515,025)

- Determined productivity of woody and herbaceous biomass species in an alley cropping configuration as well as evaluate cover crops to control erosion and improve diversity
- Aggregated production data and refine enterprise budgets for alley-cropping and other perennial-based biomass cropping systems
- Developed a decision support tool (CE²T) (<http://cropbudget.apec.umn.edu/>) for users



2010 Funded Project: Intensifying the corn-soybean rotation with the use of winter rye grown for biomass energy production; Peter Sexton, South Dakota State Univ. (DOE award: \$248,697)

- Evaluated potential of winter rye as a biomass crop established after corn varying in maturity and followed by soybean
- Use of earlier-maturing corn lines significantly lowered corn grain yield, but did not improve rye biomass yield in 2013.
- Rye did not affect soybean yields in the 2013 season. However, in a drought year (2012) the rye adversely impacted soybean yields.
- Cost of rye biomass production estimated at \$62 per ton in this study.



2013 Proof of Concept Internally Funded Project: Developing Gas Stripping - Adsorption/Desorption Separation Processes based on Porous Carbon Adsorbents for Biofuel Purification from Bioreactors; Z. Gu, SDSU (DOE award: \$30,338)

- Bio-char adsorbent can achieve adsorption of volatile chemicals
- Desorption energy decreases with loading dosages, also depends on surface area, pore volume, and surface conditions
- Intellectual property: talking with several companies about this process

2013 Proof of Concept Internally Funded Project: Catalytic Fast Pyrolysis (CFP) Conversion of Corn Stover to Drop-In Quality Hydrocarbon; L. Wei, SDSU (DOE award: \$52,805)

- Various catalysts were developed and combined with the CFP reactor to effectively convert lignocellulosic biomass to drop-in fuels.
- Intellectual property: one license; exploring other collaborations to commercialize the CFP technology.

- 2013 Proof of Concept Internally Funded Project: Electrophoretic Deposition of Biochar Nanoparticle Films for Energy Storage, Q. Fan, S. S. Yu, D. O. F. O. E. et al. (DOI: 10.1016/j.jpowsour.2013.08.078) \$23,878
- Super capacitor made using electrophoretic deposition demonstrated specific capacitance comparable to traditional, more expensive methods.
 - Intellectual property: one disclosure, one patent, one license agreement (working on another one)

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Biochar activated by oxygen plasma for supercapacitors

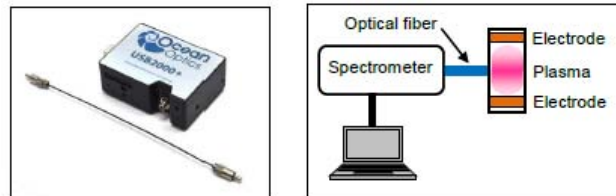
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2015 Proof of Concept Internally Funded Project: Plasma Activation of Biochar for Supercapacitors; Q. Fan, SDSU (DOE award: \$66,544)

- Developed a novel plasma activation to efficiently create nanostructured porous biochar suitable for Supercapacitors
- Successfully established a plasma emission spectroscopy system using an Ocean Optics USB2000+ spectrometer
- Intellectual property: one disclosure, one patent



2015 Proof of Concept Internally Funded Project: Optimize Multifunctional Catalysts for Efficiently Converting Lignocellulosic Biomass to Advanced Biofuels; L. Wei, SDSU (DOE award: \$37,567)

- The yield and quality of bio-oil and upgraded biofuels is significantly affected by the activity and selectivity of catalysts used in biomass catalytic fast pyrolysis.
- Bimetallic Ni-Cu catalysts were more active than single Ni catalysts in hydrodeoxygenation process under mild conditions. The coking (char) yield of Ni-Cu/AC catalyst was lower than Ni/AC catalyst. The combination of Co and Mo supported on Zeolite (HZSM-5) produced higher hydrocarbon biofuel with lower oxygen content.
- Bimetallic Ni-Zn/Al₂O₃ catalysts exhibited higher activity on bio-oil yield and quality, compared to monometallic Ni/Al₂O₃ or Zn/Al₂O₃ catalysts. When an appropriate combination of Ni and Zn loading level, the yield and quality of hydrocarbon in the upgraded bio-oil could be significantly increased while at the same time the undesirable acids, aldehydes and ketones were greatly decreased. 15%Ni-5%Zn/ Al₂O₃ catalyst generated the highest oil phase yield at 44.6% with the highest hydrocarbon content at 50.1%.
- Physicochemical properties of the upgraded bio-oils such as water content, pH and HHV were also significantly improved.
- All AC supported catalysts increased the hydrocarbon yield in upgraded bio-oil in comparison to raw bio-oil, while the Ni/AC catalysts produced the highest light hydrocarbons content at 32.6% in upgraded bio-oil. The addition of Fe, Cu and Mo to Ni/AC increased the yields of alkyl-phenols, and Ni-Mo/AC generated the upgraded bio-oil with the highest content of alkyl-phenols at 38.41%.
- The technologies integrated SDSU proprietary CFP reactor and the multifunctional catalysts synthesized from transition metals supported on zeolite and activated carbon have promising potential for future commercialization to biofuel industry.

2015 Proof of Concept Internally Funded Project: Engineering *Aurebasidium Pullulans* to Produce and Secrete Beta Glucans and Poly-lysine; J. Gibbons, SDSU (DOE award: \$16,585)

- Successfully engineered *A. pullulans* to contain a plasmid directing the production and excretion of poly-lysine peptides
- Feeding trials indicate further need for research before concluding efficacy of treatments
- Intellectual property: one disclosure, one patent