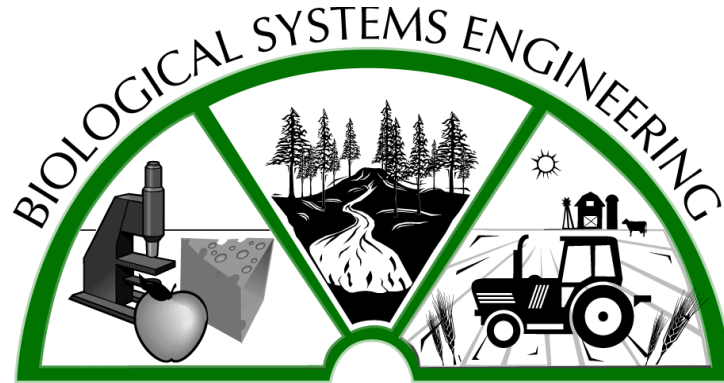


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University of Wisconsin - Madison
College of Agricultural and Life Sciences

**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 107 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 2011 Annual Summary, based on activities underway and completed in calendar year 2011. 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 ABET. The graduate program offers both Master of Science and Doctoral degrees. We have 136 undergraduate and 52 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:

Biological Systems Engineering Department
University of Wisconsin-Madison
460 Henry Mall
Madison, WI 53706 USA

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
- 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**, Assistant 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. Shinnors**, 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; Adjunct Professor in Biomedical Engineering and 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

Hailin Lin, Visiting Associate Professor, Ph.D.
(S. Gunasekaran)

Fachuang Lu, Associate Scientist, Ph.D. (X.Pan)

Jeffrey W. Nelson, Senior Research Specialist (dept. IT)
and Lecturer (farm equipment and power), M.S.

Astrid C. Newenhouse, Associate Scientist, Ph.D.;
HFHP

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

Patrick Litza, Department Administrator

Jackie Cary-Pope/Joy Liebmann, Financial Specialist

Sue Reinen/Pam Spahn, Payroll and Benefits Specialist

Debra K. Sumwalt, Student Services Coordinator

Andrew R. Grochowski, Student Worker

Postdocs and Research Interns

Asli Alkan Ozkaynak (R. A. Larson)

Kerem Gungor (K. G. Karthikeyan)

Simone Kraatz (D. J. Reinemann)

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

Horacio Andres Aguirre-Villegas (Larson/Reinemann)

Jack Buchanan (D.J. Reinemann)

Kyeong-Ok Choi (S. Gunasekaran)

David E. Cook (D.E. Combs)

Nickolas F. Deines (R. A. Larson)

Shashi Dhungel (R. Anex)

Nathen Dudenhoeffer (R. Straub)

Thais Passos Fonseca (D.J. Reinemann)

Maria Sonia Ares Gomez (D.J. Reinemann)

Lei Gu (R. P. Anex)

Sampath R. Gunukula (R. P. Anex)

Kody L. Habeck (K.J. Shinnners)

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. Shinnners)

Joseph R. Keene (K.J. Shinnners)

Sami Khanal (R. Anex)

Kelly L. Klaas (T. Runge)

Jasmeet Lamba (A. M. Thompson)

Ao Li (R. P. Anex)

Zong Liu (S. Gunasekaran)

Brock M. Lundberg (X. Pan)

Anurag S. Mandalika (T. Runge)

Chaoqun Mei (X. Pan)

Jeffrey D. Mueller (T. Runge)

Lis Nimani (X. Pan)

Jane L. O'Dell (M. R. Etzel)

Michael James Polich (A. M. Thompson)

Stephanie G. Prellwitz (A. M. Thompson)

Edgardo Ortiz Reyes (R. P. Anex)

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. Shinnners)

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)

Yi-Cheng Wang (S. Gunasekaran)

Liping Wei (J. Ralph)

Shane D. Williams (K.J. Shinnners)

Pamella J. Wipperfurth (T. Runge)

Jiang Yang (S. Gunasekaran)

Qiang Yang (X. Pan)

Jinjin Zhou (S. Gunasekaran)

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 130 undergraduate majors in Biological Systems Engineering. The major consists of a core of courses taken by all students and four emphasis areas of which students choose one: machinery systems; structural engineering systems; natural resources and environment; food and bioprocess engineering. The food and bioprocess emphasis area is split into a food engineering track and a bioprocess engineering track. The following courses are dedicated to the Biological Systems Engineering major.

- 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)

The curriculum consists of 125 credits. Our undergraduate program was evaluated in 2006 by the Accrediting Board for Engineering and Technology (ABET), and accredited again for another six years, the maximum allowable. Approximately 25 students earn B.S. degrees each year.

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.



Biological Engineering

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: Farmers 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. 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 that the rumen microorganisms were growing better on the inoculated silage. Analysis of the rumen microbial community indicated that inoculation of the silage produced no major shifts in microbial species growing in the rumen. Several analyses will be completed in 2012 to confirm if there are differences in the amounts of rumen microorganisms produced from the different silages.

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

X Pan

Funding: NSF (\$450,000, Aug. 2009 – Jul. 2014)

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.

Efficient biomass conversion: delineating the best lignin monomer-substitutes

John Ralph, Xuejun Pan and Sara Patterson

Funding: Stanford University GCEP (\$1.4M in total, \$288,927 for Pan, Jan. 2009 – Dec. 2011)

The present 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* biomimetic 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.

S **SPORL for Efficient Biochemical Conversion of Woody Biomass**

X Pan

Funding: USDA Forest Service (\$142,700, Sept. 2008 – Aug. 2011).

This research is focused on developing 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 tree tops 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.

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

X Pan

Funding: USDA McIntire Stennis Fund (\$142,457, Oct. 2007 – Sept. 2011)

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 as 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.

D **irect saccharification and fractionation of forest biomass for fuel and chemical production under mild conditions in concentrated halide salt solution**

X Pan

Funding: USDA McIntire Stennis Fund (\$162,312, Oct. 2011 – Sept. 2015)

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 (120-140°C). (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.

S **mall Scale Anaerobic Digester Research at the Institute for Environmentally Integrated Dairy Management Located at the UW-Madison Marshfield**

R Larson, BJ Holmes

Collaborators: ARS US Dairy Forage Research Center, UW Agricultural Research Station-Marshfield, Pabst Engineering, Inc.

Anaerobic digestion is a waste-to-energy technology capable of reducing air emissions which impact global climate change and transforming waste characteristics to limit pollutant transport and impact to ground and surface water. Additionally, anaerobic digestion generates profit streams including those from renewable energy production, digestate products, and tipping fees. Implementation of anaerobic digesters within the United States has typically focused on large farms, with limited cost effective alternatives for smaller operations. This research will investigate design and operational characteristics with the potential to decrease costs and increase revenues. Small laboratory batch and pilot-scale systems are being evaluated to determine efficiencies for combinations of key design and operational parameters including co-digestion of cheese whey & cheese whey permeate, mixing parameters, retention time, pathogen destruction, temperature, and digestate characteristics. A farm pilot-scale system designed by Pabst Engineering is planned for implementation in spring of 2012 at

the UW Agricultural Research Station in Marshfield, WI. This thermophilic reactor will provide field-scale data to assess full size system performance with detailed economic data. Detailed analysis of the microbial conversion of dairy manure and additional substrates into biogas has the potential to further develop this technology for implementation on small to medium sized farms. Microbial processes and end product characteristics will provide additional assessment of asset streams. Increased efficiencies in operation and design has the potential to decrease system size, increase gas production, or increase the value of asset streams in an attempt to produce an economically viable option for smaller sized operations. Analysis will continue through 2013. Results will be analyzed and made available to those currently operating digestion systems to increase efficiency and additionally to those evaluating installation for increased accuracy of economic and design assessment.

Silage Leachate & Runoff Collection and Treatment

R Larson, J Panuska

Collaborators: UW-Madison Biological Systems Engineering, ARS US Dairy Forage Research Center – Prairie du Sac, UW Agricultural Research Station-Arlington

Funding: Wisconsin Groundwater Research Coordinating Council

Silage is stored on-farm for animal feed throughout Wisconsin and the United States. Commonly thought of as an asset, the moisture in silage can produce silage leachate and runoff during a precipitation event which is a significant source of farmstead pollution. Concentrations of BOD₅ are reported from 20,000 to 80,000 mg/L, twice as high as manure slurry and 200 times that of domestic wastewater, in addition to large nutrient concentrations and low pH. This high strength waste is corrosive, deteriorates or burns vegetation, produces odors, reduces feed nutrient content, creates feed spoilage, and has severe environmental impacts. Silage leachate poses contamination potential for surface water from runoff and groundwater due to leaching below the storage pad and from runoff infiltration areas. Current knowledge concerning on-farm management and collection/treatment systems is limited leading to operation which exaggerates negative environmental impacts. This lack of data also limits the ability of regulatory agencies to outline design and management strategies to reduce the impact of silage leachate and runoff.

Research is currently being conducted at three field sites to determine the pollutant loading (including first flush) from silage leachate and runoff through changing environmental conditions and seasons. Assessing the potency of leachate and runoff throughout numerous conditions and precipitation events will provide critical data needed to design collection treatment systems which limit environmental impact while also limiting cost to producers to implement. Additionally, an innovative filter strip design is being examined to reduce leaching of nitrates and other pollutants to groundwater. Analysis of this data will

have direct implications to management of feed sources and control of parameters that influence concentrations to limit contamination of waterways.

Members of this project are also participating on a team which is developing an updated NRCS 629 treatment standard to incorporate silage leachate and runoff data and address concerns for CAFO designs. Data is currently being collected to be incorporated into outreach materials as well as recommended practices standards. Continued work will increase on-farm consultation and assessment of silage leachate systems to increase awareness and limit the potential for contamination of surface and groundwater. This research and outreach is the only work within the United States on this potential contamination source, therefore findings will be disseminated to researchers, producers, regulators, and other interested parties in Wisconsin and throughout the nation.

Solid State Anaerobic Digestion Pilot Scale System

R Larson, R Michitsch

Collaborators: UW-Madison Biological Systems Engineering, UW-Stevens Point

Funding: Wisconsin Solid Waste Research Program

Anaerobic digestion (AD) is a waste-to-energy technology which has potential to increase renewable energy production and manage waste streams within the US. AD can also mitigate greenhouse gas emissions, reduce the volume of solid waste requiring disposal in a landfill, and stabilize waste to minimize environmental impacts. Wet AD systems are increasing in number throughout the US, and Wisconsin is a leading source of this expansion. In contrast to wet digestion, dry digestion is the predominant AD technology in European countries (which have significantly more operational AD systems) in comparison to only two full-scale dry digestion systems operating within the US. Dry AD systems are able to handle solid waste streams without pretreatment, reduce solid waste volume requiring disposal up to 40%, and decrease reactor size in comparison to wet digestion systems. In order for Wisconsin to remain a leader in AD technologies and continue to implement and realize the benefits of these systems, investigation and analysis is required to assess use for various waste streams. Additionally, slow start-up has limited implementation by increasing retention times and cost.

A pilot-scale system is under construction to be completed in January 2012. This mobile dry digester unit will be used to assess gas production and waste reduction and stabilization on-site from food processors and organic food waste from municipalities. The digester includes a 100 gallon wet digester to provide inoculum for the dry digesters to decrease start-up time, and three 55 gallon dry digesters for simultaneous experimentation on feedstocks. The initial research will investigate storage methods for vegetable processing waste to determine if a reduction in reactor size coupled with storage is a feasible option. This analysis will provide detailed

operational and economic data to develop this technology and potentially to increase implementation and therefore reduce waste volumes requiring disposal, decrease environmental issues associated with waste treatment and disposal, and additionally produce asset streams in the form of biogas and digestate.

Solid/Liquid Separation System Performance

R Larson

Anaerobic digestion and bedding recovery units are increasing in on-farm use around the United States as a component of manure management systems. Anaerobic digestion is a proven waste to energy technology which produces biogas and digestate from anaerobic microbial degradation of organic sources. Nearly all on-farm systems in the United States have a mechanical solid/liquid separation system following digestion which fractions the digestate into a solid and a liquid product. Bedding recovery units use aerobic processes to degrade organic material also resulting in a similar solid and a liquid portion following processing. Processing of manure using digestion and/or a solid/liquid separation process can impact the nutrient and pathogen content of each stream. Digestion results in mineralization of nutrients and pathogen reductions based on system design of temperature and retention time. Separation (including bedding recovery units) can result in fractioning of nutrients as well as moisture, resulting in increased control of nutrient streams for increased management of manure. The liquid fraction following separation has increased content of soluble nutrients and is commonly land applied as a fertilizer source. The solid fraction is commonly used on-farm as a bedding source, but as it contains concentrated organic nutrients can also be sold as a value added product. However, the lack of data for real world performance has limited the use of these end products and has reduced revenues and resulted in operational problems for many dairies in Wisconsin.

In order to assess real world performance of digesters and solid/liquid separation systems, an assessment of 9 on-farm systems is being conducted over the course of one year. The study design includes sampling every other week pre and post digestion (if a digester is on-farm) and the solid and liquid portion after separation. This allows for assessment of the digestion process and the separation system. Samples are evaluated for nutrients, solids, pathogens (particularly those associated with herd health) and pathogen indicators. The results can be used to assess if digesters and separators are performing as designed. Additionally, this data can provide performance data on the various digester designs and separator equipment. With detailed herd management data, milk quality, and pathogen content, bedding practices can begin to be evaluated to improve herd health in dairies using recovered manure solids as bedding. The fractioning of nutrients is critical for assessing nutrient management practices and investigating the impact of recycling manure

through the system on nutrient content in both streams. Following the on-farm analysis, a solid/liquid separation system will be evaluated on a research farm to provide more control to further assess operational practices to make recommendations for desired separation performance. Results of this study are critical to developing more profitable nutrient management strategies with reduced environmental impact.

Life Cycle Assessment of Anaerobic Digestion Systems

R Larson, S Du

Waste management is becoming increasingly important for economic and environmental sustainability in industrial, agricultural, and municipal sectors. Anaerobic digestion is a proven waste-to-energy technology currently being implemented to produce renewable energy and stabilize waste to limit environmental impacts. Use of AD systems within the United States is increasing rapidly. In order to maintain economic viability, systems are being optimized for increased gas production and use of end products. The change in management, design, and operation results in unpredictable environmental impacts. Ongoing research uses a systems approach to analyze economic and environmental impacts due to changes in AD operation. A framework is being developed to perform a life cycle assessment (LCA) to determine impacts of GHG emissions, land use, nutrient losses, biogas production, and food production for changes in AD operations including substrate, digestate, and energy use. A parallel economic analysis is also being evaluated for comparison to the LCA for environmental impacts. Simultaneous assessment will highlight areas with high potential impact for AD operation and research. The analysis will provide direct data for application to operational systems to realize environmental and economic benefits, while increasing knowledge for design of future systems.

Development of a framework for systems analysis will provide the necessary tools to quantify environmental and economic impacts for assessment. Simultaneous systems analysis for economic and environmental impacts will identify areas which pose potential for reductions in economic cost without negatively impacting environmental benefits. Data can be used to weigh these options appropriately before making management, operational, and design changes. Further breakdown of this data for substrates, digestate end use, and biogas use has direct application to those currently operating AD systems to reduce emissions, reduce land use impacts and nutrient losses, and increase biogas production. Completion of this study can influence actual environmental and economic impacts through dissemination to digester operators, particularly with the addition to the curriculum of the anaerobic digestion operator training program and other information tools.

Incorporation of Animal Manures as Reinforcing Fillers in HDPE and HDPP

Roger M. Rowell
Funding: Private US Company

Animal agriculture is under increasing pressure to produce more and more meat, milk and eggs giving rise to an increasing amount of manures. In the past, manures have been viewed as a waste byproduct used mainly as a fertilizer that has a value of 2 to 4 cents per dry pound. We need to change our view of manures from waste to asset. Destroying manures by burning or lagooning may solve the environmental problem but it does nothing to add to animal income.

One of the alternatives is to use animal manures in industrial products. Wood and agricultural flours and fibers have been used as fillers in thermoplastics and this research program uses swine and cow manures as reinforcing fillers in HDPE and HDPP. This is a win-win situation as it increases the value of the animal manures, decreases the cost and improves mechanical properties of the thermoplastic composites.

Swine manure solids are collected using a flocculation process removing over 95% of the manure solids. The solids are dried, mixed with cotton-mill byproducts and composted for 30 days. The composted resource is then compounded with either HDPE or HDPP at different levels with and without a compatibilizer. A 40% blend of swine manure with HDPE and 2% MAPE gives a composite with MOE in bending of 1.31 GPa and MOR of 34.7 MPa as compared to unfilled HDPE MOE of 0.75 GPa and MOR of 15.1 MPa. A mixture of dried cow manure with straw bedding from University farms (40% with 2% MAPE) direct from the University of Wisconsin Experimental Farms, compounded with HDPE gives MOE in bending of 2.18 GPa and MOR 21.9 MPa as compared to 40% pine flour with 2% MAPE MOE 2.98 and MOR 33.4 MPa.

This project is now involved in two commercial trails to determine if this type of composite can be used in place of pure plastic products. The target audience is the farm community and branding of the products would make such that the farmer could see that the products come from a farm.

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 is greatly increased as well as decay resistance. This is a non-toxic approach to wood preservation that is presently under commercial development.

This process 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 placed 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 percent 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 than unheated 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.

Net zero energy housing in Alaska

R.M. Rowell

Funding: Private Funding

Professor Emeritus Rowell is a Board member for the Alaska Center for Appropriate Technology (ACAT) and their goal for 2012 is to build a net zero energy house in Alaska. ACAT also conducts lectures and short courses once a month on energy issues for Alaska.

Testing the Effectiveness of Plastic Films for Silage Protection

BJ Holmes, RE Muck

Collaborators: Raven Industries, Inc., ARS-USDA US Dairy Forage Research Center

Plastic film is used as a means for excluding oxygen and water from silage to help preserve its quality. In recent years, new plastic materials have been introduced that claim to exclude oxygen (oxygen barrier films) at a much higher rate than the conventional polyethylene films. Raven Industries has developed such a film and needs independent research results to demonstrate the effectiveness of their product.

A side-by-side study comparing the Raven Industries, Inc. oxygen barrier film to their conventional film when each was applied to the tops of two bunker silos at the ARS USDA Dairy Forage Research Center farm in fall of 2010. Sampling of the top layer of silage was conducted on each bunker when it was opened to feed the herd. Overall, the oxygen barrier (FeedFresh) film appeared superior to the conventional (FeedPro) film showing reduced dry matter losses in the top 6 in. and a trend toward better preservation. Also anecdotal

evidence found the FeedFresh film to be more resistant to puncture when walking on the film and from animal damage because of a mesh scrim embedded in the film.

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 biofuels 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.

Develop and Synthesize Super-Magnetic, Fluorescent Carbon-based Nanoparticles in Order to Create a New Class of Vaccines Against Infectious Diseases

*C-Pam-UW (Prof. F.S. Denes and Prof. M. Sandor and Prof. Zs. Fabry) Department of Pathology and Laboratory Medicine, UW School of Medicine and Public Health 5468 MSC.

Medical application of plasma-enhanced nanotechnology including the development of nanoparticle-based immune modulatory therapy to treat immune diseases, such as Multiple Sclerosis and rheumatoid Arthritis.

Develop and Synthesize silicon carbide (SiC) nanoparticles by starting from Octamethyl Cycloterasiloxane and Hexamethyl disilane under atmospheric plasma conditions, for photoactive applications.

*C-Pam-UW (Prof. F.S. Denes and Prof. Richard B. Timmons, University of Texas at Arlington. Department of Chemistry and Biochemistry, Arlington, TX 76019

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.

Solid Fuel Research on Combustion

Troy Runge, Jeff Mueller (MS student), Pam Wipperfurth (MS Student), and Chunhui Zhang (post-doc)
Funding: Focus on Energy, Hatch
Cooperators: Wood Residual Solutions

Two separate projects were conducted that seeks to provide answers for fuel characteristics that offer the best environmental and economic efficiencies for biomass boilers for heat and power.

The first project (Focus on Energy) was to characterize biomass for its suitability to heat and power generation, considering boiler operations and air emissions. Thirty-five solid fuels from various biomass were collected from the state were tested for ultimate (C, H, N, O, S), proximate (moisture, ash, volatiles, fixed carbon), Cl, and Hg and mineral ash analysis. Woody fuels were found in general to be the best fuel for combustion benefiting from low values in problematic elements, most herbaceous and residual fuels were not suitable due to emission or fuel handling issues. Research into methods to improve the suitability of herbaceous biomass through leaching or torrefaction was completed and the economics modeled. In general it was found that these treatments could improve the biomass' suitability for combustion but the costs were too high to implement over woody fuels.

The second project (HATCH) focused on 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 is 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.

Integrated Biorefinery

Troy Runge, Anurag Mandalika (MS student), Pam Wipperfurth (MS Student)
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 or ethanol 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.

Separating furfural produced in the reaction with a novel reactor, the formation of humins is prevented, and furfural is obtained in high yields. Four biomass types (hybrid poplar, miscanthus, switchgrass, and corn stover) were researched based on high productivity, high ecological sustainability and low expected cost. Extraction conditions were optimized and the hydrolysates converted to furfural. 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.

Acid Catalyzed Dehydration

Troy Runge, Shengfei Zhou (PhD student), and Chunhui Zhang (post-doc)
Funding: BSE research assistantship

The research is investigating the formation mechanism and kinetics of humin, a degradation by-product, formed during the acid hydrolysis and dehydration of saccharides. The acid catalyzed process is utilized to create levulinic acid and furfural which have been identified as important biobased intermediates to form fuels and materials. The proposed research will elucidate the reaction mechanisms and kinetic rates through model compound studies and verify the reactions with biomass experiments. The goal is to understand the humin polymerization mechanism that occurs during biomass acid treatments, to identify means to reduce its formation. The expected outcomes of this research will enhance the scientific and technical understanding of creating levulinic acid and furfural from biomass and provide guidelines to produce improved yields of these renewable chemicals.

Energy Power and Energy Systems

Energy.A.Syst Comprehensive Web-Based Farmstead Energy Self-Assessment Tool Kit

*DJ Reinemann, PW Walsh, SA Sanford, J Kepka, R Hackner, J Brinker, J Schultz
Funding: NCRS Conservation Innovation Grant
Collaborators: UW Biological Systems Eng.; GDS Associates

This project will develop a comprehensive farm energy self-assessment tool and provide an on-line resource center, Energy.A.Syst, so agricultural producers can conduct

customized energy analyses. The development of self-assessment tools will allow producers to conduct energy analyses of their current farming practices and production facilities with emphasis on electrical energy, natural gas, propane, and fossil fuel consumption. The self-assessment tools will estimate energy, cost savings, technology transfer feasibility, and environmental conservation and pollution benefits. The Energy.A.Syst site will also provide tools for more detailed on-farm energy audits that local utility representatives or energy service professionals might use. The web site will provide resource materials to producers with reference information to assist in planning, installing, and operating energy efficient technologies. Another component of the Energy.A.Syst effort will be tools to assess opportunities for renewable energy production (primarily wind, solar, biogas, and biomass combustion). The combined analyses of energy use reduction and non-renewable energy estimation will allow for measuring environmental services and accounting for greenhouse gases.

Structures/Construction

Shallow Post and Pier Foundation Design Standard

D R Bohnhoff

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

ASAE EP 486 Shallow Post Foundation Design is an existing ASABE standard that has been approved by ANSI as an American National Standard, and that has been adopted by reference in the International Building Code (IBC). An initial draft of a replacement document was developed at UW-Madison and sent to the ASAE EP 486 Standard Development Committee (SDC) in June, 2011 for review. Feedback received from this review is currently being used to modify the replacement document. Current plans are to complete this update by early 2012 at which time the document will be sent to the SDC for balloting.

This revision seeks to address several major shortcomings. Specifically, the current standard ignores load and resistance factor design, does not address concrete footing thickness, assumes lateral stiffness of all soils increases linearly with depth, and assumes at-grade forces (axial load, shear force, and bending moment) in the post are not dependent on below-grade deformations. Lateral load equations in the current standard are restricted to applications where assumption of an infinite flexural rigidity (E^*I) hold up, and thus analysis of deeper foundations is not possible. These equations also require that the applied shear force V and bending moment M applied to a post at grade must cause post rotation in the same direction. Additionally, the current standard completely ignores safety factors (i.e., it makes no difference how soil properties are determined and end use of building does not impact design). More minor shortcomings of the current standard are:

nomenclature that is not consistent with that used in geotechnical circles, no coverage of piers or attached footings, 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 must be constant, and lack of equations for calculating actual lateral soil pressures.

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 difficulty 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.

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.

Using A Single Steel Pipe To Connect A Wood Post To Concrete

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

A series of laboratory tests were conducted and a field study initiated in an effort to develop a moment-resisting, concrete-to-wood connection that enables non-preservative treated structural wood columns to be left completely exposed to outdoor environments.

In the first phase of this study, 125- and 150-mm diameter, high-strength precast concrete piers were designed, fabricated and tested. Each pier had a 73 mm schedule 40 diameter steel pipe extending 470 mm out of the top of the pier, resulting in the piers being referred to as *precast concrete pipe piers* or simply as *pipe piers*. Welded to this pipe (and embedded in the concrete) were four steel reinforcing bars. Bar diameter was 13 mm for the 125 mm diameter piers and increased to 16 mm for the 150 mm diameter piers. Demonstrated during this phase of the study were:

- Round precast concrete pipe piers are easy to manufacture. A chop saw and MIG welder were the only tools required to turn delivered steel stock material into steel assemblies for pipe pier fabrication.

- Filling a 73 mm schedule 40 ASTM A500 structural pipe with concrete with a compressive strength of 75 MPa increased the ultimate bending strength of the pipe from 8.5 to over 13.0 kN-m.
- Pipe pier bending strength was not limited by the structural steel pipe or structural steel pipe-to-rebar interface. Consequently the effect of changing pier diameter and/or rebar size on pipe pier bending strength can be estimated using standard ACI methods.
- With respect to bending, pipe piers with a diameter of 150 mm and 16 mm diameter rebar were 67% stronger and 150% stiffer than 125 mm diameter pipe piers with 13mm diameter rebar.
- Welding a "steel interface ring" to the pipe does not significantly increase pier bending strength and thus can not be justified because of the added cost of fabrication equipment and labor.
- When applying a bending load to the side of a round pipe pier, rotation of the pier relative to the direction of the applied load does not significantly impact the resulting bending strength.

In the second phase of this study, a device for boring a 76 mm diameter hole up to 600 mm in depth was designed, fabricated and tested. The device met performance expectations and demonstrated that it was possible to drill a straight, deep hole into wood using a Forstner bit.

The third phase of this study consisted of monitoring a series of bored logs in an attempt to determine if drilling a hole in an unseasoned log would reduce the likelihood of a primary check occurring in the log as it dried. Different surface treatments were applied to the ends and inside surfaces of the logs, while bark was left on some of the specimens. Based on a careful evaluation of the specimens as they dried, it was concluded that:

- A coating of polyurethane will slow the drying process, but it is not as effective as applying a mixture of mineral spirits and wax.
- Keeping bark on a log slows the drying process.
- Drilling a borehole in an unseasoned log has a minor influence, at best, in reducing the potential for check formation in a drying log.
- The more freedom water has to escape from the log into a borehole, and the less freedom water has to leave the exterior surface of a log, the greater will be the number and size of checks on the inside surface. Conversely, the less freedom water has to escape from the log into a borehole, and the more freedom water has to leave the exterior surface of a log, the greater will be the number and size of checks on the outside surface of the log.
- More rapid drying to the inside at the expense of drying to the outside may enhance splitting.
- The lower the ratio of log diameter to borehole diameter, the lower may be the amount of checking.

Phase four of this study involved fabrication and testing of wood pole-to-pipe and wood post-to pipe connections. Two major conclusions from this phase of the study were:

- The bending strength of wood post/pole-to-pipes is controlled by the perpendicular-to-grain tensile strength of the wood, and thus is very low. The bending strength increases in direct proportion to an increase in borehole depth.
- Practical application involving a post/pole-to-pipe connection requires that the end of the post/pier be reinforced. The double threaded screws used in this study work well for this purpose, increasing the design bending strength of the glulam post-to-pipe connections by almost 300%.

In the fifth and final phase of this study, twenty eight glulam posts and sixteen black locust poles were field installed on precast piers using a polyurethane construction adhesive to minimize decay at the wood-to-concrete interface. The performance of these assemblies will be monitored and compared to the performance of both untreated poles and treated posts that will soon be embedded in soil on the same site.

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 2012.

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 has entered into contract with Dr. Bohnhoff and UW-Madison for the development of an extensive technical manual covering post-frame building design. Work on the document began in October, 2009 and is steadily progressing. Chapter titles include: The Post Frame Building Systems, NRCS Post-Frame Structures, Introduction to Structural Design, Structural Loads and Deflection Criteria, Determinate Structural Analysis, Introduction to Mechanics of Materials, Building Materials, Design Properties for Wood Members and Connections, NDS Stress Checks and Member Use Restrictions, Column and Lateral Torsional Buckling, Indeterminate Structural Analysis, Diaphragm Action and Design, Structural Analysis Examples, Foundation Design, Connection Design, Post Design, Truss/Rafter Design, Girder Design, Purlin and Girt Design, System Design, Sample Design

Ice-Bank Air Conditioner for Fresh Produce Storage

D R Bohnhoff, J C Banach, A J Gardebrecht, A J Lofy, M D Muehlbauer, L P Syse, C A Sindunata, S A Sanford
Funding: UW Madison Biological Systems Engineering

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 winter months. Much of this storage takes place when ambient conditions can be used to save energy. In this study, a model ice bank air conditioner (IBAC) was developed that uses cold winter air to cool and/or freeze water stored in a tank. Air in the produce storage facility is then blown over the top of the water/ice in the tank to both cool and humidify the storage room air. The model developed for this study showed that:

1. A system that effectively forms ice using ambient air can be inexpensively fabricated.
2. Ice needs to be formed around steel fins or other similar devices that are capable of enhancing the transfer of heat between the storage room air and the ice.
3. Using ice to condition storage room air will maintain the dew point temperature of the storage room air near 0°C regardless of the temperature of the storage room air.

Efficiency of an IBAC could be enhanced by using a programmable logic controller that switches fans on and off and controls dampers based on the time of day, weather forecasts, and weather trends with respect to time-of-day.

An IBAC could be augmented with cooling coils to freeze water at off-peak energy prices. This could extend the operating months for the IBAC into earlier fall and later spring.

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 through 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

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 impeller 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.

During 2011, all major system components of the system were tested. During early 2012, the entire system will be assembled, tested and evaluated. Total material cost is currently estimated to be in the \$1000 to \$1500 range.

Engineering Aspects of Harvesting Corn Stover as a Biomass Feedstock

K.J. Shinnners*

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 2011, research focused on developing accumulation and feeding systems for the baler and maintaining combine throughput. Bales of corn stover MOG were formed continuously without requiring the combine to stop grain harvest while the round bale was wrapped. Stover was collected in an accumulator during bale wrapping and the collected material was metered out of the accumulator into the empty bale chamber after the bale has been ejected. Because the entire process was automated and little operator input was required, the operator can concentrate on the crucial task of grain harvesting. Yield of stover was altered by corn header adjustments and type of corn header used. If corn harvest occurred early in the season so that stover moisture was great enough to cause concern about spoilage of material in the bale, then the bales were stored by wrapping in plastic film with preservation by anaerobic fermentation.

Corn Residue Management

K.J. Shinnners*

Funding: Hatch

Cooperators: UW Biological Systems Eng.

Agricultural practices of the twentieth century have decreased soil organic matter (SOM), which can lead to depletion of soil health and productivity. Maintaining SOM can not only improve soil health but also sequester atmospheric carbon. Corn residue management practices have a strong influence on SOM. This work has uniquely investigated residue management from a machinery perspective. Both existing and novel crop processing technologies based on chopping corn residue at grain harvest were evaluated for their efficacy to increase SOM and provide spring planting conditions conducive to a highly productive crop. Each system's energy has been evaluated to address its impact on the overall energy balance of corn grain and fiber production. In our experiment, we investigated three residue management practices (conventional, shredding after corn harvest, and chopping corn head), two tillage practices (no-till and conventional disk chisel) across two corn varieties (BT and non-BT). Residue particle-size was quantified because the relationship between size-reduction and subsequent tillage strategy is important. Over winter decomposition was quantified by placing mesh bags of residue back in the field and measuring ash corrected dry matter loss and compositional changes after the over wintering period. Fuel use and power requirements for several different residue management strategies were measured. Neither residue management scheme or corn variety had a significant impact on whole-plant (i.e. silage) or grain yield. Tillage practice was the only variable that affected silage or grain yield. Flail shredding stalks with a conventional stalk shredder required significantly more fuel per unit area than shredding with a rotary mower or shredding at grain harvest with a stalk shredding corn head.

Natural Resources and Environment

Soil and Plant Nutrient Dynamics and Availability with Application of Biosolids and ENCAP's Movement Control Technology

*AM Thompson, D Mailapalli, A Roa-Espinosa

Funding: ENCAP LLC.

Collaborators: UW Biological Systems Eng.; SoilNet LLC

Polyacrylamide (PAM) applied as a coating on biosolids (organic fertilizer) can effectively reduce sediment and total phosphorous in surface runoff (Mailapalli and Thompson 2011). Researchers have reported that PAM in combination with fertilizer slows nutrient release and movement compared with fertilizer applied alone. The goal of this research is to understand sub-surface movement and leaching of phosphorus

(P) and Nitrogen (N), and crop biomass yield as a result of biosolid application. Three treatments including bare soil, commercially available biosolid and PAM coated biosolid, were applied to manually packed (bulk density: 1.2 g cm⁻³) growth chamber soil columns (GCC: 5 cm diameter by 40 cm long) and greenhouse soil columns (GHC: 15 cm diameter by 40 cm long). The application rates for biosolid and PAM coated biosolid were 729 and 740 kg/ha, respectively. The GCC were incubated for 60 days in a dark growth chamber at 25^o C and no crop was grown in the columns. The GHC were incubated for 60 days in a greenhouse and ryegrass was seeded and grown in all columns under 16 h daylight and at 25^o C. The columns were irrigated every week using 200 mL DI-water for GCC and 850 mL for GHC and leachate from each column was collected in Teflon bottles. The leachate samples were weighed and analyzed for dissolved reactive P (DRP), total P, Ammonia (NH₄), Nitrate (NO₃) and total N (TN) using an AQ2 discrete analyzer (Seal Analytical Ltd, WI). The ryegrass from GHC was clipped to 5-cm length every 15 days and analyzed for biomass yield and crop nutrients (TP and TN). At the end of the incubation period, soil samples were collected at 0-1 cm, 1-2 cm, 2-4 cm, 4-10 cm, 10-20 cm and 20-35 cm sections, oven dried at 105 °C and the ground soil was analyzed for TP.

The DRP and TP concentrations and loads in the leachate from GCC and GHC were not significantly different among the treatments and were below USEPA targeted levels for groundwater. However, DRP and TP in leachate varied significantly with time and increased for all treatments after 28 days of incubation possibly due to microbial activity. The TP retained after 60-days of incubation near the soil surface (0-1 cm) was significantly greater for the biosolid treatment in GCC (no-crop) but was not significantly different among all treatments for GHC due to crop uptake. At depths below 1 cm, soil TP was not significantly different among all columns. The NH₄-N concentration in leachate was higher than the USEPA target level (0.1 mg/L) and not significantly different among the treatments. The leachate from GCC had NO₃-N concentrations greater than the USEPA target level (10 mg/L) and they were significantly different; highest for the biosolid treatment followed by PAM coated biosolid and Control. The NO₃-N concentrations among the treatments were not significantly different but were slightly higher than the targets for the GHC in the middle of the growing season. The TN concentrations (20-80 mg/L for GCC; 15-60 mg/L for GHC) in the leachate followed the NO₃-N concentration trends. Biomass yield in GHC was slightly higher for biosolid than PAM coated biosolid followed by the control but, statistically they were not significantly different from each other. Crop TP was not significantly different among the treatments.

Identifying a Critical Moisture Condition for Runoff Generation

*AM Thompson, FW Madison, T Radatz
Funding: UW Biological Systems Engineering
Collaborators: UW Biological Systems Eng.; UW Soil Sci.; US Geological Survey; UW Discovery Farms Program

Identifying time periods when land application of manure is likely to contribute to surface runoff contamination is important for making proper management decisions and reducing the risk of surface water contamination. The goal of this study was to improve understanding of the factors that influence runoff generation in agricultural watersheds during non-frozen ground periods. Six small basins (ranging from 6 to 17 ha) within two southwestern Wisconsin farm sites (DFP and PF) were instrumented and surface runoff continuously monitored from 2004 to 2007. The soils in all basins were formed in deep (~1 m) loessial sites. A direct-plant management strategy and corn-soybean crop rotation were utilized within basins at DFP. A conventional tillage system (chisel plow in the fall followed by soil finisher in the spring) and a corn-oat-alfalfa crop rotation were utilized within basins at PF. At PF, the amount of precipitation leaving the landscape as surface runoff (2%) was approximately two times greater compared to DFP (0.9%), indicating that the direct-plant management system was better at retaining precipitation than the chisel plow/soil finisher system. An antecedent soil moisture (ASM) threshold of 0.39 cm³cm⁻³ for runoff generation was determined for all six basins, despite differences in farming systems. Below this threshold, runoff coefficients (runoff depth divided by precipitation depth) were near zero. Above this threshold, runoff coefficients increased with ASM. Maximum 30 minute rainfall intensity (I30) thresholds for runoff generation increased as ASM decreased and as crop cover increased. Avoiding waste applications during time periods with a high probability of rainfall when soil moisture is at or near threshold levels decreases the risk of surface water contamination.

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 newly constructed stormwater treatment system was designed 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 four experimental swales (each measuring 8 by 100 m) constructed with native subsoil overlain with salvaged topsoil. These wetland treatment swales receive stormwater from a mixed residential and commercial watershed and are 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. Using the new stormwater treatment system with vegetated swales, we are testing 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.

In 2011, weir plates were installed to allow the hydroperiod of each swale to be adjusted to a low-, high-, or fluctuating-regime. ISCO automated samplers were installed upstream and downstream of three wetland swales and stormwater samples were collected for five storms and analyzed for total nitrogen, total phosphorus, total dissolved phosphorus, and total suspended solids at the Wisconsin State Laboratory of Hygiene. A cohesive strength meter (CSM) was used to measure critical shear stress (threshold shear stress of flowing water necessary to initiate detachment of soil particles) spatially throughout the three swales. A cryogenic soil corer was used to measure the height of sediment accumulation within glitter plots (installed in 2010) on the surface of the treatment swales. Similar data collection will continue through 2012.

With our partners, the Wisconsin Nature Conservancy and the Environmental Law Institute, we are identifying opportunities within Great Lakes watersheds to improve stormwater treatment so that fewer nutrients will make their way to coastal wetlands and nearshore waters.

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, 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 groups (forb, graminoid, and grass) in response to varying water velocity and depth treatments 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. The steel rod 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 Newton 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 the delivery of sediment from upland contributing (source) areas to receiving waters (point of impact). The Water Erosion Prediction Project (WEPP) and Soil and Water Assessment tool (SWAT) were used to estimate sediment delivery ratios (SDR) for a 5.7 ha agricultural watershed at the University of Wisconsin-Platteville Pioneer Farm in south central Wisconsin. Both models were calibrated for flow and sediment using PEST (Parameter Estimation) software and a multi-year continuous data record including precipitation, meteorological variables, runoff volumes and corresponding sediment concentrations. The output from the mechanistic models will be 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 and landscape and storm characteristics will be explored. 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 analyses throughout Wisconsin.

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

*AM Thompson, KG Karthikeyan, BJ Lepore, RD Jackson, D Hyndman, A Kendall, B Basso

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 (USGCRP, 2009). Working in conjunction with the 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 ongoing field monitoring effort to collect a detailed data set of collocated, 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 Thrust of the Great Lakes Bioenergy Research Center (GLBRC) at the Arlington Agriculture Research Station.

A randomized complete block design experiment with 8 cropping system treatments planted in 5 replicated blocks was established Spring, 2008. Instrumentation was installed to monitor subsurface water and nutrient dynamics in five of the biofuel cropping system treatments in the GLBRC biofuel plots. Eleven subsurface Automated Equilibrium Tension Lysimeters (AETLs) were installed between October 2010 and October 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. Data logger programs for controlling the operation of the AETLs were written and debugged. Lysimeter water samples were collected weekly starting January 1, 2011. Leachate volumes were measured starting January 1, 2011 and leachate samples collected after May 1, 2011 have been analyzed for Nitrate + Nitrite, Ammonia, Total Nitrogen, Total Phosphorus, Dissolved Reactive Phosphorus, pH, EC, and volume. Small scale (1m X 1m) surface runoff collection systems were installed during May 2011 in the following treatments (3 replicates each): continuous corn, monoculture switch grass, and monoculture Miscanthus. Runoff sample collection started June 1, 2011 and samples were analyzed for Total Nitrogen, Total Phosphorus, Total Dissolved Phosphorus, Dissolved Organic Carbon, Total Sediment, Total Carbon, pH, EC, and volume.

All water quality analyses were conducted in the Water Quality Laboratory in the Agricultural Engineering Laboratory Building (Biological Systems Engineering). All sample collection will continue through 2013.

Plant community richness and composition were measured in 1.5m x 1.5m quadrats using the point-intercept method in fertilized and unfertilized monoculture switchgrass, mixed native grasses, and native prairie treatments at the GLBRC site as well as at an unfertilized restored prairie in Goose Pond Sanctuary, outside of Arlington, WI. Measurements were done once each in June, July, and August 2011. Additionally, soil nitrous oxide emissions were measured bi-weekly from May 2011-September 2011 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 0-20cm, 20-50cm, and 50-80cm were taken from each quadrat every 4-5 weeks from May 2011-August 2011. These samples are currently being tested for inorganic nitrogen concentrations as well as rates of mineralization. Aboveground net primary productivity (ANPP) was estimated by clipping aboveground biomass of each quadrat to ground level in September 2011. This biomass was then dried and weighed.

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

J Panuska, AM Thompson, KG Karthikeyan, 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 (BMPs) 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 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 in 2010 and 2011. Atmospheric fallout radionuclides (¹³⁷Cs and unsupported ²¹⁰Pb) were used as tracers to identify different sources (upland, stream bank, and stream bed) of in-stream suspended sediments. In-stream suspended sediment samples were collected monthly from April through October each year 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 stream banks and actively eroding banks. All the samples were analyzed for organic matter content (percent volatile solids) and radionuclides. Radionuclide analyses are currently being conducted through low background gamma counters.

The results of radiometric fingerprinting of samples collected in 2010 show that uplands are the major contributors to in-stream suspended sediments in subwatersheds dominated by croplands whereas stream banks/beds are major contributors to in-stream suspended sediments in subwatersheds dominated by grasslands and woodlands.

Additional upland samples were collected in 2011 within four subwatersheds within the Pleasant Valley watershed in order to further characterize radionuclide fingerprints of 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/beds to in-stream suspended sediments in each subwatershed.

Equilibrium Phosphorus concentrations (EPC₀) were determined at the same sites where tube samplers were installed. Stream bed samples were collected from the top 5 cm for EPC₀ analysis in July and September 2011. Results showed that in-stream sediments acted as phosphorus (P) sinks (i.e. absorbing P) at all the sites during July. However in September two sites acted as P sources (i.e. desorbing P).

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.

Evaluation of a Modified System of Dairy Farm Regulatory Oversight

*PL Ruegg, DJ Reinemann, SA Rankin

Funding: DATCP

Collaborators: UW Biological Systems Eng.; UW Dairy Sci.; UW Food Sci

The overall objective of this project is to evaluate the ability of an alternative method of direct regulatory oversight of high-performing Wisconsin dairy farms. Specific objectives are:

- Develop and evaluate objective criteria that can be used to identify producers who qualify as "high-performing producers" based on milk quality;
- Develop criteria for FDA-approved monitoring and reporting systems on milk quality performance;
- Evaluate the performance of producers enrolled in the pilot project relative to specific outcomes important to ensuring the safety and suitability of milk produced on the farms.

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.

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.

Dairy Processing Sustainability Metrics

FX Milani, DJ Reinemann

Funding: DATCP

Cooperators: Food Science Department

The Objectives of this project are to; 1. Develop life cycle assessment (LCA) models of the Wisconsin Dairy processing industry; 2. Perform audits of dairy processing facilities to 'ground-truth' our models; 3. Develop an outreach program for the dairy processing industry with elements including, baseline environmental targets for dairy manufacturing, identifying major opportunities and best practices to reduce environmental impacts, provide training on the use of our dairy processing models to apply them to specific dairy plants; and 4. Provide information and council to the Dairy Business Innovation Center, WDATCP and dairy industry trade groups on value added cheese business plans and guidelines to improve the sustainability and competitiveness of Wisconsin's dairy industry.

Entire Environmental Impacts of Pasture Based Dairy

DJ Reinemann, V Cabrera

Funding: DATCP

Cooperators: Dairy Science Department

The objectives of this project are to:

- Quantify energy intensity of pasture based dairy systems in Wisconsin: Both embodied and Direct Energy inputs per unit of milk production
- Quantify GHG emissions (carbon footprint) of pasture based dairy systems in Wisconsin.
- Quantify other environmental impacts of pasture based dairy 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.



Natural Resources and Environment

Recycling Agricultural Plastic Films

*BJ Holmes, R Springman

Collaborators: UW Biological Systems Engineering, Farm Technology Days, Inc, ARS-USDA US Dairy Forage Research Center

Use of agricultural plastic films has increased dramatically in recent years as low-cost forage storages and greenhouses for plants and animals have become more widely used. Plastic is seen throughout the countryside as: bunker silo and silage pile covers; silo bags; bale wraps or bags; bale tubes; bale net wrap; soil mulch; and hoop structures with transparent covers. These films have a relatively short useful life from several months to several years before they become a waste product. Current disposal of waste plastic film is handled by on-farm dumping or burning, municipal landfill, and recycling. Recycling and municipal landfilling are usually acceptable environmental disposal methods, while on-farm dumping and burning raise environmental concerns and are illegal.

On-farm dumping and burning are convenient and low-cost. However, regulatory agencies throughout the country have raised concerns about the dioxin released during open burning

of waste materials in general. Increased use and burning of agricultural plastic films pose health concerns for farmers, their families, their neighbors, and the customers who consume farm products.

The Air Quality Division of the Wisconsin Department of Natural Resources (DNR), has conducted listening sessions to determine how open burning can be reduced. Recommendation 6 of the Open Burning and Backyard Dumping Stakeholder report to the DNR Board in December of 2003 states:

“Agricultural Wastes. We recommend an effort at the state level to develop workable efficient systems for the collection and recycling or disposal of agricultural plastic films and bags such as silage bags. These widely used agricultural plastic products can be very bulky, making them difficult and inconvenient to properly dispose. Farmers need convenient low cost alternatives in addition to information about regulations.”

Recycling is limited because the films become soiled, and they are bulky and difficult to handle and relatively expensive to transport to landfills or recycling centers. Until recently, recyclers required extremely clean plastic, a requirement most used agricultural plastic could not meet. Also there is no convenient method for removing feed particles and soil to make them more acceptable to recyclers. Recently developed products made from recycled plastic have lower requirements for cleanliness, which has opened new markets for recycled agricultural plastic.

A display highlighting recycling of agricultural plastics was held during Farm Technology Days held in Green County (2007), Brown County (2008), Dodge County (2009) and Pierce County (2010) and Marathon County (2011). An innovation introduced at 2010 Farm Technology Days was a plastic film “compaction basket”. The compaction basket uses an available front end loader to compact plastic film making it more dense and more economical to transport from the farm to a landfill or recycling center. Those who saw the exhibits at Farm Technology Days expressed strong interest in recycling agricultural plastic film. Their interest had encouraged a representative of Advance Granulating Solutions, Inc. (AGSI) of Savage, MN to initiate a pilot program of collecting plastic film in several Wisconsin counties during 2008. AGSI was to haul the plastic to Savage to wash and chip it prior to marketing it as a recycled plastic product. In 2008, AGSI experienced a financial set back. They have been reorganized too be Genesis PolyRecycling, Inc. and had plans to set up a processing facility in Mankato, MN. They also experience financial difficulties and have ceased accepting dirty agricultural films. They were again forced out of business in 2011. Residual Wood Solutions, Inc. of Montello, WI has developed a system for forming wood byproducts into fuel pellets using waste plastic as a binder. Residual Wood Solutions was not operating with agricultural plastic films at the end of 2010. They, Genesis PolyRecycling and DATCP have participated in the Farm Technology Days exhibit on Recycling Agricultural Plastics in the past.

The “compaction basket” has been in use at the US Dairy Forage Research Center dairy farm at Prairie du Sac since 2010. The farm crew prefers this system over their former system of storing the films in a tractor trailer box.

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

DW Kammel, BJ Holmes, DJ Reinemann
Funding: UW Coop. Ext. Service, Dairy Industry Revitalization Grant through UW Dairy Team
Collaborators: UW Biological Systems Engineering, UW Dairy Science, UW Center for Dairy Profitability, UW Milking Research and Instruction Lab, 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 properly selecting milking equipment and facilities.
- Improve efficiency 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, KJ Shinnars, M Digman, RE Muck
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.

Anaerobic Digester Operator Training Program

R Larson, C Skjolaas, J Rivin, D Kirk, V Haugen
Collaborators: UW Biological Systems Engineering, UW Extension, Michigan State University ADREC, Michigan State University Extension Dairy Science, Vir-Clar Farms & Northern Biogas

Anaerobic digestion is a proven waste-to-energy technology with numerous available technologies now available for implementation in the United States. Wisconsin is the leading state in the United States for on-farm anaerobic digestion systems installed with over 30 on-farm systems currently operational. The increase in system operations over the last decade has resulted in a demand for knowledge of system components, processes and mechanisms, and operation. As implementation of this technology on a large scale in relatively

recent in the United States there is a lack of available training in Wisconsin and the United States as a whole for safe production and use of biogas produced from anaerobic digestion systems.

A digester operator training for Wisconsin was developed based on a pilot training held in Michigan in 2010. The three day program held in Spring of 2011 included a background of digestion systems, types of digester designs, system start-up, operation schedule and analysis, current research out outreach in WI, process indicators, an operator panel, safety, electrical systems, tour, emergency action plans, industry panel, combined heat and power system, WI regulation, air quality, and digestate utilization. All speakers were selected from Wisconsin and produced updated information from that provided from the MI pilot to provide a WI specific presentation where applicable. A tour of a digester site, Vir-Car Farms, was incorporated into the training to demonstrate safety protocols and give an overview of system components.

Attendees ranged from dairy producers, to operators, to government personnel. The training was successful in creating a dialogue between producers and interested parties. There was a very positive reaction to the training provided, in particular to the hosted panels where information from those with hands on experience was provided. Many operators now have a greater understanding of their systems and can implement the strategies outline in the training. The success of the program and the connections formed will lead to a reoccurrence of this training every 2 years.

WI Small Scale Anaerobic Digester Conference

R Larson, J Rivin, C Gould, V Haugen
Collaborators: UW Biological Systems Engineering, UW Extension, SHWEC, Michigan State University Extension

As anaerobic digestion continues to increase in implementation within Wisconsin and the United States, there is minimal investment in small scale systems. Typical installation of on-farm anaerobic digestion systems is on dairies with 500+ head. This lack of investment in small scale systems is due to general lack of economic feasibility data, lack of commercially available small scale technology, costs associated with energy production and hook-up, and limited information provided concerning small scale systems.

A small scale digestion conference was held in November 2011 in Stevens Point WI. Information was provided for information on technology processes, an assessment of currently available technologies and their success, and development of value added products.

The small scale digester conference drew 60+ people from dairy producers to government employees. The conference was successful in relaying the current state of information and resulting in numerous contacts for future development of small

scale systems. The small scale digester conference is the only informational meeting of its kind within the country and will continue every other year due to the increased interest of these small systems. Collaborators involved in the process were also able to outline the areas which require attention for small scale adoption due to the conference and have begun to address these issues in order to provide increased assessment for implementation.

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

Building Extension Capacity in the North Central Region to Address Agricultural Energy Use

S.Sanford
Funding: SARE (USDA)

Objective:
The purpose of this project is to utilize the considerable energy conservation expertise among collaborating North Central Region Extension programs to develop the capacity of agricultural educators to assist agricultural producers to adopt effective energy conservation practices. The project focuses on five energy intensive agricultural systems: field crop production, animal housing, greenhouses, irrigation and grain drying. Regional Extension energy specialists have compiled existing information on energy conservation available in the region and will conduct a series of regional webinars to highlight best practices in each of the target areas. Resources

generated will be shared broadly through the extension Sustainable Agricultural Energy community of practice. The program will be evaluated to determine the degree to which Extension agricultural educators understand the methods available to save on-farm energy and the degree to which agricultural producers increase their awareness of energy conservation practices.

Progress:
Thirteen webinars were presented during May and June 2011. Presentations and recordings of presentations have been posted on the eXtension.org website. Project has been extended through 2012. Additional webinars will be developed.

Energy conservation in mint production

S Sanford, DJ Reinemann
Funding: Mint Industry Research Council

Objective:
Investigation and compilation of past and current practices utilized in the Mint Industry covering energy use and consumption, efficiency, and distillation. Wherever possible, the compilation should include comparisons between the different practices, focusing on risk/benefit of each approach. Where gaps are recognized, investigation of potential alternatives that could provide future benefits to the mint industry. These alternative sources/processes do not need to be related to the mint industry or even from agriculture itself. Deliver the White Paper in document form after a mutually agreed upon time has commenced.

Progress: Finished
The project reviewed the batch water and steam distillation methods that have been used in the past and still used today. The literature review turned up three patents for continuous flow steam distillation equipment that could reduce energy use by 65% based on patent claims. A continuous flow method would also allow for some heat recovery. Solvent extraction is used for oil seed crops and could also be used for mint however handling highly flammable solvent at a farm scale processing facility could pose a greater safety than current methods. Microwave and ultrasonics can be used to increase the extraction speed of solvent extraction methods however many of the methods reported in the literature have only been used on a lab scale and would need to be scaled up to prove they would work at a 20 ton per hour scale to meet the needs of a typical mint grower. Supercritical Fluid extraction is used to extract many pharmaceutical compounds from plant materials and could be used for the extraction of mint oil. The extraction process will extract the oil along with other compounds thus requiring secondary processing to separate the oil. The largest drawback is a \$2 million price tag that wouldn't have the capacity to process more than an acre per day. Subcritical water extraction would require less costly equipment but can cause oil degradation because of the high temperatures used. Solvent free microwave may have potential but a field test in

Oregon had poor results but likely due to the use of very dry mint hay. High plant moisture is needed to produce steam to volatilize the oils because the mint oil components have very low dielectric constants and absorb very little microwave energy. There are some other methods such as instant controlled pressure drop, moderate electric field extraction, high-voltage electrical discharge and pressurized fluid extraction that have been tested at a lab scale and patented but don't appear to be used commercially for any type of extraction. Most of the distillation methods researched would also reduce processing times from several hours with currently used batch steam distillation down to as little as 30 seconds with a continuous flow steam method.

Managed Ecosystems: Energy Inputs for organic production

P Mitchel, AJ Bussan, S. Sanford, D. Reinemann
Funding: NRI
Cooperators: Applied Economics, Agronomy

This integrated project's ultimate goal is establishing an economically viable, multifunctional organic vegetable processing industry in the Midwest. Short-term goals include identifying nutrient management practices to maximize returns and environmental efficiency (nitrogen loss and energy use) for organic production of processing snap beans and sweet corn. Intermediate-term goals include adoption of these practices in the vegetable processing system to improve grower and industry competitiveness and regional environmental quality and to build awareness of organic opportunities among growers, processors, agricultural professionals, and students.

Project Objectives:

- 1) Quantify nitrogen cycling and fate in organic snap bean and sweet corn production by using comprehensive soil, crop, and leachate nitrogen sampling in field plots.
- 2) Quantify and compare energy efficiency for conventional and organic energy use for operations and embodied energy in off-farm inputs by documenting operations and inputs, measuring fuel use, and using published studies.
- 3) Quantify returns to identify organic systems maximizing grower profits and to find the cost of limiting nitrogen loss and energy use, by estimating and optimizing a hierarchical model of nitrogen dynamics, crop yields, and profits.
- 4) Inform and train growers, processors, agricultural professionals, and students regarding economic and environmental impacts of organic production, using on-farm trials and tours, presentations at grower/processor conferences/extension publications (handouts, newsletters, web pages), and courses taught. BSE is working on objective #2.

BSE looked at the energy component of this project and found that a crop rotation that used annual legume crops to supply some of the nutrients used only 3.5% more energy than using no fertilizer on potatoes while a manure, intergrated annual cover/manure crop or intergrated perennial cover/manure crop used 40%, 37% and 37% more energy. For snap beans the type of fertilization program didn't affect the cultivation energy use; all methods were 3.5% higher than no fertilizer. For sweet corn a crop rotation that used annual legumes that were incorporated use 4% more energy than using no fertilizer while manure-based fertilization, an intergrated annual cover/manure crop or intergrated perennial cover/manure crop used 45%, 45% and 62% more energy. The intergrated system left cover crops growing in between the rows for weed control.

Greenhouse Energy Management

S. Sanford, DJ Reinemann
Erik Runkle – Michigan State University
Funding: SARE

Objectives:

Develop presentation materials and extension bulletins on energy conservation in greenhouse, energy-efficient plant production methods and the use of biomass for heating greenhouses. Conduct professional development training for extension agents, high school Ag instructor and college instructors using the developed materials. Provide access to the UW Greenhouse Energy model for calculating the potential savings from different energy efficiency measures. Make curriculum materials available on the Wisconsin Energy Efficiency and Renewable Energy website.

Progress: Finished

The project developed four PowerPoint presentation and five extension bulletins on greenhouse energy conservation and alternative fuels for heating greenhouses. There were also 13 magazine articles and several presentations to other audiences using the developed materials. A workshop for high school Ag instructors and eight webinar were attended by 42 participants from 6 different states. Subsequent programs have reached 64 additional people. The first presentations covered all aspects of greenhouse energy efficiency, the second presentation looked at thermal/shade curtain systems, the third presentation looks at energy efficient plant production methods and the fourth presentation covered heating greenhouses with biomass fuel sources. The presentation materials, presentation narrative, webinar recording and publications are available on-line at http://www.uwex.edu/energy/gh_PRES.html. The extension bulletins are available at <http://learningstore.uwex.edu/Energy-Conservation-C29.aspx>. This project was done in cooperation with Erik Runkle from Michigan State University.

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.

Environmental Quality

Irrigation Water Management

JC Panuska and SA Sanford
Funding: UW Coop. Ext. Service

Irrigation water management includes minimizing over irrigation and applying water in a uniform manner. Several programs were conducted state-wide introducing irrigation scheduling and uniformity testing to growers, state and federal agency personnel and agriculture service providers. The checkbook method of Irrigation scheduling considers water inputs and losses from the crop root zone. Inputs include rainfall and irrigation while losses include soil evaporation and plant transpiration (evapotranspiration) and when too water is applied, deep percolation. Attendees were also introduced to the Wisconsin Irrigation Scheduler (WIS), a spreadsheet scheduling tool available through BSE. Meetings also took place with growers in the central sands region to gather input on a new web-based scheduler. The uniformity test method was also introduced and discussed for different irrigation system types. For those interested in conducting their own test, contact information was supplied on where to obtain field test equipment. Irrigation system modifications for energy conservation were also presented and discussed.

Improving Water Quality

*BJ Holmes, DW Kammel, JO Peterson, DJ Reinemann, J Panuska, RA Larson

Funding: UW Coop. Ext. Service

Collaborators: UW Biological Systems Eng.; UW Soil Sci.; UW Env. Resources Ctr.; UW Nutrient & Pest Mgmt.; UW Ctr. for Dairy Profitability; USDA Natural Resource Conservation Service; Wis. Dept. of Agric., Trade, and Consumer Protection

The collaborators developed a series of educational materials and seminars and participated in events to educate communities and agencies about water quality. The following topics are included.

- Proper storage and handling of fertilizers, pesticides, and fuel to minimize losses to water resources.
- Regulations and standards to store and handle manure which are aimed at reducing the amount of manure and nutrients entering surface and ground water.
- Work with committees to establish standards for proper management of silage leachate/runoff from feed storage areas
- A survey of grazer overwintering practices which could affect surface runoff of nutrients.
- Investigation of environmentally friendly cleaning and sanitizing agents.
- Demonstration of ground water flow systems and contaminant transport using sand tank models.
- Development, testing, and teaching how to use field runoff software models.

New Irrigation Scheduling Software - Wisconsin Irrigation Scheduling Program (WISP 2011)

JC Panuska* and Frederick Wayne

Funding: Wisconsin Potato and Vegetable Growers Association
Collaborators: UW Soil Science

Irrigation scheduling and soil moisture monitoring reduces over irrigation, thus reducing nutrient and pesticide losses to groundwater while also conserving energy. The increasing cost of energy, nitrogen and pesticides along with increased concerns for groundwater quality make sound soil water management for agricultural production systems good practice. Irrigation scheduling has been promoted in Wisconsin since the mid 1980's and several computer software tools have been developed to assist with water management decisions. A new web-based irrigation scheduler is being developed as a collaborative effort between the Departments of Biological Systems Engineering and Soil Science to capture the best features of the existing schedulers while at the same time using current technology. WISP 2011 will be developed in several phases that will progressively increase program functionality and features over the next several years. The Phase I release is currently undergoing testing and is scheduled for a spring 2012 release.

Subsurface Tile Drainage of Agricultural Land

JC Panuska

Funding: UW Coop. Extension Service

Collaborators: UW Discovery Farms and UWEX CNED Programs

Land owner interest in sub-surface tile drainage systems has increased significantly in the last two years. In response to this interest, several county-based training programs have been conducted and were well attended (250 people). Instructional programming included benefits and environmental risks of tile drainage, construction methods and considerations, rules and regulations and basic engineering design concepts. Programming in the sub-surface tile drain area is anticipated to continue.

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 farmers with disabilities.

The education priority is done through exhibits at the Wisconsin Occupational Therapist Association conference. Two individuals from the Occupational Therapy Assistant program at Western Technical College experienced farm visits from the rural community. AAW is also collaborating with Occupational Therapist students from the University of Wisconsin – Madison working on a brochure for rural clinics and hospitals for Occupational Therapists to utilize basic references and questions to work with agriculturalists.

Networking was handled using past clients in Speaker's Bureau, 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 quarterly 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 nearly 2000 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 2011-2012 budget year, services were provided to 416 farmers with disabilities with 81 new referrals and 198 continuing clients. Staff from the FARM program completed 100 assessments for the DVR in their 2010 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 \$38,744 per assessment.

The 121 clients whose cases were closed during 2011-2012 grant year were surveyed to estimate the success of the program in meeting their needs. Sixty-nine farmers completed and returned their surveys, for a response rate of 57 percent. Seventy-six 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 farmers when requested by DVR staff. In addition, DATCP staff refers farmers to AgrAbility 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 Ext Services, OSHA, WI Technical Colleges, WI agriscience instructors,

A major emphasis for 2011 was focused on assisting dairy farms in response to a significant increase in compliance and outreach efforts by the Department of Labor (DOL) Occupational Safety and Health Administration (OSHA) and Wage and Hour. In January 2011 at an UW Extension co-sponsored program an OSHA Compliance Assistant announced that WI OSHA was planning to request from the regional office a Dairy Farm Local Emphasis Program (LEP). At the same time a Grain LEP was active for Region V including WI. The Dairy LEP became effective November 1, 2011.

Numerous awareness programs were offered in collaboration with UWEX, OSHA, WI Technical Colleges and insurance companies to provide producers with an understanding of OSHA and their employer responsibilities. These programs also reached a number of service-related representatives.

In collaboration with 8 UW Extension agricultural agents, Safety Reviews were conducted on 36 farms including 2 heifer raising facilities. In the 9 farm visits for Outagamie County the total cows equaled 41,000. Due to producer concerns about being identified by OSHA for inspection, all documentation from the Safety Reviews remained at the operation. Through the Safety Review process producers were introduced further to OSHA, provided management strategies for OSHA compliance and had one-to-one discussion about hazards on their operation. *One Kewaunee County producer said, "This was great, we didn't even know where to start with OSHA inspections and now we have a better idea. Please come back and see how we have improved!" At one of the heifer raising facilities an emergency alarm system was installed within a week after the review.*

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 Dairy Worker Roundtable II was held in August, 2011 and co-sponsored with OSHA. The purpose of this meeting was to bring together the agencies, organizations, and industry representatives involved in address worker safety for dairy operations. The 32 participants were from OSHA Area Offices, WisCon, DOL Wage and Hour including Specialty Populations, PDPW, DBA, UWEX, WI Technical Colleges, Rural Insurance, Hastings Mutual Insurance, National Farm Medicine Center, and dairy producers. The proposed Dairy LEP was addressed and areas of work were identified. UWEX was to take the lead on a webinar to cover the Dairy LEP when it was signed and public.

Two webinars were conducted to and offered to producers and other dairy industry representatives. The first webinar covered the 1904 Recordkeeping Standard and had 17 sites. With the current Grain LEP two sites were from agribusiness cooperatives. The second webinar was conducted to provide information on the Dairy LEP and what OSHA would cover in an inspection. The 49 sites included 7 producers and 11 UWEX offices with a mix of producers and industry representatives.

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

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.

H Health Professional Education to Support Wisconsin Communities & Farms

John Shutske

Numerous studies point to the importance of well-qualified health professionals being highly credible sources of information to promote injury prevention, health, and wellness within agricultural communities. This work has focused on developing additional knowledge and skills among health professionals including physicians, nurses, and future health professionals in their role of recognizing farm workplace risk factors for injury and occupational illness and in promoting specific behaviors and practices in cooperation with other community resources including local Extension Agents and educators. Teaching and “on-site” tours are done each year with about 30 participants in the Wisconsin Academy for Rural Medicine (WARM). The WARM program is a rural education program within the MD Program curriculum at the University of Wisconsin School of Medicine and Public Health in Madison. An additional 60 people participated in an “Integrative Cases” educational experience in which future physicians examine an issue or case from many perspectives, including basic science, clinical, public health, social/ethical issues and health care systems. This year’s cases developed to support this program focused on the needs of expanding dairy operations with hired workers; children’s safety issues; injury risk factors connected to aging; and, unique risk factors of migrant and immigrant workers connected to culture, language, and risk perception. Over the last three years, additional educational programming has been developed for the AgriSafe network in cooperation with the National Farm Medicine Center in Marshfield. Each year, the network provides multiple days of education and hands-on experience for 25-30 community-based health professionals located throughout the state.

Youth Education

Expanding Your Horizons Conference

R.A. Larson

Collaborators: UW-Madison Biological Systems Engineering Department, UW-Madison Women in Science & Engineering Leadership Institute, National EYH

This conference was designed to provide a day of career exploration activities in science, engineering, and mathematics for women in middle school. The training was attended by 6th-8th grade girls throughout Wisconsin. Middle school attendees could select multiple options held around the university throughout the day to get a more in-depth look at various STEM careers. Participants could elect to come to the BSE department to learn about waste recycling, waste-to-energy, and composting. Throughout the day 30+ middle school women came to the biowaste lab to learn laboratory procedures intended to invoke interest in the sciences and engineering while also learning about sustainability processes in biowaste.

AWARDS

David Bohnhoff was honored with the ASABE Standard Development Award. Bohnhoff is a 32-year ASABE member with exemplary leadership in the program. He worked with and developed the Design Requirements and Banding Properties for Mechanically-Laminated Wood Assemblies and the Post Frame Building System Nomenclature.

David Bohnhoff also received the Arthur J. Maurer Extra Mile Award.

Xuejan Pan received the 2011-2012 Alfred Toepfer Faculty Fellow Award. This award recognizes Pan's many accomplishments and his potential for continued growth and greater success.

David Kammel received the 2011 Agricultural Research Stations (ARS) Service Award. Kammel has provided invaluable effort and expertise in many upgrades of station facilities. Kammel aided in the design and construction of pesticide management facilities.

Debby Sumwalt received a Classified Staff Award.

PUBLICATIONS

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