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BIOLOGICAL SYSTEMS ENGINEERING

University of Wisconsin - Madison

College of Agricultural and Life Sciences

Annual Summary of

Teaching, Research & Extension

College of Agricultural & Life Sciences
University of Wisconsin-Madison

460 Henry Mall
Madison, WI 53706-1561

Preface

The Biological Systems Engineering Department, at 108 years young, is the oldest agricultural engineering department in the United States. The department has been a national leader in research, teaching, and extension. As this annual summary booklet shows, we are engaged in many exciting, innovative, forward-looking activities.

To that end, we are pleased to provide you with our 2012 Annual Summary, based on activities underway and completed in calendar year 2012. The Biological Systems Engineering Department is affiliated with the College of Agricultural and Life Sciences, the College of Engineering, the UW-Madison Agricultural Research Stations, and the University of Wisconsin Cooperative Extension Service. The mission of the department includes achieving excellence in teaching, research and extension. Our Biological Systems Engineering undergraduate program is fully accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org. The graduate program offers both Master of Science and Doctoral degrees. We have 150 undergraduate and 55 graduate students. The department offers a wide range of courses with options in Machinery Systems Engineering, Food and Bioprocess Engineering, Natural Resources and Environmental Engineering, and Structural Systems Engineering.

The goal of our research program is to contribute new and valuable knowledge to the fields of machinery systems, food and bio-processing, natural resources and environment, construction, bio-energy and energy systems, and agricultural safety and health. Research projects also serve to train graduate students and to increase the quality of undergraduate education. Our research program is financially supported by state and federal appropriations and by gifts and grants from industry, government agencies, and individuals. This support is gratefully acknowledged. The gifts and grants continue to increase as a percent of budget.

Extension and outreach programs are an integral part of the department. Many of our Extension personnel are also involved in research and classroom teaching. Extension and outreach activities are directed toward providing continuing education opportunities for the citizens of Wisconsin and the nation. The mission is to extend research knowledge and to assist in assimilating it into the community.

Since this report is a summary without a lot of detail, I encourage you to contact the specific project leader (indicated by a "*" in front of the person's name) or me. Publications listed in this report are available upon request.

I welcome your comments on the Annual Summary and other departmental matters. Please visit our website, **<bse.wisc.edu>**, to keep informed of our activities. Also, do not hesitate to contact me: e-mail **rjstraub@wisc.edu**; telephone **608-262-3311**; FAX **608-262-1228**; or mail your comments to:

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Richard J. Straub
Professor and Chair

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Faculty

Robert Anex, Professor, Ph.D.
Teaching / Research: biosystems
David R. Bohnhoff, Professor, Ph.D.
Teaching / Research: wood structures
Chirstopher Choi, Professor, Ph.D.
Teaching / Research: natural resource and environment
Sundaram Gunasekaran, Professor, Ph.D.
Teaching / Research: food and bioprocess engineering
Awad D. Hanna, Professor, Ph.D.
Teaching / Research: construction engineering and management
Brian J. Holmes, Professor, Ph.D.
Extension / Research / Teaching: farmstead engineering
David W. Kammel, Professor, Ph.D.
Extension / Research: farm structures
K.G. Karthikeyan, Associate Professor, Ph.D.
Teaching / Research: natural resources and environment
Rebecca Larson, Assistant Professor, Ph.D.
Teaching / Research: bio-waste management
Richard E. Muck, Professor, Ph.D.
USDA Agricultural Research Service: structures and environment
Xuejun Pan, Associate Professor, Ph.D.
Teaching / Research: bioenergy and bioproducts engineering
Douglas J. Reinemann, Professor, Ph.D.
Extension / Research / Teaching: machine milking, sustainable biofuels, rural energy issues
Troy Runge, Assistant Professor, Ph.D.
Teaching / Research: bioenergy and bioproducts
Kevin J. Shinners, Professor, Ph.D.
Teaching / Research: power and machinery
John Shutske, Professor, Ph.D.
Teaching / Research: Ag safety and health
Associate Dean, Extension, College of Agricultural and Life Sciences
Richard J. Straub, Professor, Ph.D.
Teaching / Research: power and machinery
Chair, UW Biological Systems Engineering Dept. and Director, Animal, Research Division, College of Agricultural and Life Sciences
Anita M. Thompson, Associate Professor, Ph.D.
Teaching / Research: natural resources and environment

Faculty with Joint or Adjunct Appointments

(Research activities and publications are not included.)

Mark R. Etzel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering
Robert J. Fick, Adjunct Assistant Professor, Ph.D.
Alliant Energy: rural energy
Richard W. Hartel, Professor, Ph.D. (UW Food Science)
Teaching / Research: food engineering
King-Jau (Sam) Kung, Professor, Ph.D. (UW Soil Science)
Teaching / Research: soil physics
Philip R. O'Leary, Chair and Professor, Ph.D. (UW Engineering Professional Development)
Teaching / Research: environmental quality
Mahesh Padmanabhan, Adjunct Professor, Ph.D.
Food engineering
Mark A. Purschwitz, Adjunct Assoc. Professor, Ph.D.
Research Scientist, National Farm Medicine Center (Marshfield, WI): agricultural safety and health
John Ralph, Professor, Ph.D. (UW Biochemistry)
Teaching / Research: dairy forage
Aicardo Roa-Espinosa, Adjunct Professor, Ph.D.
CEO Soil Net
Paul D. Thompson, Adjunct Professor, Ph.D.
Biomedical Electronics Engineering; Senior Scientist, Biological Systems Engineering, Adjunct Professor, Biomedical Engineering, Consultant to Industry in Biomedical and Biological Systems Engineering.
Peter Vadas, Adjunct Professor, Ph D. U.S. Dairy Forage Research Center
Junyong Zhu , Adjunct Professor, Ph.D. forestry

Emeritus Faculty

Bubenzer, Gary D
Buelow, Frederick H
Converse, James C
Cramer, Calvin O
Denes, Ferencz S
Finner, Marshall F
Koegel, Richard G
Massie, Leonard R
Peterson, James O
Rowell, Roger M
Schuler, Ronald T
Walsh, Patrick W.

Academic Staff

Acronyms of programs/projects:
AAW – AgrAbility of Wisconsin
CASH – UW Ctr. for Ag. Safety and Health
HFHP – Healthy Farmers/Healthy Profits Project
Names of associated faculty follow in parentheses

Larry J. Chapman, Senior Scientist, Ph.D.; HFHP
Francisco Contresras-Govea, Outreach Specialist
Vicki Janisch, Senior Outreach Specialist; AAW
Jeffrey W. Nelson, Senior Research Specialist (dept. IT) and Lecturer (farm equipment and power), M.S.
Astrid C. Newenhouse, Associate Scientist, Ph.D.; HFHP
Asli Alkan Ozkaynak, Research Associate
John C. Panuska, Faculty Associate, Ph.D.
Scott A. Sanford, Senior Outreach Specialist; Rural Energy Program (D.J. Reinemann)
Cheryl A. Skjolaas, Senior Outreach Specialist; CASH and NAP; Interim Director; CASH
Zack Zopp, Assistant Researcher

Technical Personnel

Harold M. Bohne, Senior Instrument Maker
Bradley A. Brooks, Instrumentation Specialist

Office Personnel

Sue Reien, Department Administrator
Ting Xiang, Financial Specialist
Pam Spahn, Payroll and Benefits Specialist
Debra K. Sumwalt, Student Services Coordinator
Andrew R. Grochowski, Student Worker
Dana Shinners, Student Worker
Hannah Gerbitz, Student Worker
Jennifer Sanford, Student Worker

Postdocs and Research Interns

Kerem Gungor (K. G. Karthikeyan)
Lumin Liu (X. Pan)
Damodhara Mailapalli (A. M. Thompson)
Rashad Rafique (R. P. Anex)
Elumalai Sasikumar (X. Pan)
Chunhui Zhang (T. Runge)

Graduate Students

Names of major advisor follow in parentheses

Joshua Accola (K.G. Karthikeyan/A.M. Thompson)
Horacio Andres Aguirre-Villegas (Larson/Reinemann)
David J. Altenhofen (K.J. Shinners)
Rania Bashar (K.G. Karthikeyan)
Jack Buchanan (D.J. Reinemann)
Kyeong-Ok Choi (S. Gunasekaran)
Nickolas F. Deines (R.A. Larson)
Shashi Dhungel (R. Anex)
Thais Passos Fonseca (D.J. Reinemann)
Maria Sonia Ares Gomez (D.J. Reinemann)
Lei Gu (R.P. Anex)
Thilina Gunawardhana (R.P. Anex)
Sampath R. Gunukula (R.P. Anex)
Michael A. Holly (R.A. Larson)
Andrew J. Holstein (D.R. Bohnhoff)
Wantida Homthawornchoo (S. Gunasekaran)
Kari A. C. Jordan (S. Gunasekaran)
Jacob D. Karlen (K.J. Shinners)
Joseph R. Keene (K.J. Shinners)
Sami Khanal (R. Anex)
Sarah M. Krantz (T. Runge)
Jasmeet Lamba (A.M. Thompson)
Wu Lan (J. Ralph)
Ao Li (R.P. Anex)
Zong Liu (S. Gunasekaran)
Lin Lu (S. Gunasekaran)
Brock M. Lundberg (X. Pan)
Anurag S. Mandalika (T. Runge)
Chaoqun Mei (X. Pan)
Mario Mondaca Duarte (C. Choi)
Lis Nimani (X. Pan)
Jane L. O'Dell (M. R. Etzel)
Edgardo Ortiz Reyes (R. P. Anex)
Michael James Polich (A.M. Thompson)
Stephanie G. Prellwitz (A.M. Thompson)
Joseph Van Rossum (D.J. Reinemann)
Robert Rowbotham (D.J. Reinemann)
Li Shuai (X. Pan)
Harsh V. Singh (A. M. Thompson)
Julie C. Sinistore (D.J. Reinemann)
Craig A. Slattery (K.J. Shinners)
Eakasit Sritham (S. Gunasekaran)
Ryan S. Stenjem (A.M. Thompson)
Jonathan Styx (D.R. Bohnhoff)
Yi-Kai Su (T.W. Jeffries)
Patrick Triscari (R. Larson)
Hui Wang (R.A. Larson)
Yi-Cheng Wang (S. Gunasekaran)
Liping Wei (J. Ralph)
Shouyang Xiang (T. Runge)
Jiang Yang (S. Gunasekaran)
Qiang Yang (X. Pan)
Shuting Zhang (X. Pan)
Shengfei Zhou (T. Runge)
Rafael Zortea (R. Anex)

TEACHING

One part of the department's mission is undergraduate and graduate education. The department is responsible for:

- Undergraduate Major – Biological Systems Engineering
- Graduate Program:
  - -Master of Science - Biological Systems Engineering
  - Doctor of Philosophy - Biological Systems Engineering
- Technical/Service Courses
- Farm and Industry Short Courses
- College of Agricultural and Life Sciences Student Advising

Biological Systems Engineering

Currently there are more than 150 undergraduate students enrolled in Biological Systems Engineering. Approximately 30 students earn B.S. degrees each year.

A minimum of 125 credits is required for graduation. Required courses vary depending upon the area of emphasis selected by a student. Students can choose between machinery systems engineering, structural systems engineering, natural resources and environment engineering, and food and bioprocess engineering. The food and bioprocess emphasis area is spit into a food engineering track and a bioprocess engineering track.

Courses taught within the Department include:

- Surveying Fundamentals (1 cr)
- Engineering Principles for Biological Systems (3 cr)
- Structural Design for Agricultural Facilities (3 cr)
- Sustainable Residential Construction (3 cr)
- Engineering Properties of Food and Biological Materials (3 cr)
- Measurements and Instrumentation for Biological Systems (3 cr)
- Renewable Energy Systems (3 cr)
- On-Site Waste Water Treatment and Dispersal (2 cr)
- Quantitative Techniques for Biological Systems (3 cr)
- Career Management for Engineers (1 cr)
- Rheology of Foods and Biomaterials (3 cr)
- Sediment and Bio-Nutrient Engineering and Management (3 cr)
- Irrigation and Drainage Systems Design (2 cr)
- Biorefining: Energy and Products from Renewable Resources (3 cr)
- Bioprocessing Unit Operations (3 cr)
- Engineering Principles of Agricultural Machinery (3 cr)
- Engineering Principles of Off-Road Vehicles (3 cr)
- Biological Systems Engineering Design Practicum I (2 cr)
- Biological Systems Engineering Design Practicum II (3 cr)
- Small Watershed Engineering (3 cr)

Our undergraduate program was evaluated in 2006 and accredited by the Engineering Accreditation Commission of ABET (http://www.abet.org), and reaccredited again for another six years. The program was reviewed again in late 2012. The results of that review will not be formally announced until mid-2013.

Technical/Service Courses

The department provides several service courses for other majors.

- Milking Machines (1 cr)
- Integral Ecology (1-3 cr)
- Advanced Life Cycle Assessment Methods (3 cr)
- Operating and Management Principles of Agricultural Machines (3 cr)
- Operating and Management Principles of Off-Road Vehicles (3 cr)

Farm and Industry Short Course Program

The department teaches the following courses for the Farm and Industry Short Course (FISC) program offered through the College of Agricultural and Life Sciences.

- Agricultural Safety and Health
- Agricultural Energy-Management
- Farm Machinery
- Farm Power
- Introduction to Precision Agriculture
- Livestock Housing

Graduate Programs

Each year about 45 graduate students are pursuing a Master of Science or Doctor of Philosophy degree in Biological Systems Engineering. In addition, our faculty advises several graduate-level students in other departments and in the programs of Water Resources Management and Land Resources Management of the Institute for Environmental Studies. The M.S. degree requires a minimum of 18 credits of course work and 6 credits of thesis work. A Ph.D. requires a minimum of 42-54 credits of course work and 24 credits of thesis work for a minimum of 66-78 credits beyond a B.S. degree in Biological Systems Engineering. Students who have bachelor's degrees in non-engineering fields may pursue a Master's degree in Biological Systems Engineering but must complete appropriate prerequisites.

RESEARCH

Biological Engineering

Dried Distiller Grain Based Polymer Dispersions for Paper Coatings

*T. Runge, RP Anex
Funding: USDA National Institute of Food and Agriculture, Critical Agricultural Materials Program

Summary: An attractive property of petroleum-based polymers used in paper coatings is the ability to form stable aqueous dispersions of particles up to 300nm with high solids content (> 70%). These water-based systems both increase the safety of the worker and lower volatile organic compound (VOC) content of organic solvent systems. Although high solids emulsions or dispersions are common for the petroleum based chemistry, methods to create stable usable dispersions of renewable natural polymers currently do not exist. This research will develop techniques to produce stable dispersions of extracted hemicelluloses and their derivatives and evaluate and compare the environmental impacts of these coatings with traditional polyvinyl alcohol and acetate coatings. This research will target production of a renewable chemical stream from distillers' dried grains with solubles (DDGS) a co-product of fuel ethanol production.

Great Lakes Bio-Energy Research Center: Sustainability of Bio-Energy Systems

*DJ Reinemann, P Meir, ST Gower
Funding: USDOE
Collaborators: UW Energy Institute, UW Forestry Department, Other GLBRC collaborators at Michigan State, Iowa State and Pacific Northwest Laboratories

The sustainability thrust is one of six major projects under the DOE funded Great Lakes Bioenergy Research Center. Paul Meier is the UW Liaison to the GLBRC for this activity. The UW efforts are aimed at modeling bio-energy production systems and opportunities for process efficiency by integration of biofuels production with agricultural and forest products production systems as well as energy supply and distribution infrastructures.

Thermotheological Evaluation of a Bioglass

*S. Gunasekaran
Funding: USDA, Gift Funds

The sucrose-maltodextrin based bioglass model systems were formulated (sucrose/maltodextrin mass ratios of 7:3, 5:5 and 3:7; Na citrate/sucrose mole ratios of 0, 0.1 and 0.2) with two levels of residual moisture content (0.27 to 0.35 % wb and 2.83 to 4.40 % wb). The bioglass systems were characterized using the modulated differential scanning calorimetry (MDSC). The moisture content and the components of sucrose-maltodextrin based bioglass played significant role on the glass transition characteristics of sucrose-maltodextrin based bioglass system. On average, the glass transition temperatures (*Tg*) of the systems with sucrose/maltodextrin ratio of 7:3, 5:5 and 3:7 were approximately 76.5, 83.5 and 101.0 °C, respectively. The *Tg* values tended to increase when Na citrate was added to the systems, with moat noticeable increase in systems with sucrose/maltodextrin ratio of 7:3 at low moisture content. To investigate the mobility of bioglass systems below their *Tg*, a set of samples with low moisture content was subjected to the isothermal aging experiments. In general, the Kohlrausch-Williams-Watts (KWW) decay function fitted well with the experimental enthalpy relaxation data. The β values spread over a wide range. The enthalpy relaxation time and the time required for 50% completion of the theoretical possible maximum enthalpy relaxation at a constant temperature ($t\varphi$=0.5) increased with the increasing maltodextrin content or the decreasing aging temperature. In systems with sucrose/maltodextrin ratio of 7:3, the dramatic increase in $t\varphi(t)$=0.5 and activation energy (*Ea*) values were observed with increasing Na citrate content. The dependence of the *Tg*, $t\varphi$=0.5, and *Ea* values on Na citrate content in the system with high sucrose content suggested a formation of the less-mobile large clusters as a result of molecular interaction between Na citrate and sucrose, which then led to the increase of *Tg* and the reduction of molecular mobility of the bioglass matrix.

Gold Nanoparticle Nucleation and Growth Mechanisms using Gelatin as a Stabilizer

*S. Gunasekaran
Funding: USDA Hatch

A microscopic and spectroscopic investigation of the synthesis of gold nanoparticles (AuNPs) within gelatin is reported. The AuNPs were synthesized first by reducing tetrachloraurate ions ($AuCl4^-$) by 2-[4-(2-Hydroxyethyl)-1-piperazinyl] ethanesulfonic acid (HEPES), mixing the $HAuCl_4$/HEPES solution with gelatin solution and heating at different temperatures. The polymeric structure of gelatin stabilized the $HAuCl_4$/HEPES/gelatin system and slowed the synthesis of AuNPs, enabling a time-dependent investigation. Based on the results of transmission electron microscopy (TEM) analysis and UV-vis spectra, we

identified three distinct stages involved in the synthesis of AuNPs. First, during the initial stage the reduction of gold precursor occurred along with nucleation and growth, which resulted in a red-shift phenomenon of the localized surface plasmon resonance (LSPR) peak of AuNPs in UV-vis spectra (size and size dispersion increase). Second, the LSPR peaks showed red shift first and then blue shift during the growth of AuNPs. The blue shift might result from the diffusion-limited Ostwald-ripening mechanism. Third, as the supply of the growth species became lower, during the growth of AuNPs, a diffusion-limited Ostwald-ripening mechanism along with a blue-shift only phenomenon in UV-vis spectra was observed. We also determined that slowing the synthesis process during the nucleation stage can prolong the nucleation time, which can generate larger AuNPs. The TEM analysis showed that higher heating temperature and longer heating time can lead to larger particles. By controlling the reduction (nucleation) time, heating time and temperature, AuNPs of size ranging from 5 to 17 nm can be synthesized.

Dopamine Sensing in Meat Samples

*S. Gunasekaran
Funding: USDA Hatch

Sensitive, rapid, and accurate detection of dopamine (DA) at low cost is needed for clinical diagnostic and therapeutic purposes as well as to prevent illegal use of DA in animal feed. We employed a simple approach to synthesize reduced graphene oxide sheets (rGOS) and gold nanoparticles (AuNPs) at room temperature on indium tin oxide-coated glass (ITO) slides as disposable working electrodes for sensing DA. Graphene oxide (GO) was directly reduced on ITO to remove oxygenated species via a rapid and green process without using chemical reducing reagents. AuNPs were electrochemically deposited *in situ* on rGOS-ITO with fairly uniform density and size. The sensitivity of the AuNPs-rGOS-ITO sensor for DA detection is 62.7 $\mu A \cdot mM^{-1} \cdot cm^{-2}$ with good selectivity against common electrochemically-interfering species such as ascorbic acid and uric acid, and the detection limit measured by differential pulse voltammetry (DPV), at the signal/noise ratio of 3, was 6.0×10^{-8} M. The electrochemical catalysis of DA was proven to be a surface process with electron transfer coefficient of 0.478 and rate constant of 1.456 s^{-1}. It correlates well with conventional UV-vis spectrophotometric approach (R=0.9973) but with more than thrice the dynamic range (up to 4.5 mM). The sensor also exhibited good stability and capability to detect DA in beef samples, and thus is a promising candidate for simple and inexpensive sub-nanomolar detection of DA, especially in the presence of UV-absorbing compounds.

Gelatin-Templated Gold Nanoparticles as Novel Time-Temperature Indicator

*S. Gunasekaran
Funding: USDA-Hatch

Gold nanoparticles (AuNPs) were generated by mixing of gelatin solution and gold precursor ($HAuCl_4$, 1 mM) under isothermal condition (80 °C). The effects of gelatin concentration (1 to 6%) and pH (3, 5, and 9) on the color signal of gelatin-templated AuNPs were examined. The λ_{max} of AuNPs shifted from 535 to 552 nm at 1% gelatin, and the color intensity of the AuNPs was a maximum at 2% gelatin. The speed of color development was accelerated at pH 3, and the AuNPs prepared at pH 3 were bigger (45 to 162 nm) and more irregular in shape than those prepared at pH 5 or 9. When the performance of gelatin nanoreactor as time–temperature indicator (2%, pH 5) was evaluated in a simulated frozen storage, clear color signals developed as little as 6 h of exposure at 30 °C and the intensity of the color signal was proportional to duration of exposure.

Nanoparticle-Based Visible Detection

*S. Gunasekaran
Funding: USDA-Hatch, Gift Funds

Visible indication based on the aggregation of colloidal nanoparticles (NPs) is highly advantageous for rapid on-site detection of biological entities, which even untrained persons can perform without specialized instrumentation. However, since the extent of aggregation should exceed a certain minimum threshold to produce visible change, further applications of this conventional method have been hampered by insufficient sensitivity or certain limiting characteristics of the target. Here we report a signal amplification strategy to enhance visible detection by introducing switchable linkers (SLs), which are designed to lose their function to bridge NPs in the presence of target and control the extent of aggregation. By precisely designing the system, considering the quantitative relationship between the functionalized NPs and SLs, highly sensitive and quantitative visible detection is possible. We confirmed the ultrahigh sensitivity of this method by detecting the presence of 20 fM of streptavidin and fewer than 100 CFU/mL of *Escherichia coli*.

Rheological Evaluation of Gelatin Xanthan Gum System

*S. Gunasekaran
Funding: USDA-Hatch, Gift Funds

Effects of moisture content, xanthan gum (XG) addition, and glucose syrup (GS):sucrose ratio on the gelation of gelatin-XG systems with high levels of co-solutes were investigated in the rubbery and the glass transition regions. Frequency sweep tests were performed between 0.1 and 100 rad and the storage (G') and loss (G") moduli of the system were measured in the temperature range of 60 to15 °C. The onset of glass transition region increased with decreasing moisture content. The time-temperature superposition yielded master curves of G' and G" as a function of timescale of measurement. G' and G" were superimposed with the horizontal shift factor a_T, which was temperature dependent according to the Williams-Landel-Ferry (WLF) equation. Glass transition temperature (Tg) of the samples were determined by dynamic mechanical analysis (DMA) from the peak of tan δ. Tg decreased with XG addition. The energy of vitrification of samples with XG increased compared to samples containing only gelatin. Relaxation spectra of the samples were calculated from rheological measurements using the first and second approximations. The Rouse theory was more closely followed with the second approximation.

Effects of Silage Inoculants on Dairy Cattle Use of Silage

*RE Muck, GA Broderick, PJ Weimer
Funding: USDA Agric. Res. Service
Collaborators: USDA Dairy Forage Res. Ctr.

Objectives: Famers often use bacterial inoculants to supplement the natural lactic acid bacteria on a crop at ensiling to help ensure good fermentation in the silo. About half the time, cattle performance (weight gain or milk production) is improved typically 3 to 5% by these additives. However, the reasons for such improvements are not understood. Previous work in laboratory-scale silos suggested that rumen microorganisms produced more biomass on silages inoculated with certain inoculants. The objective of this research in 2010 was to compare alfalfa silage made with and without a silage inoculant on lactating cow performance using an inoculant that had consistently improved rumen microbial growth at laboratory scale.

Progress: Alfalfa silage was made in August 2009 with and without a *Lactobacillus plantarum* inoculant in adjacent oxygen-limiting tower silos. An animal trial with 28 cows in early lactation was begun in April 2010. Cows were divided into two groups with diets containing 50% alfalfa silage along with corn silage, high moisture corn, soy hulls and a vitamin/mineral supplement. One group received the inoculated alfalfa silage and the other the untreated silage. They were fed for four weeks with intensive sampling in the final week. Then the cows were switched to the ration with the other alfalfa silage. Four cycles were performed. Intake, milk production and milk components were measured for all cows. Eight of the cows had rumen cannulas and were sampled for products of rumen fermentation, rumen microbial community and microbial protein leaving the rumen. The inoculated silage produced a 2 lbs./cow/day increase in milk production and that milk was lower in milk urea nitrogen, suggesting the rumen microorganisms were growing better on the inoculated silage. Analysis of the rumen microbial community indicated inoculation of the silage produced no major shifts in microbial species growing in the rumen. Analyses to determine if there are differences in the amounts of rumen microorganisms produced from the different silages are almost complete. As a follow up, alfalfa silages have been made at laboratory scale, with and without inoculant, to determine if the factor affecting animal performance can be isolated and confirmed using *in vitro* ruminal fermentations. The first series of silages were inconclusive, and another series of silages were made in 2012 for testing in 2013.

Extracting Value from Ensiled Biomass

*Troy Runge
Funding: Hatch, BSE department funding

This project is using a combination of a biological and chemical system to determine the economics of ensiled biomass storage for cellulosic biofuels with the added step of extracting and purifying the produced lactic acid to be utilized as value-added monomer. The project which initiated in September, 2012 has performed ensilage experiments to optimize production of lactic acid in switchgrass and washing systems to extract lactic acid with a minimal use of water.

Biochar/Manure Amendments for Improved Soil and Water Quality

*Troy Runge, Becky Larson
Funding: Hatch

The research investigates the use of biochar, a residual stream from pyrolysis or gasification, as a soil amendment to reduce nutrient and contaminant leaching from field-applied manure. The project which initiated in September, 2012 has created laboratory protocols to create biochar samples and assess the chemical characteristics using elemental analysis. Initial experiments to age biochar to improve nutrient holding capacity are underway to identify ideal conditions for soil column experiments.

Biomass Densification for Combustion

*Troy Runge
Funding: Hatch
Collaborators: Wood Residual Solutions, Montello, WI.

This project researched pellet densification through the creation of a lab apparatus able to densify pellets in a lab environment and test their physical properties. The equipment utilizes a compression frame and steel die to apply a controlled pressure and temperature creating a biomass pellet while measuring the material properties. The equipment was able to produce densities similar to commercial grade pellets and allows a host of materials and binders to be trialed. The work demonstrated thermoplastic binder such as recycled plastic and ligninsulfonates can create the highest energy density pellets. Additionally an energy and material model was created based on the pellet production process at the Wood Residual Solutions plant in Montello, WI. The model calculates the cost and energy required to produce solid fuel pellets as compared to wood chips and demonstrated that that wood chips are more energy efficient unless significant boiler efficiencies from utilizing homogeneous pellets can be gained.

Forest Products based Biorefinery

*Troy Runge, Xuejun Pan, & Junyong Zhu
Funding: Bruhn Scholarship, and Hatch

This project researches a process that fractionates biomass into a solid cellulose stream which can be the substrate for pulp production, and a liquid hemicellulose stream, which is dehydrated into furfural. Furfural shows considerable promise as a value- added coproduct of biomass hydrolysis and hemicellulose dehydration to be converted into high value platform chemicals such as levulinic acid, and onwards to GVL and jet fuel. Industrial furfural production is hampered by very low theoretical yields of ~40% owing to the formation of resinous loss products called humins. Our research project was able to extract hemicellulose in a manner from wood and herbaceous feedstocks to not significantly degrade the cellulose. The resulting material was pulped and bleached and shown to have little changes to non-extracted materials, although pulp yields were lower than expected. The hemicellulose was then used to produce furfural in a novel reactor, where the formation of humins is prevented, and furfural is obtained in high yields. The research has shown the furfural produced is relatively pure and able to be produced in excess of 85% yield which is substantially higher than conventional production.

Accelerated Renewable Energy (ARE)

*John Markley, Tom Cox, John Norman, Jim Leverich, & Troy Runge
Funding: USDA Biomass Research and Development Initiative
Collaborators: Maple Leaf Dairy (Cleveland, WI), Soil Net, LLC (Madison, WI), Braun Electric, Inc. (St. Nazianz, WI), and FEECO International, Inc. (Green Bay, WI).

The ARE project, which began in September 2012, will investigate a process to reduce environmental impacts of dairy manure (watershed pollution, bad odor, transportation involved in trucking manure, and overall carbon footprint) through on-farm fractionation and processing of manure into economically valuable products that will provide cash flow to the dairy. The project will involve the implementation of technologies at full scale at the prototype dairy farm, Maple Leaf Dairy. The Runge group is working with Soil Net on the manure processing of the project using polymer-based technologies that enable cost-effective separation ("fractionation") of dairy manure into component streams that can be further processed into co-products of ethanol, protein feedstocks, and organic soil amendments such as mulches, and customized fertilizer nutrients. The Runge group will also perform a life cycle analysis (LCA) on this integrated dairy/energy production system to help assess potential tradeoffs in economic performance, environmental quality and energy inputs. The outcome environmental impact indicators will include greenhouse gas (GHG) emissions, net energy balances, and nutrient use efficiency.

NSF CAREER: Fundamental Understanding of Behaviors and Impacts of Cell Wall Lignin during Bioconversion of Lignocellulose to Fuel Ethanol

*X.J. Pan
Funding: NSF (National Science Foundation)

The objective of this research is to investigate and understand the behaviors and impacts of cell wall lignin during the bioconversion of lignocellulosic biomass to fuel ethanol. Cellulose ethanol is the next generation biofuel. However, the low efficiency of feedstock pretreatment and enzymatic saccharification limits the commercial production of cellulose ethanol. Lignin, which accounts for 15-30% of biomass and binds cellulose together to form a recalcitrant matrix, is a key factor contributing to the low efficiency. The goal of the proposed research is to understand the changes of lignin during the bioconversion and the mechanisms of lignin-enzyme interactions. The structure of lignins in both feedstocks and pretreated materials and the structural changes of lignin during different pretreatments will be investigated. In addition, lignin model compounds will be used to elucidate the mechanisms of lignin reactions during the pretreatments and to determine the impacts of lignin on enzymes during saccharification.

Fundamental Understanding of HDA Process: One-Step Conversion of Lignocellulosic Biomass to Furan-based Precursors for Drop-In Liquid Fuel

*X.J. Pan
Funding: NSF (National Science Foundation)

This project is to fundamentally understand an innovative process (HDA: hydrolysis-dehydration-aldol condensation) for producing "drop-in" biofuel from lignocellulosic biomass. The process directly converts cellulose and hemicellulose in the biomass to furan-based precursors for fuel-grade hydrocarbons in one step under mild conditions without prior biomass pretreatment and fractionation. The precursors can be easily converted to fuel-grade hydrocarbons via hydrogenation/dehydration. Specifically, in the presence of acetone as solvent and reactant and halide salt and mineral acid as catalysts, the biomass undergoes hydrolysis of cellulose and hemicellulose to monosaccharides, dehydration of the monosaccharides to furfural and hydroxymethylfurfural (HMF), and aldol-condensation of HMF and furfural with acetone, and ends up with the formation of furan-based precursors with chain length of C5–C21. Meanwhile, lignin in the biomass is extracted with high purity, low molecular weight, and good reactivity, showing great potential in lignin co-products development.

Fast Saccharification of Lignocellulosic Biomass Under Mild Conditions in the Medium of Concentrated Lithium Bromide

*X.J. Pan
Funding: NSF (National Science Foundation)

A major bottleneck in the conversion of lignocellulosic biomass to fuels and chemicals is the lack of energy- and cost-effective technologies to release sugars from the biomass. In response to this challenge, this research is to establish an innovative chemical process for low-cost production of sugars from lignocellulosic biomass. Specifically, biomass like corn stover, switchgrass, hardwood, and softwood is directly hydrolyzed and fractionated in concentrated lithium bromide in presence of small amount of acid as catalyst under mild conditions without any prior pretreatment. Cellulose and hemicellulose of the biomass are quickly and completely hydrolyzed into monomeric sugars (hexoses and pentoses), which can be further converted into biofuels and chemicals either biologically or chmeically. The used LiBr can be separated from sugars by ion-exchange resin, solvent extraction or crystallization and reused in the process. Lignin is left over as insoluble residue when cellulose and hemicellulose are dissolved. It can be easily collected by filtration or centrifugation. The lignin is expected to have a good potential for co-product development because of high purity. It is anticipated that the process could significantly reduce the production cost of sugars from lignocellulose and therefore promote the sugar-based bioeconomy. Compared with existing technologies, such as acid hydrolysis or enzymatic saccharification, the LiBr-enhanced saccharification process (1) can directly handle small size wood chips and therefore save the cost and energy for size reduction; (2) has a high sugar recovery yield because of complete saccharification and limited sugar degradation; (3) is fast chemical process and does not need expensive enzymes; and (4) achieves fractionation of the biomass into sugars and lignin, facilitating utilization of biomass components.

Efficient Biomass Conversion: Delineating the Best Lignin Monomer-Substitutes

John Ralph, *Xuejun Pan and Sara Patterson
Funding: Stanford University GCEP Program

This research is to delineate a set of approaches for successfully altering lignin structure, in a way that allows plant cell wall breakdown to produce biofuels in a more energy-efficient manner, by providing alternative plant-compatible monomers to the lignification process.

The approach is to synthesize and test various classes of novel plant compatible monomer substitutes for their abilities to incorporate into lignins, and then to determine how such incorporation affects biomass processing in biomimetic cell wall systems. The ability of a chosen monomer to incorporate into lignins (copolymerizing with the traditional monomers) will be determined by *in vitro* iomimetic lignification involving the phenolic radical coupling reactions that typify the lignification process. Those that successfully make co-polymers will next be polymerized into a suspension-cultured cell wall system to further delineate their polymerization efficacy and to provide biomimetic cell wall material for preliminary testing of conversion efficiency following selected pretreatments and in a variety of processes.

SPORL for Efficient Biochemical Conversion of Woody Biomass

*X.J. Pan
Funding: USDA Forest Service
Collaborator: USDA Forest Service, Forest Products Laboratory

This research is to develop a commercially deployable robust pretreatment process, SPORL (Sulfite Pretreatment to Overcome Recalcitrance of Lignocellulose), to economically convert woody biomass to fuels and chemicals. SPORL overcomes the recalcitrance of softwood to achieve over 90% cellulose conversion in 40 hours with normal enzyme dosage even when pretreatment is directly applied to wood chips without further size reduction.

This proposed research includes six tasks: (1) Determine chemical composition of mountain beetle killed lodgepole pine. (2) Evaluate the recovery of hemicellulose sugars through SPORL. The efficient recovery of hemicellulose sugars is critical to improve process economics. Preliminary results indicate that SPORL produced significantly low fermentation inhibitors than dilute acid pretreatment, which suggests efficient recovery of hemicellulose. (3) Evaluate the performance of SPORL using slash and treetops to make full use of wood fractions with lowest market value from forest thinning. (4) Evaluate the performance of SPORL using mountain beetle killed pines. (5) Conduct fermentation study to obtain process data for economic analysis. (6) Conduct economic analysis for bioethanol production based on SPORL platform to demonstrate commercial viability.

Value-added Utilization of Lignin and Hemicellulose from Lignocellulosic Ethanol Production

*X.J. Pan
Funding: USDA McIntire Stennis Fund

The research will emphasize on value-added utilization of the lignin and hemicellulose fractions from the organosolv pretreatment of lignocellulosic biomass. The specific objectives of the research include: (1) Characterization of the lignin fractions (both insoluble organosolv lignin and soluble low molecular weight lignin) derived from forest or agricultural residues during the organosolv pretreatment; (2) Evaluation of the potential application of the lignins as antioxidants and development of high-value co-products like lignin-based carbon fibers; (3) Identification and quantification of the mono- and oligo-saccharides from hemicellulose and other derivatives from the saccharides, such furfural, hydroxymethylfurfural (HMF), formic acid, acetic acid, and levulinic acid; and (4) Applications of the hemicellulose fraction as livestock feed additives and conversion of the hemicellulose fraction to liquid fuels by aqueous-phase reforming.

Direct Saccharification and Fractionation of Forest Biomass for Fuel and Chemical Production Under Mild Conditions in Concentrated Halide Salt Solution

*X.J. Pan
Funding: USDA McIntire Stennis Fund

The proposed research is to develop and optimize a new process for producing sugars for liquid fuels and chemicals production directly from forest biomass without any prior pretreatment. The process will use halide salts with small amount of mineral acid as catalyst to hydrolyze cellulose and hemicellulose at low temperature and produce sugars in fermentable form. Preliminary results indicated the process works well with different types of biomass, such as softwood and hardwood. Compared with existing technologies, the proposed saccharification process has numerous advantages, including (a) the process directly deals with sawdust or small size wood chips as feedstock. No energy- and cost-intensive size reduction or other pretreatment is needed. (b) Cellulose and hemicellulose can be saccharified simultaneously into fermentable sugars without formation of fermentation inhibitors. (c) Process conditions are mild (120-140ºC). (d) No expensive catalyst is required. (e) The halide salts involved have abundant supply and can be separated and reused. (f) Lignin is left over almost in uncondensed form and has great potential for co-products development because of unique properties.

Environmental Impacts of Pasture Based Dairy

*DJ Reinemann, V Cabrerra
Funding: DATCP
Cooperators: Dairy Science Department

The objectives of this project are to:

- Quantify energy intensity of pasture based diary systems in Wisconsin: Both embodied and Direct Energy inputs per unit of milk production
- Quantify GHG emissions (carbon footprint) of pasture based diary systems in Wisconsin.
- Quantify other environmental impacts of pasture based diary systems in Wisconsin including: Land and water use, Nutrient balances (N, P, K) and erosion potential
- Provide information on the best practices to improve sustainability in grazing systems.
- Compare sustainability indicators of grazing systems to other dairy management systems in Wisconsin.
- Develop education/outreach programs to inform grazers and other interested parties in the results of our studies.

Development of Advanced Wood Fiber-Based Composites based on Fiber Modification

*R.M. Rowell
Funding: Private Company

The performance of wood fiber-based composites can be greatly improved by chemical modification of the fiber the composite is made. Dimensional stability and water repellency can be greatly improved by bulking the cell wall with bonded chemicals and by using hydrophobic reactants. Decay resistance can be greatly improved using the same chemistries since restricting access to water by the micro organisms is one way to stop or decrease fungal attack.

One of the technologies that has been studied is the reaction of wood with acetic anhydride. The dimensional stability of acetylated wood and its decay resistance is greatly increased. This is a non-toxic approach to wood preservation that is presently under commercial development. It is now commercial and patents are being written to support this research.

Removal of Contaminates from Water

*R.M. Rowell
Funding: Private Company

Small test filters are being placed in streams that are contaminated from animals that live in or around that stream. Two filters have been placed in Kansas near a cattle farm, two in Georgia near a horse farm, one in Oregon near a house farm and two in Wisconsin near a cattle farm. The water is first checked for particles and color and then a small test filter is places in part of the stream. The filters are made of small particles of bark in mesh bags. The filter remains in the stream for 2 hours and then a water sample is taken to check for particles and color.

Development of Wood with Increase Hardness.

*R.M. Rowell
Funding: Private Company

The hardness of wood can be greatly increased by impregnating the wood with acrylic monomers and polymerizing them *in situ.* A vazo catalyst is used along with heat to cure the polymer. A dye can be added to the monomer mixture to change the color of the final wood product. Hardness is increased several hundred present and the final product is used for industrial flooring. Fire retardancy is also important in harden floors where they are used in commercial applications. Several types of fire retardants are being added to the acrylic formulation and fire retardance is being determined. Since wood is a very good insulating medium, it is hard to control the temperature in the reactor. Stainless steel is being added to the reactor as a means of controlling the temperature.

Heat Treatments of Wood in Improve Decay Resistance and Dimensional Stability.

*R.M. Rowell
Funding: Private Company

Wood that is heated at high temperatures (120-350 C) becomes more decay resistant and has a higher dimensional stability that unheatd wood. The mechanism of effectiveness is due to the decomposition of the hygroscopic hemicellulose polymers in the cell wall. There is a 20-30 decrease in weight and a decrease in strength properties upon heating either in the presence or absence of oxygen. The heated wood is brash but has increased resistance to brown-rot fungi but not to white-rot fungi. After heating at 220 C for 3 hours, there is a 50% decrease in the equilibrium moisture content and an increase of 50% in dimensional stability.

Regional Biomass Feedstock Partnership – Biomass Residue Removal Tool Development

*RP Anex
Funding: North Central Sun Grant Center, South Dakota State University
Collaborators: USDA-ARS National Laboratory for Agriculture and the Environment; Idaho National Laboratory

Major food, feed, and fiber markets consume about 55-60% of the total production capacity of agriculture lands. The remaining 40-45% remains in the field and contributes to soil maintenance. The emerging cellulosic biofuels industry creates a new challenge for agronomic systems. For the first time, a commodity-scale market will exist that consumes the same biomass resources that are used in soil maintenance. A tool is needed to quantify and manage soil maintenance resource demand against a directly competing cellulosic biofuels market.

The Regional Feedstock Partnership is a collaborative research group leveraging the resources of the Department of Energy, USDA, DOE National Laboratories, and land-grant universities (led by the North Central Sun Grant Initiative) to develop sustainable bioenergy feedstocks capable of achieving transportation fuel displacement goals set forth by the DOE. A key outcome of this collaborative project is development of a tool which evaluates six agronomic factors that limit crop residue availability: (1) Loss of soil organic matter or soil organic carbon, (2) Soil erosion, (3) Loss of plant nutrients, (4) Soil water and temperature dynamics, (5) Soil compaction, and (6) Environmental degradation. The first four factors depend upon crop residue inputs and outputs, while the latter two factors are impacts that are a consequence of crop residue management practices and harvest procedures. Together, these factors define the limits or opportunity for residue removal.

We have developed a model-based tool that combines soil carbon, nutrient, and soil erosion models in a geographically-explicit modeling framework. This tool was used during 2011 in support of the development of a national biomass feedstock inventory commonly known as the “Billion Ton Update” and officially titled: “U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry.”

Biofuels and the Hydrologic Cycle

*RP Anex
Funding: National Science Foundation
Collaborators: Iowa State University

As the U.S. is embarking on a dramatic increase in biofuel production, a series of studies have raised questions about the environmental impacts and sustainability of biomass feedstock production due to concerns about water use, soil erosion, nutrient transport and greenhouse gas emissions. Although thought-provoking, these studies generally extrapolate from current conditions and fail to address the underlying human-climate-soil-vegetation dynamics that control the environmental processes involved.

Expansion of biofuel feedstock production will place increasing demands on water resources, impacting water supply, water supply reliability and water quality. In turn, production of new biofuel feedstocks will alter the hydrologic cycle. Understanding the complex, nonlinear systems underlying the water-related impacts of "second generation" biofuels will allow production systems to be designed to ensure environmental improvement and sustainability.

The focus of this interdisciplinary project is on modeling the interplay of land use, climate and the environment in future biofuel production systems. Understanding the role of biofuels in the water cycle is key to understanding many of the environmental impacts of biofuels because it is hydrologic mechanisms that underlie climate-soil-vegetation dynamics and thus control the most basic ecologic patterns and processes. The amount of soil eroding from agricultural areas is directly related to precipitation, wind, and land use. More sediment erodes from intensive land uses like growing corn than from fields of native grasses. Similarly, fertilizers and pesticides used in agriculture wash into water bodies affecting water quality. Different biofuel crops not only require different management but also alter the movement of moisture that transports the agricultural chemicals and sediments through the environment.

This interdisciplinary project advances knowledge across fields by addressing the challenge of modeling interconnected environmental processes that span the usual disciplinary domains. The research addresses the need to develop an improved understanding of and ability to predict changes in water resources and the environment caused by changes in land use patterns.

This project was featured on the radio program "Living on Earth" on August 19, 2011 in a segment titled "The future of bifuels and the weather". The program can be found here: http://www.loe.org/shows/shows.html?programID=11-P13-00033

NSF-Engineering Research Center for Biorenewable Chemicals (CBiRC)

*J Dumesic, RP Anex
Funding: National Science Foundation
Collaborators: Iowa State University (lead institution), Rice University, University of California – Irvine, University of New Mexico, University of Virginia, Salk Institute, University of Michigan, Abo Akademi University (Finland), Eindhoven University of Technology (Netherlands), Fritz Haber Institute, Max Planck Society, Technical University of Denmark

The NSF Engineering Research Center for Biorenewable Chemicals (CBiRC) is developing the fundamental knowledge and technology and the academic and industrial partnerships needed to provide a foundation for industrial chemical production to be transformed from a petroleum-based industry to a renewable resource-based industry.

The overarching goal of CBiRC is to enable the transformation of the chemical industry through the optimized coupling of two catalyst types such that a biocatalyst will convert glucose to an intermediate chemical that can be readily converted by a chemical catalyst to the desired chemical product. It is also educating a new generation of scientists and engineers capable of enabling this transformation.

The Anex research group is leading the Life Cycle Assessment support area of CBiRC. We are applying a range of analysis techniques including techno-economic analysis to predict economic feasibility. As test beds emerge within CBiRC, a key question will be when the "hand off" from biocatalytic conversion to chemical catalytic conversion should occur. For example, given the nature and value of the intermediate molecules to be produced, one can work backward from conversion of final products through separation to determine how concentrated the molecules must be for the biocatalytic process to be feasible. Techno-economic analysis is being applied along with a screening form of LCA to provide this type of information by evaluating possible alternative process options. This evaluation not only provides a basis for comparing options, but helps identify the key technological bottlenecks and their resulting leverage on the sustainability of the biorenewable chemical products targeted in the testbeds.

A Regional Program for Production of Multiple Agricultural Feedstocks and Processing to Biofuels and Biobased Chemicals.

*RP Anex
Funding: USDA-NIFA-AFRI Coordinated Agriculture Project (CAP)
Collaborators: Louisiana State University AgCenter (lead institution), Southern University, Texas A&M University, University of Arkansas at Monticello, Danisco Inc., Virent Inc.

This project involves a team of university and industry partners led by the LSU AgCenter, studying the production of biomass for economically viable conversion to biofuels and bioenergy using existing refinery infrastructure. Through new and existing industrial partnerships, this project will use energy cane and sweet sorghum to help reinvigorate the Louisiana sugar and chemical industries.

The United States Department of Agriculture's AFRI sustainable bioenergy challenge area targets the development of regional systems for the sustainable production of bioenergy and biobased products that contribute significantly to reducing dependence on foreign oil; have net positive social, environmental, and rural economic impacts; and are compatible with existing agricultural systems.

The overall project is designed to fill fundamental knowledge gaps related to sustainability growing and processing dedicated energy crops to produce drop-in biofuels and bioproducts. The science and technology being advanced will be articulated into specific biofuel pathways. The Anex research group is leading the life cycle assessment research area. It is the mission of the LCA task to evaluate the life cycle environmental impacts and measures of environmental sustainability of these biofuel pathways. The purpose of the LCA task is to: 1) identify constraints, bottlenecks, and barriers in the biofuel pathways in order to guide and focus the research effort; 2) to provide a comparative assessment of the pathways to help determine which regional feedstock systems are most sustainable; and, 3) to evaluate the environmental performance of drop-in biofuels made from dedicated energy crops grown in the south central region and processed along the specific pathways under study in this project.

Biofuel Cropping Systems for Feedstock Production and Greenhouse Gas Mitigation.

*RP Anex
Funding: USDA-NIFA
Collaborators: Iowa State University (lead institution)

The Comparison of Biofuel Cropping Systems (COBS) project at Iowa State University is designed to provide a quantitative, side-by-side comparison of corn- and perennial-based cropping systems. This project addresses the significant, practical need for clear comparisons among such cropping systems both for setting biofuels policy and for developing practical management options for producers.

The overall objectives of the COBS project are to provide comprehensive, long-term comparisons of a range of contrasting biomass feedstock production systems with respect to: Potential for biomass production, fossil-fuel replacement, and net energy returns. Potential to reduce greenhouse gas emissions and to increase belowground carbon storage. Potential to maintain soil quality and reduce water-quality impacts of nutrient exports. Rather than maximizing any single performance criterion, the COBS project investigates trade-offs and opportunities to optimize system performance relative to many criteria.

We are conducting a complete LCA of the drop-in biofuel systems that would utilize the biomass developed in each treatment of the COBS experiment. Our LCA studies will quantify and compare: (1) the fossil fuel displacement, (2) drop-in biofuel net energy return, (3) environmental impacts of perennial and corn-based cropping systems, and (4) the net environmental impact of land use change associated with biofuel feedstock production. Through detailed life-cycle assessment based on uniquely comprehensive data from our side-by-side cropping system experiments, we will be able to predict the environmental impacts of shifts in land use among the prototypical cropping systems at the COBS site. We will be able to accurately quantify environmental trade-offs of land use changes among a complete set of performance metrics reflecting a wide range of environmental impacts, productivity, and energy return on investment.

Climate Change, Mitigation, and Adaptation in Corn Based Cropping Systems.

*J Lauer, RP Anex
Funding: USDA-NIFA Coordinated Agriculture Project (CAP)
Collaborators: Iowa State University (lead institution), Lincoln University; Michigan State University; The Ohio State University; Purdue University; University of Illinois; University of Minnesota; University of Missouri; University of Wisconsin; USDA Agricultural Research Service – Columbus, Ohio; South Dakota State University; and USDA National Institute of Food and Agriculture (USDA-NIFA).

This five-year project assesses the environmental, economic and social impacts of long-term shifting weather patterns and increasing climate variability, and how these affect the Midwest's crop management systems. A transdisciplinary team is working together to focus on mitigation and adaptation of the corn-based cropping system. A network of more than 20 sites across the region provides baseline measurements on greenhouse gases, carbon, nitrogen and water usage. Project participants are applying physical, climatic, and socio-economic models to the data to derive its "real world" implications. Extension and education programs are working with farmers and teachers to connect them with project analyses and promote collaborative learning

The Anex group from the University of Wisconsin is leading the systems analysis effort in this project. The systems analysis team will apply climate and physical models to synthesize results from the field tests and extend them to predict climate and economic impacts under future scenarios. Models used include DAYCENT for coupling crop and climate models, the Soil Landscape Interface Model (SoLIM); for extending the results to the on-farm scale, and SWAT to extend these models to the watershed level and incorporate economic land-use models with physical and climate models.

On-Farm Biomass Processing: Towards an Integrated High Solids Transporting/Storing/Processing System.

*RP Anex
Funding: USDA-NIFA Biomass Research and Development Initiative (BRDI)
Collaborators: University of Kentucky (lead institution); North Carolina State University; Oak Ridge National Laboratory; University of Wisconsin; USDA-ARS–FAPU; USDA-ARS-NSL; Cornell University; USDA-ARS-GSWRL; Case-New Holland America.

This project brings together an interdisciplinary team of agricultural machinery manufacturers (CNH America), farmers, agricultural and biological engineers, microbiologists, chemical engineers, chemists, agricultural economists, plant and soil scientists, and horticulturists to develop a system to convert biomass on-farm to butanol, ethanol, acetone, and organic acids. The proposed work will advance the current knowledge and technology through the application of the systems approach, integrating knowledge and technology from several disciplines into the development of an onfarm biomass conversion system with a realistic chance of being adopted by producers.

The proposed biomass conversion process steps, the pretreatment of the biomass feedstocks to make cellulose accessible and the subsequent conversion of cellulose to biofuels and biochemicals, are scaled to the farm, employing a modified bunker silo as the reactor and taking advantage of the high density feedstock bales to increase the production efficiency. A high solids processing system will be developed to convert biomass into butanol, ethanol, acetone, and organic acids, combining existing processing technologies with approaches that make use of the potential to maximize productivity using process cycling and on-farm energy integration.

The Anex group from UW-Madison is leading the life cycle assessment effort. Life cycle assessment models will be integrated with geographic information systems (GIS), economic, and environmental models to evaluate a range of management strategies, feedstocks, regional impacts, land suitability, and potential fossil fuel displacement. Biomass processing models will be developed to evaluate alternative on-farm processing options and their potential impact on bioenergy production. Economic and environmental analyses will be used to determine the level of incentives required to increase bioenergy production and protect the environment when these goals conflict with maximizing farm profitability.

Design and Development of an Atmospheric Pressure, Hybrid Dense Medium (DMP) Plasma Tool (Submerged Arc Plasma) combined with Ultra Sound (US) Environment.

*F.S. Denes
Collaborators: Biological Systems Engineering and Center for Plasma Aided Manufacturing UW Madison.

Goal: Synthesis of controlled- dimensional-size, sole, hybrid and magnetic nanoparticle systems with potential use in microelectronics, optics and biotech applications.

Atmospheric Pressure, DMP/US Plasma-Aided Synthesis of Carbon-based Nanoparticle Systems that are Decorated with Primary Amine Functionalities.

*F.S. Denes
Collaborators: Biological Systems Engineering, Center for Plasma Aided Manufacturing UW Madison, R.B. Timmons, University of Texas at Arlington, and Prof. M. Sandor and Prof. Z. Fabry Department of Pathology and Laboratory Medicine, UW School of Medicine and Public Health 5468 MSC.

Coating Magnetic Iron Oxide Nanoparticles with Surface layers Resulting from Plasma-generated Nascent Atomic and Molecular-Fragment Particles.

*F.S. Denes
Collaborators: Biological Systems Engineering, Center for Plasma Aided Manufacturing UW Madison, R.B. Timmons, University of Texas at Arlington, and Prof. M. Sandor and Prof. Z. Fabry Department of Pathology and Laboratory Medicine, UW School of Medicine and Public Health 5468 MSC.

Goal: Development of functional nanoparticle systems for targeted drug-delivery applications.

Design and Development of an Atmospheric Pressure Surface-Plasma Tool Provided with Cooling/heating Possibilities (Peltier Effect) of the Surface that is Exposed to the Plasma Layer.

*F.S. Denes
Collaborators: Biological Systems Engineering and Center for Plasma-Aided Manufacturing, UW Madison.

Goal: Conversion of low-temperature- and low pressure-deposited organic, crystalline or non-crystalline, sole or multiple thin layers into solid phase three-dimensional macromolecular networks with potential use in microelectronics and optical applications. The functionality of the plasma tool is under evaluation.

Energy Intensity and Environmental Impact of integrated Dairy/Bio-Energy Systems in Wisconsin: The Green Cheese Project

*DJ Reinemann, KG Karthikeyan, L Armentano, V Cabrera, J Norman, PD Thompson, TP Fonseca
Funding: Wisconsin Focus on Energy, Environmental and Economic Research and Development Program
Collaborators: UW Biological Systems Eng.; UW Dairy Sci.; UW Soil Sci.

We are developing a decision aid for dairy farmers, dairy processors and policy makers, to quantify the energy intensity and environmental impacts of integrating dairy and bio-fuels production systems as well as the implications of implementing selected new technologies and management practices on the energy, green-house-gas (GHG) and nutrient balance of individual farms and aggregated for the state of Wisconsin. Dairy production is the backbone of Wisconsin's rural economy. The development of renewable energy sources, particularly bio-fuels and other bio-feedstock for energy production will need to be incorporated into the dairy production infrastructure of the state so that both economically viable and practical.

Energy Power and Energy Systems

Energy Self-Assessment Website Maintenance

*DJ Reinemann, SA Sanford, Paul Kaarakka (Soil Science)
Funding: USDA-NCRS
Collaborators: UW Biological Systems Eng.

Project provides maintenance and web hosting services for the Energy Self-Assessment web site previous developed. Provide troubleshooting, error corrections and programming support. Answer e-mail and phone inquires as needed. Provide assistance and programming in transferring the website to USDA at the end of the maintenance period.

Structures/Construction

Shallow Post and Pier Foundation Design Standard

D R Bohnhoff
Funding: Natl. Frame Building Assn.; UW Biological Systems Eng.

ASAE EP 486.1 *Shallow Post Foundation Design* was an existing ANSI/ASABE standard referenced in the International Building Code (IBC) that was in need of a significant overhaul. Work on a revision began in 2007 at UW-Madison, and in June, 2011 a near complete draft of a replacement document was sent to the ASAE EP 486 Standard Development Committee (SDC). The last major part of the document (LRFD resistance factors and ASD safety factors) was formulated in early 2012, enabling a subsequent review of the document by the SDC. Following adjustments recommended by the SDC, the document was forwarded to ASABE for an approval vote. By late summer, the document received the necessary ASBAE committee approvals, and a subsequent approval by ANSI.

The revised document: ASAE 486.2 *Shallow Post and Pier Foundation Design* addresses several major shortcomings of it predecessor. Specifically, it addresses both pier and post foundations, includes a load and resistance factor design (LRFD) methodology in addition to allowable stress design (ASD), has requirements for concrete footing thickness, does not assume lateral stiffness of all soils increases linearly with depth (any variation in stiffness can be modeled), and at-grade forces (axial load, shear force, and bending moment) in a pier/post are not assumed independent of below-grade deformations. Lateral load capacities are no longer restricted to applications where assumption of an infinite flexural rigidity (E*I) held up, and thus analysis of deeper foundations are possible. Additionally, the former version completely ignored safety factors (i.e., it made no difference how soil properties were determined and end use of building did not impact design). Other more minor shortcomings of the previous version (that were addressed in the revised edition) were: nomenclature was not consistent with that used in geotechnical circles, there was no coverage of attached footings, there was a requirement that soils must be homogeneous for the entire embedment depth, a requirement that the effective width of the below-grade portion of the post or pier be constant, and a lack of equations for calculating actual lateral soil pressures.

Efforts going forward will be concentrated on the development of documents that show how to properly implement the engineering practice with a series of example analyses.

Bending Properties of Wood I-Sections

D R Bohnhoff, A J Holstein
Funding: USDA Hatch; UW Biological Systems Eng.

With few exceptions, post-frame buildings are currently constructed with posts featuring identically-sized members that are vertically-laminated by nailing and/or gluing. I-shapes, while standard for columns in steel buildings, have not been used in post-frame construction. Possible reasons for this include: (1) the difficultly of forming a long, straight and non-twisted I-sections from three-pieces of dimension lumber, especially if the wood has been preservative treated (this because of warping associated with treating and subsequent drying), (2) complete dependence of wood I-section strength on flange-to-web connections (which makes behavior difficult to predict), and (3) the difficulty of splicing flanges to form longer wood I-sections.

With respect to warping, many residential builders now use laminated strand lumber (LSL) studs instead of dimension lumber studs in tall walls to escape warping related finishing problems. In like fashion, one would have to believe that the use of LSL in place of dimension lumber for I-post webs would produce straighter, and less-twisted posts.

With respect to bending about the strong axis, a wood I-section that exhibits complete composite action (i.e., an assembly in which there is no slip between flanges and web) is generally always superior to a rectangular post. For example, a post that is vertically-laminated from three nominal 2x6's is not as strong in bending as a wood I-section fabricated from three nominal 2x4's when the flanges and web are rigidly glued together and web shear does not limit assembly strength. With respect to weak-axis bending, wood I-sections generally have an advantage over rectangular posts that are nail-laminated because of interlayer-slip in the nail-laminated assembly. To reduce interlayer slip in nail-laminated assemblies under lateral load, engineers frequently add a bead of elastomeric adhesive between layers.

In addition to potential bending strength advantages over rectangular posts, wood I-sections are thermally more efficient. I-section webs (which are only 1.5 inches thick) represent the only spot in the wall where wood runs uninterrupted between exterior and interior building surfaces. For a nine-foot bay spacing, this is equivalent to only 1.4% of the total wall area. Current mechanically-laminated posts not only have 3 to 4 times this area, but the space between laminations allows unimpeded air infiltration through the wall.

The objective of this research project was to use MLBeam (a special finite element analysis program for horizontally mechanically laminated assemblies) to optimize the design of wood I-sections, and then laboratory test selected I-section designs.

During 2008, lumber for laboratory testing was obtained and the specific gravity and modulus of elasticity of each piece ascertained. In 2009, a series of load-slip tests were conducted on mechanical fasteners and the resulting data was used along with MLBeam to model and optimize I-section design. This modeling work was immediately followed by the fabrication and laboratory testing of 36 I-sections and ten vertically-laminated assemblies. To determine the effect of polyurethane adhesive, 18 of the I-sections were fabricated using only screws, and the other 18 were fabricated using both screws and polyurethane adhesive. All 10 vertically-laminated assemblies were fabricated using screws only.

These bending testing showed that bending strength and stiffness were increased by the reconfiguration of members into an "I" shape. The design bending strength of the I-sections fabricated with screws and adhesive was 170% greater than that for the traditional vertically-laminated assemblies. Initial bending stiffness was similarly increased by 520%. The addition of polyurethane adhesive to the I-sections resulted in a 54% increase in composite action which led to increases in design bending strength (75%) and initial bending stiffness (150%).

Details of modeling and laboratory tests were made public in to papers published in 2010.Publication of work on this research continued through 2012.

Bending Properties of Concrete -to- Wood I-Section Connections

D R Bohnhoff, A J Holstein
Funding: USDA Hatch; Perma-Column, Inc.

Post-frame building posts are either (1) embedded in the ground in which case they function as part of the foundation, (2) attached to a concrete slab, (3) attached to a concrete wall, or (4) attached to a concrete pier. Any post embedded in the ground must be preservative treated. Posts attached to concrete generally do not require preservative treatment unless above ground conditions require it.

Over the past decade, an ever increasing number of post-frame buildings have featured posts attached to concrete piers – both precast and cast-in-place piers. This trend is driven by a desire to produce a more durable and environmentally-friendly structure. Most builders and owners feel that a concrete pier will outlast an embedded, preservative-treated post. Builders are also concerned about the corrosiveness of wood treatments which have replaced CCA. Building on concrete slabs, walls and piers provide similar levels of post protection, however of these three, piers require measurably less concrete. Additionally, precast piers can be easily removed and reused.

With the development of a wood I-section (see previous section) has come the need to develop an adequate means for connecting wood I-sections to concrete. The method of attachment used can significantly impact how applied building loads are distributed to building components. In most cases, posts are attached to concrete using relatively light hardware such that the connection behaves more like a "pin". By providing a much more rigid connection, design engineers are often able to either reduce overall post size, rely less on diaphragm action, and/or rely less on rigid frame design for building stability.

In this study, twelve different wood I-section-to-concrete connection designs were studied: six utilizing hot-rolled steel angle screwed to the wood I-section, two using hot-rolled steel plate bolted to the wood I-section, and four using cold-formed steel C-sections bolted to the wood I-section. Three replicates of each design were tested. These tests showed that connections made with cold-formed steel C-sections had the highest bending strength and stiffness, however, when material cost, labor, and fabrication equipment are taken into account, the design featuring hot-rolled steel plate may be a more attractive connection for some practitioners. Details of these laboratory tests were made public in an ASABE paper published in 2010. Publication of work on this research continued through 2012.

Insulated Wood Foundation for Hoop Houses

D R Bohnhoff, A J Holstein
Funding: UW Biological Systems Eng., Happy Roots Farm, USDA NRCS

A hoop house is a structure whose main structural components are semi-circular hoops. Virtually all hoop houses are covered with greenhouse plastic (e.g., 6 mil, multilayer, UVA protected polyethylene), in which case they may be referred to as a polytunnel or polyhouse. Hoop houses that are tall enough to walk in comfortably are called high tunnels.

Construction of high tunnels in the Midwest continues to increase at an increasing rate as more small farmers look to extend their growing season. In some cases, row covers and heating tubes are used in high tunnels to enable year-round vegetable production.

Hoop houses are popular because of their low cost which can be attributed to the low cost of the plastic cover, and the minimal foundation system required for their support. With respect to the latter, it should be noted that anchorage/support of smaller hoop houses is obtained by simply driving the ends of the semi-circular hoops into the ground. Conversely, shallow cast-in-place concrete pier foundations are typically used to support large hoop houses.

The primary purpose of this project was to develop and construct an insulated wood-foundation for hoop houses that are both large and intended for year-round operation. The drive to develop a wood foundation for hoop houses is directly attributable to the construction and cost advantages that they have shown to have over concrete piers in post-frame buildings. In addition, isolated foundations fabricated from rectangular components are easier to insulate than are those involving circular piers.

A secondary objective of this study was to demonstrate use of the newly revised ASABE Engineering Practice (EP) for shallow post and pier foundations (ASAE EP486.2). In practice, few hoop houses have been structurally analyzed, and seldom, if ever, has a hoop house foundation been checked for its adequacy under load.

In 2012, a 30- by 72-ft hoop house with 8 foot side and a 6-foot hoop spacing was designed and constructed. The end of each hoop was bolted to a wood pier fabricated from nominal 2- by 6-inch, No.2 CCA-treated southern yellow pine.

Each pier consisted of a single piece of lumber to which the hoop was attached with three 3/8-inch diameter bolts. Attached to the bottom of this piece of lumber where two 12-inch long 2- by 6-inch uplift blocks and a 12-inch long 2- by 6-inch bearing plate.

The manner in which the wood pier foundation was designed, enabled quick attachment of 1-inch thick extruded polystyrene board insulation around the perimeter of the foundation. This insulation varied from 18 inches in depth to 24 inches in depth.

A publication detailing the design and construction of the insulation wood foundation is currently in development for presentation at the 2013 ASABE International Meeting.

Thermal Envelope Design For Post-Frame Buildings

D R Bohnhoff, A J Holstein
Funding: USDA Hatch; National Frame Building Association

To properly estimate the heat flow through a building's exterior shell, one must determine the overall thermal efficiency of the building's envelope. The envelope is comprised of all the materials that physically separate the building's exterior and interior environments. Each of these materials may have a different level of thermal transmission and the combination of materials may create complex modes of heat transfer, including air infiltration. Heat transfer through the envelope therefore becomes non-uniform, three-dimensional, and very difficult to accurately model. The best method for determining the overall thermal efficiency of a building's envelope is the large scale testing of representative wall and roof sections side by side in laboratory conditions. This testing is carried out using a Rotatable Guarded Hot Box (RGHB).

To determine the thermal transmittance (or thermal resistance) of an assembly under steady state conditions, it is necessary to know the heat flow moving through a given area of the assembly and the temperature difference on both sides of the assembly. Whereas area and temperature are easy quantities to measure, heat flow requires a five sided metering box – a box that is placed with its open side against the warm face of the test panel. If the temperatures on the inside and outside surfaces of the metering box are the same, there will be no heat flow through the walls of the metering box, and thus any energy input to the metering box must flow through the assembly to maintain steady state conditions. To maintain the same temperature on both sides of the metering box, the metering box is surrounded by a guard box (hence the name guarded hot box). The temperature in the guarded hot box is regulated during the test so that it matches that inside the metering box.

In order to test specimens over a greater temperature gradient a climate chamber is attached to the other side of the test specimen which can be cooled and maintained at a steady state temperature. To test roof sections as well as wall sections the entire apparatus will be mounted in a steel frame that allows it to be positioned horizontally, vertically, and at any angle in between. Hot boxes of this type are referred to as "rotatable." Design of the UW-Madison RGHB relatively complete and fabrication is well underway completion expected during the summer 2013.

Material Conditioning and Storage with Saturated Salt Solutions

D R Bohnhoff, B A Brooks
Funding: UW Biological Systems Engineering

Changes in the properties of feeds, foods, fiber and other organic materials during storage is highly dependent on the temperature and water vapor pressure of the surrounding environment. By regulating temperature and relative humidity, the respiration rates and/or moisture content of an organic material can be controlled. This research is part of a larger effort to investigate sustainable ways for storing organic materials. More specifically, this research is aimed at evaluating inexpensive, low energy consuming and environmentally-friendly ways to maintain desired storage environments.

In 2008, a series of experiments involving popcorn seed were undertaken. The objective of the study was to increase the moisture content of some very dry popcorn by suspending it above saturated salt solutions in a controlled temperature environment. For optimal popping (large popping volume and minimal unpopped kernels), popcorn should be near a moisture content of 14.0%. At higher or lower moisture contents, popping is less than ideal. In fact, at moisture contents 5% above or below the optimal, expect popping volume to be cut in at least half.

In our study, both sodium chloride and potassium chloride salts were used. These two salts comprise virtually all salt used to soften water, hence they are inexpensive, safe, and readily available. The results of initial studies demonstrated that very dry popcorn – popcorn that most people would have long thrown out because of extremely poor popping – could be easily re-conditioned to a product with outstanding popping characteristics. Ongoing work involves laboratory studies to assess relationships between numerous factors affecting conditioning rates.

By locating storage containers a few feet below the ground surface, a fairly constant temperature can be achieved year round. If organic materials are sealed in these containers over saturated salt solutions, the material can be stored at a fixed temperature and relative humidity year round without requiring any outside energy source.

NRCS Technical Manual For Post-Frame Building Design

D R Bohnhoff
Funding: USDA Natural Resources Conservation Service

The NRCS entered into contract with UW-Madison for the development of an extensive technical manual covering post-frame building design. Work on the document began in October, 2009 and has steadily progressed. Prior to 2012, drafts of the following chapters were completed: The Post Frame Building System; Introduction to Structural Design; Determinate Structural Analysis; Mechanics of Materials; Building Materials; Design Properties for Wood Members and Connections; and Stress Checks and Member Use Restrictions. During 2012, drafts on chapters titled: Indeterminate Structural Analysis; Structural Loads and Deflection Criteria; FEA Program Features, Modeling Techniques and Limitations; Post Design; and Purlin and Girt Design were completed. The remaining chapters are being drafted through a subcontract with UW-Madison and should be completed during 2013.

Small-Scale Facilities for Winter Storage of Fresh Produce

D R Bohnhoff, S A Sanford, J. Hendrickson
Funding: SARE (USDA)

Many small vegetable growers could increase their incomes and supply more local produce by increasing the amount of fall harvested crops that are grown and stored for marketing during the winter months. Winter storage facilities are needed to hold and maintain crop quality during the winter and differ from summer storage in that they need to be able to cool and warm depending on outside temperatures as well as maintain humidity levels. Many of the facilities used currently are not planned well for material handling and lack equipment and controls to maintain proper humidity to keep product weight loss at a minimum. There are limited resources to help growers plan, construct and manage a storage facility. This grant will develop sample plans for an earth-contact storage room, an above-ground storage room and a storage room built into an existing structure. The plans will be scalable so growers can modify them as needed to fit their own situation. We will develop a spreadsheet decision tool to aid growers in determining if winter storage crops will be economical for a growers operation. Extension bulletins will be developed to guide growers though the planning and construction process and management of a storage facility. A grower advisory group will be used to provide input and critique the plans and printed materials. Outreach will be multifaceted utilizing workshops, webinars, printed materials, an informational web site and consulting. Ultimately, the information will provide growers the tools needed to plan, build and manage a storage facility for an economic benefit.

Safety and Health

Promoting Prevention and Health among Wisconsin's Rural Older Adults

*LJ Chapman, AC Newenhouse
Funding: USDA NIFA Rural Health and Safety Education Competitive Grants Program
Collaborators: UW Biological Systems Eng.; UW Coop. Ext. Service

As stated in our original application, our project has three objectives:

Program Objective 1. Improve fall protection among at least 10% of the estimated 1,207 older adults residing in the community in five rural counties (Columbia, Sauk, Richland, Iowa and Green) who are receiving home health care services by promoting the awareness and adoption of vitamin D supplements and a home exercise program (covered by Medicare) through a concentrated education and outreach effort to providers of home health services, and to rural older adults and other community partners.

Program Objective 2. Improve fall protection among at least 10% of the estimated 1,441 older adults residing in long term care facilities in the same five rural counties by promoting the awareness and adoption of vitamin D supplements and a home exercise program (covered by Medicare) through a concentrated education and outreach effort to the staff of long term care facilities and to older rural adults (i.e. vitamin D supplements and nursing staff fall dairies).

Program Objective 3. Evaluate the success of the efforts in the two settings to increase awareness and adoption of fall prevention measures among providers of home health services and staff in long term care facilities in the five rural counties. Also, network with community partners including older rural adults, their family members, care providers and others in the various settings they may reside in to encourage adoption of more intensive, multi-factorial fall prevention interventions.

Machinery and Harvesting

Hazelnut Husker, Separator and Sorter

D R Bohnhoff, B J Noe, I E Nordeng, J D Swarthout, B S Welsh
Funding: D R Bohnhoff, UW Madison Biological Systems Engineering

Currently, a number of small farmers in the upper Midwest are growing hybrid hazelnuts in hopes of discovering a cultivar with characteristics that would enable hazelnuts to be profitably grown in the region. This effort has its roots in work initiated by Phil Rutter of the Badgersett Research Corporation located near Canton, MN (http://www.badgersett.com/) and is now being promoted by the Upper Midwest Hazelnut Development Initiative (http://www.midwesthazelnuts.org/).

Hazelnuts grow in clusters, which each nut in the cluster surrounded by a husk. To ensure that the nuts do not fall prey to wildlife, the hazelnut clusters are removed from hazelnut shrubs before they are fully mature. Although this removal has been by hand, this past year saw the first attempt at mechanical picking in upper Midwest. Once clusters are picked, they are air-dried and then husked. Husked nuts are then typically sorted by size and sold. Further processing involves removal of the kernel from the shell and almost always requires a commercial processing license and food-grade equipment.

Until a high producing cultivar is found, most farmers growing hazelnuts in the upper Midwest will not be able to invest large sums of money in hazelnut harvesting and processing equipment. As a result, individuals associated with the Upper Midwest Hazelnut Development Initiative (UMHDI) have pushed for the development of a low-cost husker. Although various huskers have been developed, their use is restricted to small batches or they are felt to be too expensive.

In an attempt to meet specifications set forth by the UMHDI, a husker has been developed that consists of (1) a bin with a mechanical feed, (2) a hammer mill that removes the nuts from their husks using rubber flails/hammers, (3) an air separator with a special air lock system that separates the nuts from their husks in a continuous manner, (4) a rotary drum sorter that separates nuts by size, and (5) a set of husked nut storage bins. These five units are mounted on an easily movable cart along with the 1.5 hp electric motor that is used to drive the devices. A separate movable cart contains (1) a 2 hp motor with impellor to generate the vacuum needed for the system, (2) a cyclone separator to separate large husk particles from small husk particles, (3) a large particle storage bin (located beneath the cyclone separator), and (4) a 5 micron filter bag with collector storage for fine particles. A hose from the inlet side of the cyclone separator connects to the top of the air separator on the other cart.

The entire system was tested in June of 2012. Unfortunately, several problems were encountered requiring re-design of many machine elements. Fabrication of a second version began toward the end of 2012 and should be ready for testing in late February, 2013.

The Value of a Packing Device for Improving Bunker Silo Densities

BJ Holmes, RE Muck, FE Contreras-Govea
Funding: USDA Agric. Res. Service
Collaborators: Agricultural Research Station-Arlington, Agromatic, Inc., USDA Dairy Forage Res. Ctr.

Objectives: High bulk density is important for bunker and pile silos to minimize dry matter losses, especially when silos are opened for feeding. As forage harvesters have increased in capacity, achieving a high density in bunker silos has become more difficult as the available packing time per ton of crop decreases. A new class of pull-behind devices for packing tractors has entered the market to potentially increase silage density. The object of this study was to compare corn silage density with and without the use of a pull-behind packer.

Progress: Whole-crop corn was harvested and placed in two bunker silos at the UW Agricultural Research Station at Arlington in September 2012. One bunker was filled at a time with alternate loads emptied on the left and right sides of the face. Three similar, dual-wheeled, 30,000 lbs. tractors were used to fill the bunkers. One tractor equipped with a blade spread corn on both sides of each bunker. After each load was spread, another tractor was used to pack each load in place. One side was packed by tractor alone and the other side with a tractor pulling a 10,000 lbs. silage packer. Spreading and packing times were recorded for each load. As the silos are emptied during 2013, core samples will be taken periodically to measure density on both sides at 6 different heights and 2 distances from the side walls.

Engineering Aspects of Harvesting Corn Stover as a Biomass Feedstock

K.J. Shinners*
Funding: John Deere Harvester Works
Cooperators: UW Biological Systems Eng.

This research deals with the engineering aspects of bio-mass feedstock production from corn crop residues. Biomass feedstocks can be used to produce transportation fuels by enzymatic hydrolysis and fermentation, by gasification or by direct combustion. The objectives of this project were to modify the grain combine harvester to produce a bale of corn stover at the same time grain is harvested using a single-pass

approach and to quantify machine performance and system productivity. The single-pass system used a towed round baler powered by the combine to collect the cob and husk MOG exiting the rear of the combine. . In 2012, evaluations were conducted when harvesting wheat grain and straw. Straw yields produced by grain yields of more than 120 bu/ac challenged the capacity of the accumulator, resulting in considerable reduction in harvesting speed. Accumulator unloading time was well correlated with straw particle-size. Modifications to the ear-snapper header in the form of stalk cutoff disks were made to increase corn stover yield compared to the stock configuration. The addition of the stalk cutoff disks increased stover yield by 6 – 73% depending on number of rows modified, crop moisture and maturity. Performance characteristics such as bale density, stover yield and specific fuel consumption were quantified.

Harvest of Perennial Grasses as Biomass Feedstocks

K.J. Shinners*, J.C. Friede
Funding: USDA through CenUSA
Cooperators: UW Biological Systems Eng.

This goal of this research is to develop logistics systems that are easily adaptable, produce highly consistent feedstocks, and are efficient and sustainable. Toward that goal, in 2012 our research concentrated on three areas: enhanced field drying techniques; improved bale aggregation and handling; and quantification of the total energy required to produce the physical form needed for a near conversion ready feedstock. Field Drying: We investigated two techniques to enhance the drying rate of switchgrass: intensive conditioning and wide-swath drying. Intensive conditioning involved mechanisms to hard crush the stem accompanied by shear forces to disrupt the waxy epidermis of the stem. Wide-swath drying involved a post-cutting tedding operation that distributed the crop across the full cut-width. Although not consistent across all studies, intensive conditioning generally was more effective than wide-swath drying at improving switchgrass drying rate. The combination of intensive conditioning and wide-swath drying consistently resulted in the greatest drying rate. In three separate studies, this combination produced switchgrass moisture contents well below 15% (w.b.) on the second day after cutting. Bale Aggregation: A baler was modified to accumulate bales and place them in straight rows perpendicular to the direction of travel with rows located either in the headlands or in the middle of the field. This strategic bale placement scheme was investigated as a means to improve bale handling logistics. Time and motion studies for various bale handling strategies were conducted. Overall, accumulation and strategic bale placement reduced time to load bales by 38% and total travel distance in the field by 40%. Energy Requirements: The energy required to size-reduce biomass crops either at the time of harvest or post-storage was quantified for corn stover, switchgrass, reed canarygrass, and sorghum. Three size-reduction mechanisms were used: round baler with pre-cutter; forage harvester; and tub grinder. Using a pre-cutter on a baler increased bale density by 0 to 10% and increased specific fuel consumption by 10% to 23% with an average of 17%. A wide particle-size distribution resulted from use of the baler pre-cutter. Size-reduction by chopping with a forage harvester or by tub-grinding produced similar particle-size and mass throughputs. However, the combination of baling followed by post-storage tub grinding required more than twice the specific energy compared to chopping with a forage harvester.

Natural Resources and Environment

Optimization of Dual Conjunctive Water Supply and Reuse Systems

*Choi, C., Mondaca, M.
Funding - NSF

The purpose of the study is to develop a faster and more accurate means of estimating the cost inherent to designing and operating the water distribution systems of residential subdivisions. The study will use Genetic Algorithm to minimize the cost of constructing and operating a water distribution network while maintaining the minimum pressure needed to meet the peak demand and the fire flow constraint. The significant independent variables associated with this problem include the total area covered by the network, the population density of the area and the overall slope of the terrain within the area. Similar studies have been conducted previously, but none considered the hydraulic components involved, and none sought to model better network configurations at the same time. The present study will produce a reliable method for estimating the cost of operating an actual water distribution network. To accomplish our goal, we plan to survey the standard street layouts of several existing residential subdivisions and then, using Genetic Algorithm, determine the costs associated with the construction and operation of a range of different network configurations. In this way, we will be able to reassess the cost-function analysis of the real-world water distribution network configurations as well as the cost-functions of various hypothetical configurations. Ultimately, we want to develop a modeling tool that engineers and managers can use to quickly and accurately assess the costs of operating mid-sized, mid-density residential subdivisions. The tool could also be used to estimate the optimal cost to construct the water distribution network configuration for a particular subdivision with the known slope of the terrain and the projected population density.

P Index and Snowmelt Runoff Risk Assessment: Demonstration and Refinement

AM Thompson, *J Panuska, L Ward-Good and KG Karthikeyan
Funding: USDA NRCS – Conservation Innovation Grant
Collaborators: UW Biological Systems Engineering; UW Soil Science, Dane County Land & Water Conservation Division, Madison Metropolitan Sewerage District

Wisconsin's current nutrient management standard limits the volume of liquid manure and restricts application locations for winter spreading. Many small and medium sized dairy farms do not have adequate storage to contain all of the manure generated during the four to five month period when the soil is frozen, therefore winter spreading remains a common practice with 60% of the state's dairy farmers hauling manure to fields daily. The Wisconsin (WI) P Index is a modeling tool developed to assist producers with nutrient management planning and is used in preparation of the large majority of nutrient management plans in Wisconsin. The P loss that occurs during the snowmelt and rain on frozen ground period can be significant. Accurate estimates of management and site effects on snowmelt runoff volume are important to identify high P loss areas and evaluate suitable management options. No widely accepted method currently exists for estimating average runoff volume from snowmelt and rainfall on frozen and thawing soils that is appropriate for a field-scale management planning tool like the P Index. It was therefore necessary to develop an empirical method that uses the monitored long-term average frozen soil period runoff from agricultural watersheds. Using this method, prior to calculating an individual field's P Index, the initial runoff volume at the watershed scale is adjusted using a "Fall Soil Condition" factor that accounts for potential in-field melt water storage in surface depressions from tillage. For some field conditions, fall tillage may result in lower annual total surface runoff P losses. Thus, quantifying the effects of management (fall tillage in particular) on snowmelt runoff allows for the selection of management scenarios that can lower total average annual P loss from specific fields. The goal of this research is to test and refine the method used in the WI P Index to determine the effect of field management practices on frozen soil runoff volume.

Laboratory and Field Evaluation of Two Passive, Low-Cost Samplers for Monitoring Edge of Field Surface Water Runoff

*J. Panuska, D. Busch, R. Stephens, P. Parker and J. Elmo Rawlings
Funding: *UW Consortium for Extension and Research in Agriculture and Natural Resources (CERANR)*
Collaborators: University of Wisconsin-Madison, University of Wisconsin-Platteville, University of Wisconsin-Stevens Point, University of Wisconsin-Platteville and University of Wisconsin-Platteville

The demand for information regarding the quality and quantity of surface-water runoff from agricultural landscapes has increased greatly in recent years and there have been many automated and passive devices constructed to monitor this runoff. Automated equipment functions well and allows for considerable flexibility in designing a monitoring program; however, automated equipment is expensive and requires significant technical expertise to operate and maintain. Passive samplers, in contrast, rely on the flow of water to collect the sample and are less expensive to purchase, operate, and maintain. Unfortunately, the application of passive sampling devices is hampered because they often require significant hydraulic head differential (i.e. slope) to operate and/or are only capable of monitoring catchments of 1 acre or less. The principle investigators have developed prototype samplers that overcome the two main barriers to passive sampler use. These samplers obtain a small portion of total discharge, and can therefore be used to monitor large catchments. In addition, they can be used in locations with little slope. Initial tests using tap water have shown that the samplers function well. However, additional research is needed to determine if the samplers can operate under field conditions. The passive samplers will cost significantly less to operate and will require much less technical skill to install, operate, and maintain. The goal of this project is to determine if the passive samplers accurately estimate event discharge, water quality, and runoff sediment characteristics. If successful, the research will create much greater opportunity for monitoring surface-water runoff for a multitude of applications such as: TMDL load allocation, BMP evaluation, computer model validation, and green tier certification.

Implications of Phosphorus Recovery from Wastewater for Biosolids Management

*K.G. Karthikeyan, K. Gungor, R. Bashar
Funding: USDA Cooperative State Research, Educ. and Extension Service
Cooperators: UW Biological Systems Eng.

Biosolids application to croplands, a popular nationwide practice, is typically not environmentally sustainable under N-based nutrient management. With increasingly stringent effluent P regulations, this problem will be exacerbated due to even higher biosolids P content. Wastewater treatment plants (WWTPs) can employ emerging P recovery technologies (in both main- and side- streams) to meet the effluent P standards and produce high grade P minerals (slow-release fertilizers or P industry raw material). Project objectives are to: (a) evaluate the cost-effectiveness of the emerging P recovery and the established P removal processes, (b) generate critical data to support environmentally sound management of biosolids P, and (c) create a comprehensive cost evaluation tool for the commercially-available P recovery processes. A combination of laboratory experiments and modeling analysis are being employed. Cost-effectiveness of several conventional P removal and emerging P recovery configurations will be evaluated using a WWTP simulation software (P recovery units will be integrated into this software). Forty residual (biosolids + recovered minerals) samples will be collected from exemplary WWTPs to directly determine P source coefficients. A cost evaluation tool capable of estimating fixed and variable costs, and struvite (Mg ammonium phosphate mineral) selling price will be developed for a full-scale operational struvite recovery unit. Our results will help determine the environmental sustainability of biosolids management, specifically for P, under various scenarios comprising both established P removal wastewater treatment processes and emerging P recovery technologies.

Crop Plant Uptake of Pollutants of Emerging Concern

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Funding: USDA Cooperative State Research, Educ. and Extension Service
Cooperators: UW Biological Systems Eng.; UW Soil Science; Wisconsin State Lab of Hygiene

Land application of biosolids and irrigation with reclaimed water are widely practiced throughout the world, the former in both humid and dry regions and the latter in semi-arid/arid areas. Both practices offer numerous benefits (reliable water supply from reclaimed water; nutrients + organic matter inputs) that could increase agricultural sustainability, an important consideration given increasing global food demand and erratic rainfall patterns. However, the presence of certain constituents could impose restrictions and create serious environmental risks. Specifically, pharmaceuticals and personal care products (PPCPs), a subset of chemicals of emerging concern (CEC), deserve serious attention because conventional wastewater treatment processes do not effectively remove them from treated effluent, and they have been detected in wastewater effluents, biosolids, soils receiving biosolids applications, and surface and ground waters. Some CECs can be taken up by crop plants, and yet information on polar/ionogenic CECs (characteristics of PPCPs) is lacking and the mechanisms of CEC translocation to different plant components are poorly understood. We are systematically evaluating the bioaccumulation of CECs with contrasting chemical characteristics by crop plants differing in their edible parts (tomato, carrot, and spinach). Specific objectives are to: (a) determine the influence of soils and biosolids on CEC bioaccumulation, and (b) elucidate the influence of CEC chemical characteristics on plant uptake. Project results will increase our understanding of the fate of wastewater-derived chemicals (in biosolids and treated effluents) in agricultural systems.

Subsurface Fate and Transport of Cryptosporidium in Soils of Wisconsin's Carbonate Aquifer Region

*K.G. Karthikeyan, A.M. Thompson, S.C. Long, F. Madison, Z. Zopp, B.J. Lepore
Funding: Wisconsin Groundwater Coordinating Council
Cooperators: UW Biological Systems Eng.; UW Soil Science; Wisconsin State Lab of Hygiene

The risk of contaminating groundwater in carbonate aquifers, with their dissolved cracks, fissures and subterranean caves, by surface applied manure-borne *Cryptosporidium* is exceedingly high when thin macroporous soils overlie the bedrock. Such a landscape is found in much of Northeastern Wisconsin and understanding how its soil properties vary and influence the transport potential of pathogens is critical to protecting the region's groundwater resources. To gain this information, ten regional soils have been sampled and are being characterized according to critical transport related soil properties: macroporosity, soil texture, percent organic matter, hydrophobicity and bulk density. Large, intact soil cores of the two soils having the highest and lowest *Cryptosporidium* transport potential will then be extracted for simulated rainfall experiments designed to: **1)** Determine whether irradiated *C. parvum* and carboxylated microspheres are effective surrogate soil surface-to-groundwater tracers for future field studies of *C. parvum* transport, **2)** Determine the *C. parvum* fate and transport potential for several Wisconsin soils which have been developed overlying NE Wisconsin's vulnerable carbonate aquifer, **3)** Relate the soil *C. parvum* transport capacity to hillslope position, soil texture, soil moisture content, percent organic matter, and hydrophobicity, and **4)** Determine the ability of polyacrylamide (PAM) addition to retard the downward migration of manure-borne *C. parvum.* The information from this study will be useful to farmers, farm managers and

professionals responsible for manure-spreading decision making from the standpoint of groundwater problems and public health concerns. Additionally, our findings will be of use to agricultural and environmental scientists seeking to develop a better long-term assessment of risk and understand implications of land management decisions.

Mechanistic Insights into the Use of Oxide Nanoparticles Coated Asymmetric Electrodes for Capacitive Deionization

*K.G. Karthikeyan, M. A. Anderson, K. Gregory, L. Han
Funding: Qatar Foundation and Carnegie Mellon University
Cooperators: UW Biological Systems Eng.; UW Civil & Env. Eng.; Carnegie Mellon University

Capacitive deionization (CDI) is an emerging water desalination method, which employs high surface area porous electrode materials for electro-sorption of ions. We used an asymmetric CDI cell constructed with alumina and silica nanoparticle (NP) coated electrodes and KCl as a probe electrolyte to gain insights into electro-sorption behavior and elucidate underlying process mechanisms. This CDI system is efficient for use in desalination and up to 15 to 60 μmole/g (total electrode) sorption capacity was achieved. Higher removal of K^+ compared to Cl^- was obtained attributable to competition between OH^- and Cl^-. The presence of NPs not only creates highly accessible surface area but also increases the charge efficiency by shifting the applied potential to a high efficiency range due to protonation/deprotonation occurring on metal oxide surfaces. Data were described using both mechanistic electrical double layer (EDL) based Gouy-Chapman-Stern (GCS) formulation and empirical Freundlich equations. Our results suggest that the presence of metal oxide NPs can effectively modify the isoelectric points and an increase in planar charge efficiency of up to 20% could be achieved. However, global charge efficiency was still severely constrained by backward thermal diffusion and mass transfer limitations. EDL over-lapping effect plays an importance role in determining critical pore size for electro-sorption. The GCS model revealed that only BJH associated (pore size: 1.5 to 50 nm) surface area is effective for electro-sorption. Though the Freundlich equation adequately described the sorption data, we attribute this sorption behavior to reduction in micropore overlapping effects and an increase in mass transfer caused by higher concentration gradients. Our results are expected to guide the design and development of appropriate electrode materials for CDI.

Enhancing Solubilization of Animal Manure Organics and Phosphorus

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Funding: Wisconsin Fertilizer Research Council
Cooperators: UW Biological Systems Eng.

The major objectives of this study were to: (a) investigate the potential of commercial enzyme use and pH control for enhancing dairy manure fermentation, and (b) model dissolved organic matter and orthophosphate (PO_4-P) dynamics of the fermenters. Anaerobic lab-scale batch fermenters (initial total solids concentration (TS_o) = 3.8%) were fed with separated dairy manure solids and operated at two different pH levels (5 and 9.5). The enzyme-supplemented alkaline fermenters clearly outperformed the acidic fermenters in terms of chemical oxygen demand (COD) solubilization: *ca.* 50% vs. 20%. Soluble PO_4-P in the acidic fermenters was comparably higher, but constituted less than 20% of total phosphorus. Better soluble COD (> 80%) and soluble PO_4-P (> 70%) yields were noted for the dilute fermenters (TS_o = 0.6-0.8%). The commercial enzyme used in alkaline fermenters delivered an improved soluble organic yield of 0.5 g COD g^{-1} VS. An existing model was retrofitted, calibrated and validated for simulating the dynamics of soluble COD, volatile fatty acids, and soluble PO_4-P under various conditions (i.e., pH, enzyme addition). The calibrated model was validated using independent datasets (R^2 > 0.95) and found to have a tendency to slightly overestimate the soluble COD and VFA levels.

New Generation Mult-scale Land and Water Resources Model for Arid Zones

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Funding: UW Biological Systems Eng.; Qatar Environment and Energy Research Institute (QEERI), Doha Qatar
Cooperators: UW Biological Systems Eng.; QEERI

Pressures from population growth, expanding economies and climate change raise concerns over security of water supply in arid zone countries. There is a need, therefore, to manage arid zone resources in as efficient a manner as possible and this may be at spatial scales ranging from fields to river catchments. Mathematical models are an important aid in such management but available models have particular deficiencies in representing processes in the arid zone water cycle and in linking water resources responses and outputs across spatial scales. The overall goal of this project is to further research the hydrostructural pedology paradigm in soil-water physics to more accurately predict water flow in soil than the current modeling frameworks, specifically in the vadose zone by linking field and laboratory measurements. A central feature is to couple new understanding and model capability at the micro-

scale of soil-water physics (the KAMEL® platform, supplied by QEERI) with an existing and well-defined modeling framework for the macro-scale of the water cycle as represented by the catchment (e.g., the SHETRAN modelling system). KAMEL is an advanced thermodynamic and hydrodynamic model of the soil medium and represents the emergence of hydrostructural pedology, a new discipline at the heart of physics-based modeling of the natural environment. SHETRAN is a general, physically based, spatially distributed modeling system that can be used to construct and run models of all or any part of the land phase of the hydrological cycle, at scales from plots to the catchment. Validation of KAMEL will provide a quantitative description of not only water movement but will also define the thermodynamic status of the soil that is undergoing various biogeochemical processes.

Innovations to Improve Stormwater Management

*AM Thompson, J Zedler, S Loheide, J Panuska, S Prellwitz, J Miller, J Doherty, Z Zopp,
Funding: EPA-Great Lakes Research Initiative
Collaborators: UW Biological Systems Engineering, UW Botany, UW Civil and Environmental Engineering, The Nature Conservancy, The Environmental Law Institute

The goal of this study is to test innovative environmental approaches to treating stormwater in order to achieve beneficial outcomes for streams, wetlands, and nearshore waters of Great Lakes watersheds. A stormwater treatment system was constructed to test alternative methods of improving the quality of urban runoff to coastal wetlands. The Stormwater Management Research Facility (SMRF) is located at the University of Wisconsin-Madison Arboretum and consists of a small pond (0.12 ha) that overflows into a 1.43-ac basin that is divided into three experimental swales (each measuring 8 by 100 m) constructed with native subsoil overlain with salvaged topsoil. These wetland treatment swales received stormwater from a mixed residential and commercial watershed and were allowed to discharge or retain stormwater through use of adjustable weirs at the inlet and outlet of each swale.

In November 2009, each swale was seeded with 27 native plant species to achieve our experimental vegetation treatments and we tested three hypotheses, namely that: (1) a fluctuating hydroperiod will remove nutrients more effectively than well-drained or inundated conditions; (2) diverse vegetation will treat stormwater more effectively than vegetation with few species; and (3) combinations of hydroperiod and plant diversity will best accomplish one or more of six desired outcomes (response variables): removal of phosphorus in particulate and dissolved forms; removal of nitrogen (e.g., through denitrification); reduced erosion (e.g., through soil stabilization); enhanced infiltration; persistence of diverse native vegetation; and resistance to weed invasion.

While construction of the three replicate swales was identical, distinct hydroperiods developed in response to subsurface heterogeneities. Despite identical plantings, the vegetation of each swale developed substantially different composition and species richness. The combination of hydroperiod (high-, intermediate-, and low-water level recession rate) and vegetation led to (i) differences in soil substrate establishment that ranged in erodibility and (ii) varied responses in nutrient removal. Critical shear stress was measured as an indicator of soil stability and was highest in the high-recession rate swale and lowest in the low-recession rate swale. These values are a result of various surface substrates that developed within the swales. Biotic substrates (moss and algae) were the most resistant to erosion while abiotic substrates (organic matter, bare soil, and muck) were the least resistant. Total removal of TSS, N, and P for 13 storms was highest in the high-recession rate swale and lowest in the low-recession rate swale. The low-recession rate swale produced the most biomass (and least diversity), yet exported the most nutrients and was the most prone to erosion. The high-recession rate swale produced the least biomass (and most diversity), yet exported the least nutrients and was the most resistant to erosion.

Overall, we found significant differences in six services (stormwater retention, peak-flow attenuation, soil stability, sediment/nutrient removal, primary productivity, and diversity support) among the three swales. Stormwater retention, flow attenuation, sediment/nutrient removal, soil stability, and diversity support were all positively correlated, suggesting a strong synergy amongst these ecosystem services. On the contrary, plant productivity was negatively correlated with all of the other services considered. Recognition of this unexpected trade-off is critical since healthy and robust looking vegetation may not indicate a well-functioning stormwater treatment wetland.

Quantifying Hydrodynamic Drag of Native Wisconsin Wetland Plants

*AM Thompson, and Z Zopp
Funding: UW Grad School, EPA-Great Lakes Research Initiative
Collaborators: UW Biological Systems Engineering

Production of hydrodynamic drag by vegetation reduces the velocity of flowing water, thereby increasing residence time which can enhance particle settling and nutrient reduction. The use of wetlands to treat urban stormwater is dependent, in part, on the ability of the vegetation to generate drag and reduce flow velocities. This study measured the hydrodynamic drag of ten native Wisconsin wetland plants categorized by three functional classes (forb, graminoid, and grass) in response to varying water velocities and depths representative of expected storm event flows through wetland treatment swales at the University of Wisconsin Arboretum. Drag forces were measured in a recirculating laboratory flume. Experimental treatments consisted of three plant growth periods (two, four, and six months), four flow velocities (0.08, 0.15, 0.23, 0.30 m/sec) and three flow depths (0.06, 0.18, 0.30 m). The plants were grown in a greenhouse with similar lighting and

temperature conditions to that of a Wisconsin summer. A representative shoot from each species was attached at its base to a 0.32 cm diameter vertical steel rod that was connected to a horizontal aluminum air sled above the flume. The sled hovered on a 360 degree stream of compressed air, which allowed the sled to move without friction. The sled was connected to a 1.5 N load cell that measured the drag force generated by the plant. In addition to drag force, plant wetted frontal area and shoot bending angle were measured for each plant and flow condition. Results will be used to identify native Wisconsin wetland species and/or classes that are best suited to reduce stormwater runoff velocity and maximize potential water quality benefits in urban stormwater treatment systems.

Characterizing Sediment Delivery in Wisconsin Agricultural Basins

*AM Thompson, H Singh, J Panuska
Funding: USDA NIFA Hatch
Collaborators: UW Biological Systems Engineering

The goal of this study is to improve prediction of sediment delivery from upland contributing (source) areas to receiving waters (point of impact). A sensitivity analysis of grassed waterways (GWW) sediment delivery was conducted using the event and process-based Water Erosion Prediction Project (WEPP) model for a nested watershed located at the University of Wisconsin – Platteville Pioneer Farm near Platteville, WI. The model was calibrated for flow and sediment using the PEST (Parameter Estimation) software and a multi-year continuous data record including precipitation, meteorological variables, runoff volumes and corresponding sediment concentrations together with a digital elevation model and soil database. A program was developed using the FORTRAN language to link PEST with WEPP which automated the calibration process for the nested watershed. The calibrated model was used to find the GWW parameters most sensitive to sediment delivery. Based on the sensitivity analysis, model simulations were conducted for various combinations of channel length, Manning's coefficient for roughness and slope for storm events of varied intensities/durations. Two different executable files were developed using FORTRAN to automatically run multiple WEPP scenarios (various combinations of channel length, Manning's roughness coefficient and slope). The output from WEPP is being used in concert with storm, soil and landscape characteristics to parameterize and evaluate several simple empirical sediment delivery equations. Relationships between sediment transport equation parameters, landscape and storm characteristics will be explored. Critical shear stress was measured throughout the watershed with a Cohesive Strength Meter to support model validation. The parameterization process will be extended to agricultural watersheds across different physiographic regions of Wisconsin. Results from this study will be integrated into the Snap-Plus nutrient management planning model currently used by local water quality managers and will support TMDL development throughout Wisconsin.

Implications of Climate Change and Biofuel Development for Great Lakes Regional Water Quality and Quantity

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Funding: US Geological Survey-National Institutes for Water Resources
Collaborators: UW Biological Systems Engineering, UW Agronomy, Michigan State University, Ball State University, US Geological Survey

Many questions remain unanswered about the sustainability of water resources in the Great Lakes Region with impending climate change and major land use changes associated with intensive biofuel production. Land cover/management changes associated with conversion of prime farmland and marginal land set aside in conservation programs to biofuel crop production systems across the Great Lakes basin will have unknown, but potentially significant, impacts on the quantity and quality of groundwater recharge. This recharge is the primary source of water to streams, lakes, and wetlands across the region. Additionally, Midwestern climate is predicted to change significantly in the coming decades with warmer temperatures, as well as higher precipitation and evapotranspiration, potentially leading to a net soil moisture deficit along with more frequent flooding. Working in conjunction with the DOE Great Lakes Bioenergy Research Center (GLBRC), researchers from the University of Wisconsin (UW)-Madison, Michigan State University (MSU), Ball State University (BSU) and the United States Geological Survey (USGS) are conducting a collaborative multi-scale effort to: 1) expand an ongoing field monitoring effort to collect a detailed data set of surface and subsurface water and nutrient fluxes and above- and below-ground biomass for a variety of model biofuel feedstock cropping systems, 2) use our data set along with regional water quality and quantity data, provided in part by USGS, to further develop, parameterize and validate a new biogeophysical hydrology model, 3) use our model to explore the implications of coupled climate change and biofuel-based land-use changes for Great Lakes Basin water quantity and quality, and 4) perform a side-by-side comparison between a new landscape hydrology code and a USGS hydrology model. Forecasting the effects of large-scale changes in agricultural management practices on groundwater is a significant shift from the past when such impacts were given little consideration. There is urgent need for studies of coupled land use and climate change because both changes are happening simultaneously. Our analyses will provide important information for water resource managers charged with protection of water for ten percent of the United States population and also land managers and farmers concerned with optimizing sustainable biofuel production in a time of impending climate change.

Linking Cropping System Diversity to Water and Nutrient Dynamics in Alternative Biofuel Production Systems

*AM Thompson, KG Karthikeyan, R Jackson, R Stenjem, M Polich
Funding: UW Water Resources Institute; USDA NIFA Hatch
Collaborators: UW Biological Systems Engineering; UW Agronomy

Several high yielding cropping systems (e.g., corn, perennial switch-grass, hybrid poplar trees) are being proposed as potential cellulosic ethanol feedstocks. Assessing the sustainability of these systems requires a better understanding of water, sediment, and nutrient export dynamics when these systems are managed specifically for biofuel production. Objectives of this project are to: a) quantify both surface and sub-surface water and nutrient fluxes across varying spatial and temporal scales under the proposed alternative biofuel production systems, b) link the diversity and composition of species, functional groups, and cropping systems to water and nutrient dynamics, and c) scale results from Objectives (a) and (b) above to heterogeneous landscapes and determine long-term impacts using APEX model simulations. This project involves intensive experiments, performed on field sites comprising alternative biofuel production systems already established as part of the Sustainability Area of the DOE Great Lakes Bioenergy Research Center (GLBRC) at the University of Wisconsin (UW) Arlington Agricultural Research Station (AARS), Arlington, Wisconsin.

A randomized complete block design experiment with 8 cropping system treatments planted in 5 replicated blocks was established in Spring 2008. Instrumentation was installed to monitor subsurface water and nutrient dynamics in five of the biofuel cropping system treatments. Eleven sub-surface Automated Equilibrium Tension Lysimeters (AETLs) were installed between Oct. 2010 and Oct. 2011 in the following treatments: continuous corn (3; between and within plot duplication), corn-soybean-canola rotation (2; between plot duplication), monoculture switch grass (3; between and within plot duplication), monoculture Miscanthus (1), and hybrid poplar (2; within plot duplication). Volumetric soil moisture reflectometers and soil temperature probes were installed at each lysimeter location. Sub-surface (below the root zone) drainage samples were collected weekly during wet periods (e.g. spring, early summer) and bi-weekly during dry periods (e.g. late summer, fall, winter). Samples were analyzed in our laboratory for dissolved reactive phosphorus (DRP), nitrite (NO_2^-), nitrate plus nitrite (NO_3^- + NO_2^-), ammonium (NH_4^+), total nitrogen (TN), total phosphorus (TP), dissolved organic carbon (DOC), pH, and EC.

Small scale (1m X 1m) surface runoff collection systems were installed in the following treatments (3 replicates each): continuous corn, monoculture switchgrass, and monoculture Miscanthus. Natural runoff events (14) were collected between 30 Mar. and 26 Aug. 2012. Rainfall simulations were conducted on all runoff plots in mid-Nov. 2012. Runoff samples were analyzed for TN, TP, total dissolved P, total organic matter, pH, EC, and volume. Surface soil moisture was measured adjacent to the runoff plots from Jun. through Sep. 2012.

Plant community richness and composition were measured (Jul. 2012) in 1.5m x 1.5m quadrats using the point-intercept method in fertilized and unfertilized monoculture switchgrass, mixed native grasses, fertilized Miscanthus and native prairie treatments at the GLBRC site as well as at an unfertilized restored prairie in Goose Pond Sanctuary, outside of Arlington, WI. Soil nitrous oxide emissions were measured twice monthly from May-Sep. 2012 in each quadrat using a closed trace gas flux chamber method. Concurrently, soil temperature and soil volumetric water content were measured. Soil samples at depths 0-20, 20-50, and 50-80 cm were taken from each quadrat every 4-5 weeks from May-Aug. 2012. These samples are currently being tested for inorganic nitrogen concentrations as well as rates of potential net mineralization. Total soil carbon and nitrogen concentrations are also being analyzed for 2012. Leaf Area Index measurements (Mar. 2011 – Oct. 2012) were made. Aboveground net primary productivity (ANPP) was estimated by clipping aboveground biomass of each quadrat to ground level in Aug. 2012. This biomass was then dried and weighed. Plant matter total C and N is currently being analyzed for samples collected in 2011 and 2012. All plant community, ANPP, and nitrous oxide emissions data have been entered into a computer database. Preliminary analysis investigating the relationships among the plant community, nitrous oxide emissions, ANPP, and soil conditions (temperature/moisture) was conducted. Additional analyses with these data and soil inorganic nitrogen data are still being carried out.

As cellulosic biofuel production expands, cropping systems will need to be matched to climate, soils, and environmental concerns in a region, due to differential impacts of each cropping system on water and nutrient dynamics. Results from the first 18 months of this study suggest that high yielding perennial cropping systems, such as switchgrass and hybrid poplar, could reduce NO_3-N losses compared to systems involving corn (as the latter also requires additional N inputs). However, switchgrass systems could be vulnerable to leak more nutrients during seasons when ET demand is low (spring, winter) leading to high drainage volumes. Limited data (only for 1 season) indicate that both drainage rates and nutrient losses could be lower under hybrid poplar throughout the year. Selection of appropriate cropping systems for a region should consider potential differences in leachate dynamics and nutrient concentrations to minimize environmental impacts of biofuel production systems. The results from this study will provide critical information about vegetation diversity, nutrient retention, and water dynamics that will complement other agronomic, biogeochemical, and biodiversity efforts to assess tradeoffs in ecosystem services under alternative biofuel cropping systems.

Tools Integrating Landuser Management Decisions with Watershed Processes to Achieve Water Quality Goals

*AM Thompson, KG Karthikeyan, J Panuska, L Ward-Good, P Nowak, T Cox, F Fitzpatrick, J Lamba
Funding: USDA NIFA National Integrated Water Quality Program, Integrated Research, Education and Extension Applications
Collaborators: UW Biological Systems Engineering; UW Soil Science, UW Community and Environmental Sociology, UW Ag. & Applied Economics, UW Extension, WDNR, Dane County Land & Water Conservation Division, USGS, NRCS, The Nature Conservancy

Phosphorus (P) export in runoff from lands is of continuing concern. Certain inappropriate behaviors at vulnerable locations in the landscape result in disproportionately greater sediment and P loss occurring at those locations, thus suggesting a targeted approach to mitigation would be the most effective. To test this idea, a paired watershed study is currently underway in southwestern Dane County evaluating the ability of a targeted best management practice (BMP) implementation strategy to reduce sediment and P loads at the watershed outlet. The Wisconsin Phosphorus Index (WPI) was used to rank all fields within the Pleasant Valley watershed and land owners having fields with the top 10 ranked WPI values were contacted. Eight of the top 10 land owners are working with the Dane County Land and Water Department staff implementing BMPs. A focused farm-specific whole-farm implementation approach is being used that will optimize economic and environmental benefits for the land owner.

Characterization of in-stream suspended sediment apportionment in the Pleasant Valley watershed, which is located in the non-glaciated region of southwestern Wisconsin in the Sugar Pecatonica River Basin, was conducted between 2010 and 2012. Atmospheric fallout radionuclides (^{137}Cs and unsupported ^{210}Pb) were used as tracers to identify different sources (upland and stream bank) of in-stream suspended sediments. In-stream suspended sediment samples were collected monthly from April through October in 2010 and 2011, and from February through October in 2012 using passive time integrated in-stream tube samplers. These tube samplers were installed at six different locations in the watershed. All source materials samples were collected from the top 2.5 cm. Upland surface soil samples were collected in areas representing various land use, soil type, and slope combinations in a 20m x 20m grid with 5-m spacing within the watershed and composited for analysis. Representative samples were also collected from actively eroding banks. All the samples were analyzed for organic matter content (percent volatile solids), specific surface area, and radionuclides. Radionuclide analyses was conducted through low background gamma counters.

The results of radiometric fingerprinting of samples collected in 2010 and 2011 show that stream banks are the major contributors to in-stream suspended sediments in all the subwatersheds. In-stream suspended sediments and uplands samples are currently being analyzed for trace metals to further discriminate among different land uses (tilled cropland, no-till cropland, grassland, pasture, and woodland). These data may help us to better understand the relative contribution of different upland sources and stream banks to in-stream suspended sediments in each subwatershed.

In addition, two runoff generating events were captured to elucidate the sediment transport processes within this watershed at a shorter time scale. For these events, ^{7}Be was also used as a tracer in addition to ^{210}Pb and ^{137}Cs. The preliminary results from this event sampling show that sediment eroded from stream banks and uplands is getting deposited within the streams during smaller rainfall/runoff events. However, during larger rainfall/runoff events resuspension of the stream bed sediment occurs at some sites within this watershed. The Soil and Water Assessment Tool (SWAT) model is being used to identify fields within the watershed that contribute disproportionate amounts of pollutants to streams. Field level management information was incorporated into SWAT, including fertilizer/manure application rate, tillage, crop rotations, and crop operations. The model is currently being calibrated against the measured data collected by the USGS at the watershed outlet.

Food Engineering and Processing

The Influence of Milking Management on Microbial Quality of Bulk Tank Milk

*PL Ruegg, DJ Reinemann, SA Rankin
Funding: Hatch
Collaborators: UW Biological Systems Eng.; UW Dairy Sci.; UW Food Sci

This project will enroll 16 commercial dairy farms in a longitudinal cohort study to evaluate the ability to influence milk quality and safety by development and delivery of a milking hygiene training program for farm personnel. Microbial quality of samples of bulk tank milk will be assessed using bacterial count data (standard plate count; laboratory pasteurized count, coliform counts) and somatic cell count data performed on each load of bulk tank milk by the milk processor. Microbial quality will also be measured by detection of specific zoonotic pathogens isolated from milk samples and studies will be performed to determine if the quantity of coliform bacteria in milk can be used to predict the occurrence of Salmonella spp. and Listeria spp. in bulk milk. Study personnel will visit the farms each month and collect data to assess the relationship between measures of milking performance and the occurrence

of coliform bacteria in milk. Practical methods to monitor likely causes of microbial contamination will be evaluated. Microbial quality of milk samples obtained from 8 farms that receive a monthly milking technician training program will be compared to quality of milk obtained from 8 control farms using a switchback design.

Milking Machine Research

DJ Reinemann
Funding: Avon Dairy Solutions

This project is aimed at developing methods to characterize the performance of the milking liner and to gain a better understanding of the physiological interactions between milking machine liners and the cow. We are especially interested in understanding the influence of liner shape, material and novel new design elements.

Education

Development of Affordable Bioenergy and Bioproducts Laboratories for Education

*Troy Runge, Eric Singsaas, Zauche, Tim, and Baxter, Chris
Funding: USDA Higher Education Challenge Grant
Collaborators: UW Stevens Point, UW Platteville

This educational project will create twelve laboratory bioenergy classes that are developed to be low-cost enabling any interested University to implement either as supplementation to existing classes or as a stand-alone bioenergy lab class. The target student audience includes individuals in the STEM areas that will directly be involved with bio-based materials and energy, as well as other students that want to augment their education in the area of bioenergy. This project will result in twelve bioenergy lab activities that will be optimized using feedback from students and faculty at the three involved campuses. The materials can be used to augment existing classes or as a stand-alone bioenergy lab class. The project which initiated in September has created draft materials for 6 of the 12 labs for implementation in the Fall 2013 semester. Additionally, a draft assessment plan has been created to determine if the lab-based classes improve student understanding of bioenergy curriculum and student engagement in agriscience related fields.

EXTENSION

Dairy Production

Development of an International Web-Based Educational Program for Machine Milking

*DJ Reinemann, TH Passos-Fonseca, SA Sanford
Funding: Assn. of Equipment Manufacturers

The goal is to combine the efforts of international experts to develop a web-based educational program for milking and milk quality advisors. An international group of experts was assembled to develop a comprehensive curriculum covering the principles of machine milking, milking machine design standards, and milking machine testing, and began creating digital instructional media from the milking machine curriculum already developed by my Milking Instruction and Research Lab. We are coordinating this effort with milking manufacturers and milk plants in the U.S., Australia, New Zealand, and the U.K.

Dairy Production and Profitability

* BJ Holmes, DW Kammel, S Sanford, R Larson, DJ Reinemann,
Funding: UW Coop. Ext. Service,
Collaborators: UW Biological Systems Engineering, UW Dairy Science, UW Center for Dairy Profitability, UW Milking Research and Instruction Lab, UW School of Veterinary Medicine, University of Minnesota, University of Illinois, Iowa State University, MidWest Plan Service, Four-States Dairy Programming Group

Increasing profitability on dairy farms requires proper selection of facilities for housing, feeding, and milking. The following strategies have been proposed:

- Enhance milk production efficiency by improving cattle environment, including long day lighting which has the benefit of improving the safety of workers as they work in the barn.
- Reduce electric hazards and expenses by improving the efficiency of electrical energy use.
- Increase milk harvesting profitability by property selecting milking equipment and facilities.
- Improve efficiently of feed storage and handling through better methods of providing balanced diets and ample feeding space.
- Enhance dairy industry modernization by encouraging selection of profitable facilities.

- Protect water quality with improved methods of handling and storing manure, silage leachate, and milking center wastewater.
- Enhance calf and heifer health by improving ventilation systems in calf and heifer barns.

In collaboration with companies, other universities, and other UW departments, faculty planned and participated in conferences on a variety of dairy-related topics. We have developed publications and software to inform farmers and their advisors on farmstead planning, feed storage, feeding, animal housing, milking, energy efficiency, and manure handling systems.

Faculty have aligned themselves with self-directed teams such as the UW Cooperative Extension Dairy Team and the Four-State Dairy Programming effort. Extension educational programs related to dairy are coordinated within a team.

The Dairy Modernization workgroup of the UW Cooperative Extension Dairy Team developed and is marketing a collection of materials on a CD (Milking Parlor Start-up, Low Cost Parlor and Dairy Housing and Manure Management Alternatives) for use by agents, instructors at vocational/technical schools, and farmers to help with decision-making when transitioning from stall barn milking to milking in a remodeled parlor and housing cows in freestall barns.

Funding through a USDA-supported project is helping to develop:

- Dairy modernization website;
- Design and management options for low-cost, retrofitted milking parlors,
- Regional modernization planning workshops;
- MWPS Dairy Freestall Housing and Equipment Handbook revision development;
- Milking parlor management user group;
- Heat abatement in dairy barns;
- Dairy modernization farm visits

Maintaining Forage Quality from Harvest through Storage and Feeding

*BJ Holmes, RE Muck, M. Digman
Funding: UW Coop. Ext. Service; UW Biological Systems Eng.; ARS-USDA Dairy Forage Res. Ctr.
Collaborators: UW Coop. Ext. Team Forage; UW Agronomy

Forage is an extremely valuable component of the feed for dairy and beef animals. The quality of forage as delivered has a significant impact on the production efficiency of these animals. However, losses in feed quantity and quality through harvest, storage, and feeding are very high on many dairy and livestock farms. The following practices contribute to these losses.

- Hay exposed to precipitation.
- Hay stored without adequate protection from precipitation.
- Hay and corn silage harvested too dry or too wet.
- Hay and corn silage inadequately packed and/or covered in bunker silos, piles, and silo bags.
- Hay and corn silage improperly removed from bunker silos, piles, and silo bags.
- Corn silage improperly processed.
- Improper use of inoculants and additives that are intended to enhance forage fermentation and preservation.

Presentations were made at Forage Field Days, county extension meetings and the Wisconsin Custom Operators Conference to encourage producers to improve management in these areas. Articles on these subjects have appeared in conference proceedings, the *Crop Manager* newsletter and on the UW Cooperative Extension Team Forage website, <www.uwex.edu/ces/crops/uwforage.htm>. Computer spreadsheets were developed as decision aids and are also available at this website. M. Digman coordinated the Wisconsin Custom Operators Conference educational program.

Forage production members of Team Forage have encouraged producers to select appropriate varieties, to properly adjust equipment, and to harvest at the correct stage of maturity to enhance yield and quality. Our group has been working to preserve and feed as much of that yield and quality as possible. As recommended practices are adopted, the efficiency of forage production and livestock feeding will improve. The Harvest and Storage Work Group of Team Forage has established a website, <www.uwex.edu/ces/crops/uwforage/storage.htm>, for access to publications and software related to these topics.

The Dairy Modernization Extension Program

*Kammel, David W.
Collaborators: UW Cooperative Extension, ANRE Program Area

The Dairy Modernization Extension Program is a long term educational program and has an established recognition with Wisconsin county agricultural educators, agricultural lenders, and dairy producers. It has also garnered attention and created similar programs in other states such as Minnesota, Iowa, Illinois, Pennsylvania, New York, and Maine. The majority of work in this programmatic area is with individual dairy producers and county agricultural educator requests to develop and deliver topics in that area and provide on farm assistance. It includes presenting and coordinating programs in dairy facilities and feeding systems including low cost milking centers, free stall barns, compost bedded barns, special needs and transition cow barns, and calf heifer housing. I had over 1200 contacts via email or phone for requests for information, and spoke to over 1000 participants in extension meetings. I

worked in 42 counties with 40 different agents on client requested farm visits developing plans and providing educational materials to approximately 200 individual farms. Much of this work has been with family dairy farms growing through the transition from 60-100 cows in a tie stall barn into newer milking parlor and freestall or bedded pen housing systems and calf and heifer housing systems. New requests include integrating technology such as automatic milking systems and calf feeding systems into existing and new facility design has become more common. I have also worked with dairy goat/sheep farms as they develop their new farmsteads and point of sale operations. Requests for dairy and beef cattle handling systems are also popular.

International Dairy Training

*Kammel, David W.
Collaborators: UW Cooperative Extension, ANRE Program Area

There are a variety of international visitors that visit Wisconsin and the UW –Madison campus to be educated on modern dairy cow farmstead design. I have been invited to present dairy educational seminars through the Babcock Institute, World Wide Sires, for several groups of Chinese, and have hosted lectures on campus for international visitors from Phillipine, Finland, Belarus, and Ukraine. I was invited to speak on cow comfort and dairy farmstead design by the Dos Pinos Dairy Cooperative in Costa Rica as well a s dairy producer group in Finland.

University of Wisconsin System Research Farms Support

*Kammel David W.

I worked on several UW ARS design projects for pesticide mixing and loading pads, beef cattle handling system, and beef feeding system at several outlying stations, as well as UW Madison Dairy Cattle Center project. Most recently I was contacted to help in the design of the Beef cattle center at UW River Falls to redesign their beef handling systems used for teaching. I was also asked to help with Northeast Iowa Technical College Calmar Dairy farm teaching facility, and the UW Platteville Beef Research and teaching center.

Milking Parlor Management User Group

*DJ Reinemann, K Bolton. P Ruegg
Funding: UW Coop. Ext. Service
Collaborators: UW Biological Systems Eng.; UW Coop. Ext. Service

The objective of this project is to develop a self-sustaining user group focused on milking parlor management. The modern milking parlor is a data collection center for the dairy farm. Twice daily visual inspection of cows occurs in parlors that are not automated. In automated parlors, milk yield and other animal health and behavior data are collected during milking using a variety of sensors. These data have the potential to substantially improve the profitability of a dairy farm as well as improve detection of animal health issues and thereby improve animal welfare. These potentials are seldom used to their fullest capacity, however. National and international competitiveness in dairy production will increasingly rely on better information management to improve profitability, food safety, and animal welfare.

Electric Power and Energy Systems

WI Energy Extension Partnership Initiative

*S Gruder, SA Sanford
Funding: US Dept of Energy
Collaborators: UW Extension, UW Biological Systems Eng., WI State Energy Office

UWEX is partnering with the WI State Energy Office to develop a strategic plan for long term development of bio-energy and build community capacity for energy efficiency, renewable energy in WI. The two year project will provide an increase in outreach and educational programs, and engagement of stakeholders to increase the understanding of energy systems and renewable energy by governments and local businesses. The objective in the Agricultural sector is to increase on-farm energy conservation, energy audits, reduce energy use for the production of food and fiber and increase the awareness and use of bio-fuels through an outreach education program. Technical assistance will also be provided to facilitate and create an energy planning process for local governments and locally-based businesses.

Farm Energy and Stray Voltage Program

*DJ Reinemann, MA Cook, R Kasper, D Hansen
Collaborators: UW Biological Systems Eng.; WI Public Service Commission; WI Dept. of Agric., Trade, and Consumer Protection; Midwest Rural Energy Council

The objective of this program is to promote safe, efficient use of electrical energy in rural areas. Issues addressed include energy conservation and load management technologies for farms and food processing plants, electrical safety and power quality on farms, detection and mitigation of stray voltage, renewable energy sources, and distributed generation prospects for farms. Educational activities include the following:

- Presentations at Wisconsin Farm Technology Days and other agricultural events;
- Presentations at county, state, and national seminars;
- Support of Midwest Rural Energy Council educational efforts;
- Stray Voltage Investigators Training courses;
- Support of other state agencies with rural energy activities.

Safety and Health

AgrAbility of Wisconsin

R Straub, V Janisch
Funding: USDA NIFA; UW Coop. Ext. Service
Collaborators: UW Biological Systems Eng.; Easter Seals Wis.; Wis. Div. of Vocational Rehabilitation; Wis. Dept. of Agric., Trade, and Consumer Protection

AgrAbility of Wisconsin (AAW) is a partnership of UW Cooperative Extension and the FARM program at Easter Seals Wisconsin. Together they provide education and assistance to farmers with disabilities through three priorities: education, networking, and assistance. The primary goal of this partnership is to ensure the success of farming operations of famers with disabilities.

The education priority is done through presentations and hands on experience with Occupational Therapy and Physical Therapy students from across Wisconsin. Students from the Occupational Therapy Assistant program at Western Technical College experienced farm visits from the rural community and presentations were given to the Occupational Therapy Assistant program at MATC. AAW has also collaborated with Occupational Therapist students from the University of Wisconsin – Madison working on training materials for rural clinics and hospitals for Occupational Therapists to utilize basic references and questions to work with agriculturalists. AAW has also worked with the Bio Medical System engineering students developing a device for an amputee to use the damper pedal while playing the piano. AAW worked with the Intro to Engineering Students in 160 developing and designing a device for low harvesting produce for individuals with lower body limitations.

Networking was handled using past clients in Speaker's Bureau, AgrAbility of Wisconsin Summit, Neighbor to Neighbor meetings, and farmers' network. An advisory council meets annually to provide input for improving the program. Members of the council include past clients and representatives from agribusinesses and state agencies.

AgrAbility is promoted through staffed displays at machinery shows, demonstrations and presentations at county, area, and statewide events. The bi-annual newsletter Plowing Ahead is prepared, posted at website www.bse.wisc.edu/agrability, and sent to county Extension offices, Division of Vocational Rehabilitation (DVR) offices, rural hospitals, current and former clients. AgrAbility staff provides an in-depth awareness program through radio programs, newspaper articles, and visits to key community people and events.

For assistance priority, AgrAbility of Wisconsin staff provided direct assistance to over 2,100 Wisconsin farmers and family members with disabilities since 1991. The primary disabilities addressed were back pain, arthritis, spinal cord injuries, respiratory and cardiac problems, amputations, and cancer.

During the 2012-2013 budget year, services were provided to 403 farmers with disabilities with 94 new referrals and 183 continuing clients. Staff from the FARM program completed 104 assessments for the DVR in their 2012 grant cycle which provided support to implement the plans resulting from those assessments. DVR support facilitated the purchase of such assistive technology as powered feed carts, utility vehicles, skid-steer loaders, added steps for tractor, feed bins, and conveyors. The average DVR support per farmer served was $37,607per assessment.

The 139 clients whose cases were closed during 2012 grant year were surveyed to estimate the success of the program in meeting their needs. Forty-five farmers completed and returned their surveys, for a response rate of 32 percent. Seventy-one percent of these indicated they do a better job of farming as a result of the program.

The Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) staff provides financial analysis of the famers when requested by DVR staff. In addition, DATCP staff refers farmers to AgrAbilitiy through their Farm Center.

Improving Worker Safety on Dairy Farms

*C. Skjolaas, J.Nelson
Funding: UW Coop Ext Services
Collaborators: UW Biological Systems Engineering, UW River Falls, UW Coop Extension, OSHA, WI Technical Colleges, WI Agriscience Instructor

A continued emphasis for 2012 focused on assisting dairy farms in response to an OSHA Local Emphasis Program (LEP) initiated in November 2011. Cooperating with Professional Dairy Producers of Wisconsin (PDPW) training was provided to OSHA Compliance Safety and Health Officers, Compliance Assistance Specialist and Area Directors responsible for LEP inspections and outreach. On farm training was conducted at the UW Blaine Dairy Center to provide example dairy facilities without putting a dairy farm at risk of OSHA compliance. In response to information on the LEP, a webpage was created on the http://fyi.uwex.edu/agsafety to make a common reference site for individual's seeking further information and guidance. A two page "Quick Glance at the OSHA Dairy LEP" was developed and distributed through the UWEX agricultural agents' newsletters and at the annual PDPW conference in collaboration with the UWEX Dairy Team display. Materials were prepared for the DNR/UWEX CAFO Update Meetings held during February/March.

Dairy Worker Roundtable III was held in September, 2011 and co-sponsored with OSHA and Rural Insurance. The purpose of this meeting was to bring together the agencies, organizations, and industry representatives involved in address worker safety for dairy operations. The 31 participants were from OSHA Area and Regional Offices, WisCon, DOL Wage and Hour including Specialty Populations, PDPW, DBA, UWEX, WI Technical Colleges, Rural Insurance, National Farm Medicine Center, and dairy producers. Findings of the dairy LEP were reviewed and preliminary plans for year 2 of the LEP shared.

Two webinars were conducted to and offered to producers and other dairy industry representatives related to the LEP in December 2012. On December 6th the webinar shared LEP findings and plans for year 2 of the LEP. Webinar participants included producers, UWEX agents, insurance company representative, OSHA staff and other industry related services. The December 13th webinar focused on OSHA Recordkeeping and Reporting Requirements and how they apply to agricultural operations. Both webinars were recorded and archived at fyi.uwex.edu/agsafety.

As part of the Susan Harwood grant awarded to UW-River Falls cooperated on Year 1 of the grant that was completed September 2012. Grant activities included assisting with development of training resources focused on OSHA compliance and dairy farms. In addition assistance was provided for the train-the trainer session (13 participants) held June, 2012 and as an instructor for one producer session (6 producers) held August 2012.

The fyi.uwex.edu/agsafety website continues to be developed and provide social media interaction with agriculture community. The Dairy LEP is available on the site with additional source information to guidance documents as a service to the industry. This effort will continue to be developed and incorporated into other social media dissemination methods including the associated Facebook page.

To address safety issues related to manure storage and handling, presentation was made at the Midwest Manure Expo, August 22, 2012. A factsheet "Non-Enclosed Manure Storage Safety Tips" was developed in cooperation with Penn State and from UW BSE Cheryl Skjolaas, David Kammel, Brian Holmes and Rebecca Larson. It is available on fyi.uwex.edu/agsafety. A confined space training session was conducted in collaboration with a PNAAW member for 22 individuals working in manure handling and storage confined spaces.

In continued efforts related to agricultural equipment issues on public roads, an Implement of Husbandry (IoH) Workgroup was convened in October 2012. Cheryl Skjolaas and Richard Straub were appointed members of that workgroup. IoH workgroup reviewed current use of agricultural equipment, industry needs, road and bridge designs, and current state statutes with an Interim Report due to the Secretary of Transportation at end of January 2013. This is the first significant review of Implement of Husbandry Laws since the 1940's.

Continued providing administrative assistance for the Wisconsin Safe Operation of Tractor and Machinery Certification Program for Youth Operators. Proposed rules on changes to the Hazardous Occupation Order for Agriculture were withdrawn in April 2012 and local programs were offered. The community based programs registered 421 youth as receiving the state certificate this year. A professional development session was taught
for 54 AgriScience Instructors at part of their statewide annual conference in June 2012. Educational resources for instructors continued to be shared on the website fyi.uwex.edu/tractorcert.

Preparing for Farm Emergencies trainings are a continued need from rural rescue personnel. Equipment and resources between departments and the cooperatives for responding to a grain entrapment. An additional benefit of these programs is the community connections developed for assisting with other rural emergencies.

The Safety Reviews served as a needs assessment and provided valuable insight used when a grant was submitted in collaboration with UW River Falls for an OSHA Susan Harwood developmental grant. The grant was awarded in October, 2011 for 1 year with a possible 3 year renewal. The purpose of the grant is to develop a program for dairy managers to improve their understanding of OSHA and developing effective occupational safety and health programs. The broader goal is to develop an OSHA 10 hour course for Agriculture based on

the existing 10 hour course for General Industry and also to incorporate this into the UW Madison FISC Ag Safety and Health course and UW River Falls courses.

The fyi.uwex.edu/agsafety website continues to be developed and provide interaction with the agriculture community via the subscribe feature. In addition, on a weekly basis questions are received from the site via email. This features offer individuals a route to make direct contact for information without the concern of contacting OSHA. The questions are responded to in a timely manner and in conjunction with the appropriate agency resource person. The Dairy LEP is available on the site with additional source information to guidance documents as a service to the industry. This effort will continue to be developed and incorporated into other social media dissemination methods including the associated Facebook page.

To address safety issues related to manure storage and handling, presentations were made at the Midwest Manure Summit and the Anaerobic Digester Training for Digester Managers.

In cooperation with UWEX Dairy Worker Team and Brian Holmes, a Horizontal Silo Management and Safety video is under development. This information was requested by producers and timely with the Dairy LEP item addressing bunker silos. Video is to be completed in early 2012.

Road Safety and agricultural equipment issues heated up in late 2011. Working with the UWEX Nutrient Management team and the Professional Nutrient Applicators of Wisconsin (PNNAAW) a 1-day meeting was conducted to discuss equipment issues specifically for the nutrient applicator industry. The results of the Road Study were disseminated along with facilitated discussion on equipment issues. The 72 participants represented the major equipment and tire manufacturers, AEM, PNAAW, WCO, PDPW, WI Farm Bureau, legislative representatives, DOT, DATCP, UW BSE and UWEX. Issues related to agricultural equipment on public roads will continue into 2012.

Department of Wage and Hour proposed rule changes to the Hazardous Occupation Order for Youth working in Agriculture in September 2012. Public comment was very strong for and against the rule changes and the proposed rules remained unsigned at the end of 2011. This proposed rules have significant impact on the Wisconsin Safe Operation of Tractor and Machinery Certification Program for Youth Operators. Pending the changes and final rules, initial discussions have started between instructors, UWEX, and DPI. While programming focus remains on prevention, Preparing for Farm Emergencies trainings are a continued need from rural rescue personnel. A 3 hour webinar was offered with over 100 hundred participants at 4 sites. This webinar served as a base training for the Waupaca County Farm Rescue program held in June, 2011 with over 100 participants. J. Nelson was the lead instructor for the webinar and the tractor overturn session on the training day. C. Skjolaas assisted with the webinar and taught a session on rescue situations involving TMRs and skid-steer loaders. The Chippewa County Farm Rescue training had 33 32 participants. C. Skjolaas also conducted 3 on-farm programs to familiarize local departments with modern dairy farms in Fond du Lac, Sheboygan and Manitowoc counties in cooperation with the local fire association, UWEX and LTC reaching 150 rescue personnel. In September, Rio Creek Cooperative in Kewaunee County hosted a grain rescue training for departments in Door and Kewaunee Counties. The family run cooperative had all 15 employees attend the training along with 52 fire and rescue personnel. A key part of the training was the identification of equipment and resources between departments and the cooperatives for responding to a grain entrapment. An additional benefit of these programs is the community connections developed for assisting with other rural emergencies.

AWARDS

David Bohnhoff was honored with the ASABE 2012 Evelyn E. Rosentreter Standards Award.

John Ralph was honored with the Fulbright Fellowship, Vienna 2012-13.

John Ralph was honored with Stanford's Global Climate and Energy Program Distinguished Lecturer Award.

Scott Sanford was honored with the 2012 ASABE Educational Aids Blue Ribbon Award.

Kevin Shinners was honored with the 2012 Spitzer Excellence in Teach Award from the College of Agriculture and Life Sciences.

PUBLICATIONS

PEER REVIEWED PUBLICATIONS

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