2010

BIOLOGICAL SYSTEMS ENGINEERING

University of Wisconsin - Madison

College of Agricultural and Life Sciences

Annual Summary of

Teaching, Research & Extension

College of Agricultural & Life Sciences
University of Wisconsin-Madison

460 Henry Mall
Madison, WI 53706-1561

Preface

The Biological Systems Engineering Department, at 106 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 2010 Annual Summary, based on activities underway and completed in calendar year 2010. 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 105 undergraduate and 42 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

Mathew Digman, Assistant Professor, Ph.D.
Extension / Research: machinery systems

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. Shinners, Professor, Ph.D.
Teaching / Research: power and machinery

John Shutske, Professor, Ph.D.
Teaching / Research: Ag safety and health
Associate Dean, Extension, College of Agricultural and Life Sciences

Richard J. Straub, Professor, Ph.D.
Teaching / Research: power and machinery
Chair, UW Biological Systems Engineering Dept. and
Director, Animal, Research Division, College of Agricultural and Life Sciences

Anita M. Thompson, Associate Professor, Ph.D.
Teaching / Research: natural resources and environment

Patrick W. Walsh, Professor, J.D.
Extension / Research: energy and environmental policy, legal liability
Director, Solid and Hazardous Waste Education Center

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.

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: Wood Chemistry, PhD course at the Royal Institute, Stockholm, Sweden. Fall 2010
Schuler, Ronald T

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
Hailin Lin, Visiting Associate Professor, Ph.D. (S. Gunasekaran)
Fachuang Lu, Associate Scientist, Ph.D. (X..-J. Pan)
Bob Meyer, Senior Outreach Specialist; AAW
Alberto R. Negri, Researcher, Ph.D.; Runge Lab
Jeffrey W. Nelson, Senior Research Specialist (dept. IT) and Lecturer (farm equipment and power), M.S.
Astrid C. Newenhouse, Associate Scientist, Ph.D.; HFHP
Mike Nimmer, Assistant Researcher, (A. M. Thompson)
Mark E. Novak, Senior Outreach Specialist; Rural Energy Program (D.J. Reinemann)
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

Technical Personnel

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

Office Personnel

JacqueLynn M. Cary-Pope, Financial Specialist
Patrick Litza, Department Administrator
Susan M. Reinen, Payroll and Benefits Specialist
Debra K. Sumwalt, Student Services Coordinator

Graduate Students

Names of major advisor follow in parentheses

Horacio Andres Aguirre-Villegas (D.J. Reinemann)
Maria Sonia Ares Gomez (D.J. Reinemann)
Jack Buchanan (A. M. Thompson)
Sofie Cattoir (S. Gunasekaran)
David E. Cook (K.J. Shinners)
Shashi Dhungel (R. Anex)
Nathan Dudenhoeffer (R. J. Straub)
Kody L. Habeck (K.J. Shinners)
Thomas J. Hoffman (K.J. Shinners)
Andrew J. Holstein (D. R. Bohnhoff)
Wantida Homthawornchoo (S. Gunasekaran)
Natalie Huisman (K.G. Karthikeyan)
Kari A. C. Jordan (S. Gunasekaran)
Jacob D. Karlen (K.J. Shinners)
Joseph R. Keene (K.J. Shinners)
Sami Khanal (R. Anex)
Kelly L. Klaas (T. Runge)
Jasmeet Lamba (A. M. Thompson)
Brock M. Lundberg (X. Pan)
Anurag S. Mandalika (T. Runge)
Jeffrey D. Mueller (T. Runge)
Lis Nimani (X. Pan)
Jane L. O'Dell (M. R. Etzel)
Asli Alkan-Ozkaynak (K.G. Karthikeyan)
Jose Pantoja (D.J. Reinemann)
Thais Passos Fonseca (D.J. Reinemann)
Stephanie G. Prellwitz (A. M. Thompson)
Robert Rowbothan (D.J. Reinemann)
Li Shuai (X. Pan)
Harsh V. Singh (A. M. Thompson)
Julie C. Sinistore (D.J. Reinemann)
Craig A. Slattery (K.J. Shinners)
Eakasit Sritham (S. Gunasekaran)
Ryan S. Stenjem (A. M. Thompson)
Erik L. Storvik (A. M. Thompson)
Yi-Kai Su (T. W. Jeffries)
Thomas Syring (D.J. Reinemann)
Patrick Triscari (R. Larson)
Joseph Van Rossum (D.J. Reinemann)
Yi-Cheng Wang (S. Gunasekaran)
Liping Wei (J. Ralph)
Shane D. Williams (K.J. Shinners)
Pamella J. Wipperfurth (T. Runge)
Shin Yee Wong (M. R. Etzel)
Jiang Yang (S. Gunasekaran)
Qiang Yang (X. Pan)
Jinjin Zhou (S. Gunasekaran)

Postdocs and Research Interns

Simone Kraatz (D.J. Reinemann)
Philipp Lehmann (K.J. Shinners)
Seokwon Lim (S. Gunasekaran)
Hao Liu (X. Pan)
Xiaolin Luo (X. Pan)
Damodhara Mailapalli (A. M. Thompson)
Elumalai Sasikumar (X. Pan)
Chunhui Zhang (T. Runge)
Zack Zopp (A. M. Thompson)

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 100 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 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)
- Biological Concepts for Engineers
- Computational Fluid Dynamics Simulation in Food and Bioprocess Engineering
- 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)
- Engineering Principles of Agricultural Machinery (3 cr)
- Engineering Principles of Off-Road Vehicles (3 cr)
- Biological Systems Engineering Senior Design (3 cr)
- Small Watershed Engineering (3 cr)

The curriculum consists of 128 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 20 students earn B.S. degrees each year.

Technical/Service Courses

The department provides several service courses for other majors.

- Milking Machines (1 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
- Livestock Housing

Graduate Programs

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

RESEARCH

Biological Engineering

Effects of Silage Inoculants on Dairy Cattle Use of Silage

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

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

Progress: Alfalfa silage was made in August 2009 with and without a *Lactobacillus plantarum* inoculant in adjacent oxygen-limiting tower silos. An animal trial with 28 cows in early lactation was begun in April 2010. Cows were divided into two groups with diets containing 50% alfalfa silage along with corn silage, high moisture corn, soy hulls and a vitamin/mineral supplement. One group received the inoculated alfalfa silage and the other the untreated. 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. Analysis of samples taken from the rumen is continuing in order to determine if what occurs in the rumen can explain the increase in milk production from inoculated silage.

Incorporation of Animal Manures as Reinforcing Fillers in HDPE and HDPP

Roger M. Rowell*, and David Bossmasn
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 died cow manure with straw bedding (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.

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.

Removal of Heavy Metals from Acid Mine Drainage in a National Forest

R.M. Rowell*, and Tom Boving
Funding: The Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET)

Filters containing modified bark have been placed in a drainage site in Rhode Island. City water runoff is run through two filter units removing soluble heavy metal ions (Mn, Zn, Fe and Al). The filters were installed in fall of 2006. The first set of data shows that the fiber-based filters, along with a change in pH to 5, removes more than 80% of the iron and aluminum.

Development of wood with increase hardness.

R.M. Rowell*
Funding: Private Company

The hardness of wood can be greatly increased by impregnating the wood with acrylic monomers and polymerizing them *in situ.* A vazo catalyst is used along with heat to cure the polymer. A dye can be added to the monomer mixture to change the color of the final wood product. Hardness is increased several hundred present and the final product is used for industrial flooring.

Heat treatments of wood in improve decay resistance and dimensional stability.

R.M. Rowell*
Funding: Private Company

Wood that is heated at high temperatures (120-350 C) becomes more decay resistant and has a higher dimensional stability that unheatd wood. The mechanism of effectiveness is due to the decomposition of the hygroscopic hemicellulose polymers in the cell wall. There is a 20-30 decrease in weight and a decrease in strength properties upon heating either in the presence or absence of oxygen.

Biomass Densification

T. M. Runge* and Chunhui Zhang
Funding: Focus on Energ
Cooperators: Wood Residual Solutions

The research seeks to provide answers around the sustainability of biomass densification that offer the best environmental and economic efficiencies for biomass transportation for energy projects. The research created 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 be 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, which will be performed in 2011. 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. The model is being verified and used to complete scenario analysis in 2011. The information from this project was utilized to provide technical outreach talks on biomass fuel development at several conferences including:

- Platts Biofuel Conference at Chicago, IL on October 5, 2010.
- TAPPI Management Meeting at Madison, WI on November 4, 2010

Biomass for Jet Fuel

Troy Runge*, Chunhui Zhang, and Pam Wipperfurth
Funding: Congressional Directed Funding through UW Superior, Bruhn Fellowship
Cooperators: James Dumesic (Chemical and Biological Engineering)

The biomass for jet fuel project investigated a process to convert woody biomass into levulinic and Formic Acid, which have been shown to be capable of being converted catalytically to jet fuel by others (Bond et al., Science 2010). The conversion yield to these products by acid treatments was optimized and more importantly, degradation products were minimized. The degradation products have been shown to hinder the catalytic reactions necessary for the subsequent conversion steps. The ability to utilize these levulinic and formic acid products in the next conversion steps was also investigated to demonstrate the feasibility of the process. The data is currently being analyzed and submitted for publication to provide publically available information for bioenergy projects.

Biomass for Power Plants

Troy Runge* and Jeff Mueller
Funding: USDA Hatch Grant

Biomass was analyzed for suitability for combustion to help guide biomass supply chain development for bioenergy to power conversions for both energy efficiency as well as environmental emissions. Testing has been completed to characterize biomass as solid fuels were completed on approximately 30 different biomass samples, representing a wide variety of woody materials, bioenergy crops, agriculture residuals, and waste products. The tests included proximate analysis, ultimate analysis, and potential air pollution precursors of mercury and chloride was directly used was used to help guide the biomass supply chain development for the UW Madison Charter Street Heating Plant upgrade project.
The data is also being submitted for publication to provide publically available information for bioenergy projects. Additionally, this data was used along with information on biomass availability to create several presentations at bioenergy conferences including.

- International Bioenergy Days at Rockford IL on September 28, 2010
- Midwest Biomass Conference at Dubuque, IA on November 17, 2010

Cellulose Materials from Bioenergy Crops

Troy Runge* and Pam Wipperfurth
Funding: Kimberly-Clark Corp

The impact of hemicelluloses extraction prior to making pulp was investigated to determine the feasibility of an integrated forest biorefinery. Four biomass types (hybrid poplar, miscanthus, switchgrass, and corn stover) were selected based on high productivity, high ecological sustainability and low expected cost. Hemicellulose extraction conditions were optimized to maximize extraction while maintaining cellulose integrity. The extracted biomasses were then used to create bleached pulps, which were analyzed for physical properties to determine suitability for tissue production.

The results indicated that the extraction of hemicelluloses does not lower the cooking yield, but does lower the overall yield of process by approximately 10% due to the extraction step. The resulting pulps produced from the extraction process had lower hemicelluloses content than conventional pulps by a factor of approximately four. The reduction in hemicellulose and a subsequent increase in alpha cellulose content caused a decrease in bonding of the pulp and a significant increase in bulk properties. The lower strength properties and higher bulk properties could make this type of treatment for a pulp advantageous for some tissue or other absorbent pulp applications. However, the ~10% reduction in yield may not make this process viable for a biorefinery as pulp is currently more valuable than biofuel on a mass basis. The data is currently being analyzed and submitted for publication to provide publically available information for bioenergy projects. Additionally, this data was used along with information on biomass availability to create a presentations and paper at the 4th ISETPP conferences at the South China University of Technology, Guangzhou, China (November 10, 2010).

Isoprene from Biomass

Troy Runge* and Kelly Klaas
Funding: Congressional Directed Funding through UW Superior
Cooperators: UW Stevens Point - WIST

This project is being conducted with the goal of furthering a method to manufacture and collect isoprene from biomass as a useful biochemical that can be used in synthetic rubber manufacture. The research is being done collaboratively with Dr. Eric Singsaas at the University of Wisconsin – Stevens Point, who has determined a method to produce isoprene in a bioreactor by a strain of *e.coli*. The project will further this process by determining a method to collect and purify the isoprene from the headspace of the bioreactor. The proposed method will utilize two vessels, one to collect the liquid isoprene and one to dissolve and disperse the isoprene into a solvent to allow utilization in further manufacturing processes.

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)

Abstract:

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)

Abstract:

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* iomimetic lignification involving the phenolic radical coupling reactions that typify the lignification process. Those that successfully make co-polymers will next be polymerized into a suspension-cultured cell wall system to further delineate their polymerization efficacy and to provide biomimetic cell wall material for preliminary testing of conversion efficiency following selected pretreatments and in a variety of processes.

SPORL for Efficient Biochemical Conversion of Woody Biomass

X Pan

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

Abstract:

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.

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

X Pan

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

Abstract:

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

Testing the Effectiveness of Plastic Films for Silage Protection

BJ Holmes, RE Muck

Collaborators: Raven Industries, Inc.

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 was started when the films were applied to the tops of two bunker silos at the USDA ARS Dairy Forage Research Center farm in fall of 2010. Sampling of the top layer of silage was conducted on one bunker when it was opened to feed the herd. The second bunker will be sampled when it is opened in spring of 2011. Results will be analyzed and reported following this sampling.

Small 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, tipping fees, and the sale of carbon credits. 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 that have the potential to decrease costs and increase revenues. Small laboratory batch and pilot-scale systems are to be evaluated to determine efficiencies for combinations of key design and operational parameters including co-digestion of cheese waste, mixing parameters, retention time, pathogen destruction, temperature, and digestate characteristics. A farm pilot-scale system designed by Pabst Engineering in planned for implementation in 2011 at the UW Agricultural Research Station in Marshfield, WI. This large 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 the summer of 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.

Develop and Synthesize Magnetic, Fluorescent Carbon-based Nanoaperticles that Display and Array of Antigenes and Adjuvants in Order to Create a New Class of Vaccines Against Infectious Diseases

*FS Denes, M Sandor, ZS Fabry
Collaborators: UW Ctr. for Plasma-Aided Manuf.; UW Pathology and Laboratory Med.; UW Sch. of Med. and Public Health

Objective: Medical application of plasma-enhanced nanotechnology, including development of nanoparticle-based immune modulatory therapy to treat autoimmune diseases, such as multiple sclerosis and rheumatoid arthritis.

It has been demonstrated that magnetic nanoparticles are specifically taken up by dendritic cells, cells that are critical for initiating immune responses. Experiments are also underway for remote accessing magnetic nanoparticles *in vivo* to generate hypertheramal effects and to selectively "kill" particle-associated

Use of Plasma-Synthesized Carbon-Based and Specifically Functionalized Nanoparticle Systems in HIV Research and Development of Potential Therapies

*FS Denes, DI Watkins
Collaborators: UW Ctr. for Plasma-Aided Manuf.; UW Sch. of Med. and Public Health; UW Primate Inst.

Our laboratory uses the macaque animal model to search for and develop effective, novel AIDS vaccine strategies. These investigations use nanoparticles synthesized in the laboratories of the Center for Plasma-Aided Manufacturing (C-PAM) and Biological Systems Engineering using atmospheric pressure, non-equilibrium plasma technique, i.e., small non-toxic carbon-based molecules, which are not only magnetic but can also bind to proteins or small peptides of interest.

To date, there has not been a successful AIDS vaccine in monkey studies or human trials. Considering that almost 40 million people are now infected with HIV, developing a successful vaccine is crucial. One can elicit one or more of the following immune components in a vaccine: antibodies, cytotoxic T cells (CD8+), or helper T cells (CD4+). Antibody-eliciting vaccines have shown little or no promise in combating HIV, while CD4+ T cell-eliciting vaccines have been untested yet seem to be crucial in fighting both human and simian immunodeficiency viruses.

Recent *in vivo* immunogenicity experiments from our lab have shown that conjugating small SIV peptides to Professor Denes' nanoparticles elicits SIV-specific CD4+ T cells. These induced immune responses in macaques are not only strong, but long-lasting. With these data, we are writing an NIH R21/R33 grant to determine the importance of eliciting CD4+ T cells prior to infection using these nanoparticles. It is suggested that eliciting these cells will improve the animals' AIDS prognosis. Our collaborators are very excited by the recent nanoparticle vaccine success, and they are confident that C-PAM and BSE researchers will continue their integral part in these joint investigations.

It was emphasized that these novel studies could not be done without the work of Ferencz Denes and C-PAM. C-PAM and its multidisciplinary research has been critical in our recent vaccine development, and we hope this collaboration will continue as we set up our future vaccine studies.

Design and Development and Testing of Novel Atmospheric Pressure Plasma Installations (Submerged arc reactor and flat ceramic plasma reactor) with Potential Scaling-Up Possibilities for Pilot and Industrial Technologies

F.S. Denes
Funding: UW Ctr. for Plasma-aided Manufacturing; UW Biological Systems Engineering.; UW-Primate institute .
Cooperators: UW Mechanical Engineering (Robert Sandberg, Mechanical Engineer, Emeritus)

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

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

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

Energy Power and Energy Systems

Energy.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). Current work at UW-Madison involves the development of an initial draft of a replacement document. Once this draft has been completed, it will in effect, be turned over to a special standard development committee for formal technical review, subsequent modification and eventual 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.

Post-Frame Building Systems Nomenclature Standard

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

ASABE S618 Post Frame Building Systems Nomenclature was approved by ANSI as an American National Standard on December 31, 2010. The new standard establishes standard terminology for use in the design, construction, marketing and regulation of post-frame buildings. It also provides security against inappropriate application of post-frame building terminology by individuals involved in code development and specification writing.

The original drafting of the standard and the development of all accompanying figures was done at UW-Madison by Dr. Dave Bohnhoff who also chaired the ASABE Standard Development Committee that reviewed and revised the draft and subsequently approved it as an ASABE Standard.

As completed, the new ASABE standard contains 11 sections titled as follows: (1) purpose and scope; (2) normative references; (3) building systems; (4) building subsystems; (5) primary framing members; (6) secondary framing members; (7) diaphragm components; (8) foundation components; (9) foundation types; (10) dimensions; and (11) commentary.

Without doubt, ASABE S618 is among the most complete and technically consistent nomenclature documents in existence for a particular building system. Considerable time and effort was put into the 139 definitions appearing in the new standard. Extreme care was taken to make sure terminology was consistent with definitions appearing in other national standards such as the National Design Specifications for Wood Construction, and/or with verbiage routinely published or otherwise well-entrenched in the design community by other major national organizations.

Bending Properties of Wood I-Sections

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

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

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

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

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

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

During 2008, all lumber for laboratory testing was obtained. The specific gravity and modulus of elasticity of the lumber was ascertained. In 2009 a series of load-slip tests were then conducted on the mechanical fasteners and the resulting data was used along with MLBeam to model and optimize I-section design.

Thirty-six (36) I-sections and ten vertically-laminated assemblies were subsequently fabricated and tested to failure in bending. 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%).

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.

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

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

The move away from preservative treated wood has spurred the development of non-treated wood posts supported on concrete piers. The goal of this project was to investigate the design of such a system that could withstand permanent outdoor exposure.

The specific design investigated featured the use of a single structural pipe with one end anchored in concrete and the other end inserted into at borehole in the post. Moisture-curing polyurethane was used to bond the pipe to the post and to minimize absorption of water into the interface between the concrete and post.

Although the connection investigated could be used with concrete in any form, the pipes in this study were cast into both 5- and 6-inch diameter piers with a concrete length near 60 inches. Although pipes were only embedded into the piers a couple inches, four reinforcing bars welded to each pipe ran the entire length of the pier. Special carts were developed that enabled casted the piers in an inverted manner.

Both black locust pole and glue-laminated southern pine posts were used in this study. Black locust was chosen because of its strength, naturally high decay resistance, and because of its listing as an invasive species in Wisconsin. Southern pine glulams were investigated because of strength and the wide availability of Southern Pine lumber and because the use of dry lumber eliminates problems associated with curing wood – something that was a major issue with the field harvested black locust.

It should be noted here that one of the reasons for the pipe design was that the wood borehole it requires was something that it was felt may eliminate primary checking in logs when placed in the log at the time of harvest (i.e., prior to drying). This was investigated as part of this study.

A special boring rig was designed and built for this study, and has worked quite well. The rig has the capability of drilling a 3-inch diameter borehole up to a depth of about 2 feet.

Two sets of flexural tests were designed, one set to determine the bending strength of the pipe-to-pier connection, the other to determine the bending strength of the wood-to-pipe connection. To enhance the later, special screw reinforcing around the base of the borehole is being investigated. The pipe-to-pier connections were completed in 2010, the wood-to-pier tests are scheduled for the spring of 2011.

A series of exposure durability studies is currently being constructed. Piers were embedded in late fall prior to ground freeze. During the spring 2010 these piers will be fitted with glulam posts and black locust poles.

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 is complete and fabrication is progressing with expected completion in summer 2011.

In addition to work on the RGHB, two articles were published in 2010 by Bohnhoff on below-grade thermal insulation of post-frame buildings. One article addressed insulation to control frost heave, the other addressed insulation to control energy transfer. The latter article addressed methods for installing below-grade thermal insulation in post-frame building systems.

Vertically, Mechanically-Laminated Assembly Design

D R Bohnhoff
Funding: USDA Hatch; UW Biological Systems Eng.

In 2008, we initiated a project to revise ANSI/ASAE EP559, *Design Requirements and Bending Properties for Mechanically Laminated Columns*. This standard was originally drafted by researchers at UW-Madison in the mid-90's and was in need of an update. In addition to changes that would make it consistent with the latest versions of the standards that it references, the EP needed to give equal consideration to ASD and LRFD design formats, and it needed to include information for more commonly used preservative wood treatments, as well as the compatibility of these treatments with various mechanical fastener substrates and coatings.

All preceding shortcomings were addressed in verbiage that we drafted in 2009 for the revision. In addition, we included (1) language to address the use of engineered lumber products mechanically-laminated assemblies, (2) test protocols for structural finger joints, and (3) procedures for calculating axial load capacities. The proposed changes were balloted by ASAE EP 559 Standard Development Committee in October, 2009. Negative ballots were addressed and the document reballoted in spring of 2010, at which time it was unanimously approved.

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

Small-Scale Facilities for Winter Storage of Fresh Produce

D R Bohnhoff, S A Sanford, J Banach, A Gardebrecht, A Lofy, M Muehlbauer, L Syse
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. Winter storage facilities are needed to hold and maintain crop quality during winter. They differ from summer storage facilities in that they often need to both cool and warm storage room air depending on outside temperatures. This must be done while maintaining proper humidity levels. Many of the facilities currently used are not well planned for material handling and lack equipment and controls to maintain such proper control.

One of the objectives of this study is to develop small-scale storage facilities that are more sustainable by utilizing changing thermal properties of ambient air and soil to help cool

and heat the storage facility. Work to date has involved information retrieval as well as the development of an ice bank air conditioner which uses ambient air to chill and freeze water. Storage room air is circulated over the top of this cold water/ice to both cool and humidify the air.

Safety and Health

Promoting safety and health among Wisconsin's older rural adults

L.J. Chapman, A.C. Newenhouse, J. Mahoney
Funding: USDA
Collaborators: UW Biological Systems Engineering

As stated in our original application, our project has three objectives:
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.
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).
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, multifactorial fall prevention interventions.

Machinery and Harvesting

Engineering Aspects of Harvesting Corn Stover as a Biomass Feedstock

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

This research deals with the engineering aspects of bio-mass feedstock production from corn crop residues. Biomass feedstock can be used to produce transportation fuels by enzymatic hydrolysis, by gasification or by direct combustion. The objectives of this project are to:

- Modify the grain combine harvester to allow either single-pass or two-pass harvesting of grain and stover in separate crop streams;
- Quantify the machine performance and system effectiveness;
- Develop model of the true costs of harvesting, storing and transporting corn stover

Three approaches to corn stover harvest were considered: two single-pass systems and a two-pass system. One single-pass system uses a baler towed and powered by the combine to collect the cob and husk MOG exiting the rear of the combine. In 2010, research focused on maintaining combine throughput and developing systems to deliver MOG to the baler and manage the material handling to feed the baler. Another single-pass approach involves a novel method where the corn grain and stover at black-layer or later maturity was harvested simultaneously using a forage harvester and the combined fractions treated with amendments as the crop was placed into anaerobic storage. The amendments helped preserve the feedstock and begin pretreatment of the stover fraction. It is envisioned that after storage the combined pretreated feedstock will be shipped to satellite facilities where the grain and stover fractions will be separated and both fractions further processed for improved utilization and transport efficiency. This harvest system improves the transportation logistics of biomass by combing the low-density stover with the high-density grain. The moist silage system is more robust than separate grain/stover harvest and storage systems, resulting in a longer harvest window, thereby significantly reducing the capital and labor intensity of the harvest to storage logistics The two-pass system involves a unique corn head which captures stalks and leaves before they enter the combine and forms a windrow of this material under the combine. MOG consisting of cob and husk that exits the combine are dropped onto this windrow and then the windrow chopped with a forage harvester after some period of field wilting. This approach requires a second harvest pass, which increases cost, but it eliminates the logistic problems associated with simultaneous harvest of grain and stover. Grain harvest rate is virtually unaffected by this harvesting approach and stover harvesting rates can be extremely high when a self-propelled forage harvester is used.
Our economic analysis of corn stover harvest and logistics has shown that the whole-plant single-pass approach is by far the lowest cost system. The two-pass system which involves harvesting the windrows with a forage harvester and preserving the stover by anaerobic fermentation also provided a strong economic return.

In-Field Cubing of Biomass Feedstocks

K.J. Shinners*, X.P. Pan
Funding: DOE Sun Grant Program, Alliant Energy, John Deere Moline Technology and Innovation Center
Cooperators: UW Biological Systems Eng.

Although it is often assumed that the density of biomass feedstocks needs to be significantly increased to reduce costs, our economic modeling has shown this is actually not a valid assumption for most conversion platforms. However there is a specific utilization of biomass that does require a high-density form. When biomass is converted to energy by co-combustion with coal for electrical generation, then the feedstock needs to have roughly the same physical properties as coal. This allows the biomass material to be efficiency handled by existing coal handling equipment and co-combusted in stoker boilers. Normally, high-density cubes or pellets created from biomass feedstocks are created in a stationary industrial facility. The biomass is first baled in the field and stored on the farm, and then the bales are transported to the central densification facility for conversion into cubes or pellets. However, the expense and effort of baling, and handling, storage deconstruction and size reduction of the bales adds considerably to the cost of the biomass feedstock. In this project we looked to reduce the cost of creating a high-density feedstock by conducting the cubing operation at the time of harvest with a mobile in-field cuber.

A laboratory test fixture was developed that was used to determine the conditions required to cube biomass at the time of harvest. We investigated fundamental variables such as die temperature, feedstock moisture and particle-size, back pressure, and amendment rate on cube properties like unit density and durability. The best results were obtained when die temperature was below 100°C, feedstock moisture was less than 15% (w.b.) and when lime was added as a binding agent at rates less than 1% of DM. Modifications were made to an in-field cuber that reflected the laboratory results. The modified in-field cuber had a die cooling system to maintain die temperature below 100°C and a system to apply lime at the desired rates. Results of the field modifications were often less than satisfactory. It was very difficult to maintain the required conditions on the machine and even more difficult to produce the required low moisture in the windrow. Although the modified machine made high-density cubes of reed canarygrass and corn stover, we were not able to produce cubes of switchgrass. No matter the feedstock, the system throughout was very low, which negatively impacts the cost of in-field cubing. Our economic analysis showed that the in-field cubing would not be cost competitive with the bale-to-cube system it was intended to replace.

Anaerobic Storage of Corn Stover as Animal Feed and Biomass Feedstock

K.J. Shinners*,
Funding: Archer-Daniels Midland
Cooperators: UW Biological Systems Eng.

Biomass feedstocks are most efficiently harvested by direct-cutting or after a short period of field wilting. In either case, the feedstocks are targeted to be 35-50% (w.b.) moisture, which we define as “moist feedstocks”. This is a robust harvest system because it offers a long harvest window and does not require extended periods of dry weather to produce a dry crop for baling. The feedstock is efficiently size-reduced by the forage harvester at the time of harvest, producing energy savings and efficient material handling. Because the feedstocks are not dry, they must be preserved by fermentation during anaerobic storage. In this research corn stover was ensiled at 40 – 52% (w.b.) moisture and stored in pilot-scale silo bags. The stover was stored either without amendment (control) or with *Lactobacillu*s buchneri applied as an amendment to improve aerobic stability of the feedstock upon removal from storage. An additional treatment included lime at 5% of DM applied before storage. Lime was used as an amendment to enhance the conservation of DM during storage while also increasing its *in vitro* digestibility. The feedstocks were stored in the silo bags for almost 6 months. At removal from storage, the aerobic stability of the feedstocks was determined over a five day period. Stover was very well preserved by ensiling, with losses for all treatments less than 4% of DM. The application of the lime amendment produced the lowest DM loss in storage. *Lactobacillu*s buchneri treated stover had the best aerobic stability with significantly lower heating over the five day period after removal from storage. Combined storage and aerobic losses were 2.7, 4.8 and 5.8% of DM for the lime, control and *Lactobacillu*s buchneri treatments, respectively. Anaerobic storage and preservation of moist corn stover by fermentation was a very successful method of conserving stover value.

Natural Resources and Environment

Recycling Agricultural Plastic Films

*BJ Holmes, R Springman
Collaborators: UW Biological Systems Engineering; Advance Granulating Solutions, Inc. (AGSI); Genesis PolyRecycling, Inc., Residual Wood Solutions, Inc; Department of Agriculture, Trade and Consumer Protection; Department of Natural Resources, Farm Technology Days, Inc.

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). 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 Mankota, MN. They also experience financial difficulties and have ceased accepting dirty agricultural films. 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 is not operating with agricultural plastic films at the end of 2010. They, Genesis PolyRecycling and DATCP attended the Farm Technology Days exhibit on Recycling Agricultural Plastics.

Investigation of Small Farm Scale Anaerobic Digesters

R.A. Larson, B.J. Holmes
Funding: USDA
Collaborators: UW Biological Systems Engineering

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 renewable energy production, digestate products, tipping fees, and the sale of carbon credits. Implementation of anaerobic digesters within the United States has typically focused on large farms, limiting cost effective alternatives for smaller farms. Small laboratory, pilot, and field-scale thermophilic digesters have been designed to examine the microbial conversion of dairy manure and additional substrates into biogas to develop the technology for implementation on small to medium sized farms. Increased efficiencies for key design and operational parameters including co-digestion, variation in volatile solids, mixing, retention time, and temperature will provide data for profitable design and operation. Microbial processes and end product characteristics provide additional assessment of asset streams. Specific objectives include:

1. Investigate the performance of a prototype digester intended for small-medium size dairy farm operations.
2. Investigate the performance of small scale digesters using supplemental substrates derived from food industry and municipal/commercial food waste streams.
3. Investigate the performance implications and energy requirements of operating thermophilic digesters in winter conditions.

Assessment of performance will provide insight into feasibility of innovative designs and determination of the gas production implications due to operation and design. Optimization of operation and design enables further evaluation for economic viability and a greater understanding of blending ratios. Data is integral in developing an economically viable solution for anaerobic digestion installation and operation on small-scale farms to increase installations on a large scale.

Particulate Phosphorus Transport and Delivery

JC Panuska
Funding: UW Coop. Ext. Service

Phosphorus (P) loss from agricultural systems can lead to adverse water quality impacts to receiving waters. These impacts include the excessive growth of aquatic plants that can impair use. Phosphorus loss occurs in both the sediment attached (particulate) and the soluble (dissolved) forms. Stationary horizontal tube samplers were installed in grass waterways at the UW Platteville Pioneer Farm during the growing season. Sediment from the samplers was analyzed for P and organic matter distribution by sediment particle size. The results of this research will be used to improve the particulate transport and fate algorithms in the nutrient management planning tool SNAP Plus.

Sediment and Phosphorus Loads in Runoff and Leachate using ENCAP's Movement Control Technology in Combination with Surface Application of Biosolids

*AM Thompson, D Mailapalli, A Roa-Espinosa
Funding: ENCAP LLC.
Collaborators: UW Biological Systems Eng.; SoilNet LLC

Polymer application for controlling erosion and nutrient transport has been well documented. However, comparatively less information is available on the effect of polymer application together with soil amendments. In this study, we investigated the effect of polyacrylamide (PAM) in combination with surface application of gypsum and Milorganite™ (Milwaukee Organic Nitrate) biosolid for reducing sediment and phosphorous transport under laboratory rainfall simulations. The treatments considered were bare soil, gypsum, Milorganite™, gypsum+Milorganite™, PAM-coated gypsum and PAM-coated Milorganite™. Application rates for gypsum and Milorganite™ were 392 kg ha^{-1} (350 lb/acre) and 726 kg ha^{-1} (650 lb/acre), respectively. The PAM was coated on gypsum and Milorganite™ at an application rate of 11.2 kg ha^{-1} (10 lb/acre) and 22.4 kg ha^{-1} (20 lb/acre), respectively. Rain simulation experiments were conducted using a rainfall intensity of 6.5 cm h^{-1} for one-hour on a 10% slope. Surface runoff was collected from each soil box at 10 min intervals and leachate was collected over the 60 min simulation. The reduction in runoff or leachate for all treatments was not significantly different from the bare soil control. The sediment loss for PAM coated Milorganite™ was reduced by 77%, when compared to bare soil. However, the sediment loss was not significantly different for all other treatments. The PAM-coated gypsum was not effective for erosion control in our study, and there appears to be a correlation between effectiveness and prill size. However, the gypsum (coated and uncoated) contributed about half of the dissolved reactive phosphorous (DRP) export (in the runoff) compared to bare soil (1.3 mg). The PAM-coated Milorgante™ reduced the DRP and total phosphorous (TP) export to 0.3 to 0.5 times that of Milorganite™ and to levels similar to bare soil. The decreased sediment and phosphorous export for the PAM-coated Milorganite™ treatment is a signal for potential management practice for controlling erosion and nutrient transport in agricultural landscapes.

Improving Methods for Predicting Runoff from Urban Lawns

*AM Thompson, R Bannerman, T Stuntebeck, J Stier
Funding: Wis. Dept. of Natural Resources
Collaborators: UW Biological Systems Eng.; UW Horticulture; US Geological Survey

Cities in Wisconsin are being asked to estimate their stormwater pollutant loads and develop stormwater plans describing approaches to controlling any pollutant loads that exceed state performance standards. Both of these tasks require that engineers have access to good estimates of loads from different types of urban source areas, such as streets and lawns. Urban runoff models used by engineers in Wisconsin do a reasonable job of predicting runoff from impervious areas, such as parking lots, but recent data collected by the USGS in Madison indicates greater uncertainty with predicting runoff from lawns.

Although runoff from lawns on a per area basis is less than impervious areas, the amount of area lawns represent can make them important in determining pollutant loads and sizing stormwater control practices. For example, some of our best data available now for Madison, WI indicates about 4% of the annual rainfall will run off a lawn, but this relatively low amount of runoff might represent about 15% of the total annual stormwater discharge from a medium density residential area. This is because lawns can represent 60% of the total drainage area for a medium density residential basin. An annual contribution of 15% of the annual discharge is made more important for pollutants with relatively high concentrations in lawn runoff.

Many variables influence the amount of runoff from urban lawns, including soil characteristics (moisture content, degree of compaction, infiltration rates, and soil texture), rainfall characteristics (depth and intensity), topography, and condition of the turf. Using lawn runoff data (6 lawns over a 5 year period) collected by the USGS, a logistic regression analysis was conducted to determine the relative importance of these variables on lawn runoff generation. The analysis indicated that antecedent soil moisture is a critical variable affecting runoff generation from lawns.

A field study was conducted at the University of Wisconsin O.J. Noer Turfgrass Research Facility. Six turf grass field plots were instrumented to monitor precipitation, soil moisture, runoff, and meteorologic variables. Data collection began in late summer 2008 and continued through the fall of 2010. The effects of antecedent moisture and slope length on lawn runoff generation for natural rainfall are currently being evaluated.

Characterizing Thermal Pollution in Urban Landscapes

*AM Thompson, JM Norman, M Nimmer
Funding: USDA-CSREES
Collaborators: UW Biological Systems Eng.; UW Soil Sci.

Impervious surfaces in urban areas are a source of thermal pollution in cold climates and threaten the health of cold-water ecosystems. Impervious surfaces absorb energy from the sun. During a rainfall/runoff event, runoff absorbs some of that heat and is warmed. The higher runoff temperatures can raise the temperature of receiving waters. Stream temperature is a major limiting factor for cold-water fisheries, and increases in water temperature can result in biological impairment to aquatic habitat.

In May 2009, instrumentation was installed to monitor rainfall and runoff rates and temperatures from a 12 ha residential development in Sun Prairie, Wisconsin. Thirty-five storm events were monitored from May through September 2009. Weather data including wind speed, air temperature,

solar radiation, and humidity were obtained from the nearby UW-Arlington Research Station. A simple thermal urban runoff model (TURM) was previously developed for the net energy flux at the impervious surfaces of urban areas to account for the heat transferred to runoff. The runoff temperature is determined based on the interactions of the physical characteristics of the impervious areas, the weather, and the heat transfer between the moving film of runoff and the impervious surface common in urban areas. Key surface and weather factors that affect runoff temperature predictions are type of impervious surface, air temperature, humidity, solar radiation before and during rain, rainfall intensity, and rainfall temperature. Runoff from pervious areas is considered separately and estimated using the Green-Ampt Mein-Larson rainfall excess method. Pervious runoff temperature is estimated as the rainfall temperature. Data from the residential development are being used to evaluate TURM at the sub-watershed scale and a numerical routine that accounts for heat losses in a storm sewer has been added to the model.

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 cm^3cm^{-3} for runoff generation was determined for all six basins. 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 manure application during time periods when soil moisture is near or above a critical soil moisture threshold would decrease the risk of surface water contamination.

Innovations to Improve Stormwater Management

*AM Thompson, J Zedler, S Loheide, J Panuska, Z Zopp, S Prellwitz, J Miller, J Doherty,

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 treatment/research facility is located at the University of Wisconsin-Madison Arboretum and consists of a small pond (0.30 ac) that overflows into a 1.43-ac basin that is divided into four experimental swales (@26x328 ft). Each swale has a weir that can be adjusted to discharge or retain stormwater, and each swale has native subsoil overlain by salvaged topsoil. In Nov. 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. 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.

Characterizing Sediment Delivery in Wisconsin Agricultural Basins

*AM Thompson, H Singh, J Panuska

Funding: USDA-CSREES

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 Revised Universal Soil Loss Equation (RUSLE2) combined with digital elevation models

(DEM) and soil databases will be used to estimate sediment delivery ratios (SDR) for agricultural basins in different physiographic regions of Wisconsin. Continuous monitoring data from the University of Wisconsin - Discovery Farms Program will be used to evaluate the delivery ratios. The Discovery Farms Program conducts environmental research on privately owned farms throughout the state of Wisconsin (http://uwdiscoveryfarms.org). Relationships between SDRs and landscape and storm characteristics will be developed. 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, BJ Lepore, RD Jackson, KG Karthikeyan, 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

Funding: UW Water Resources Institute; USDA CSREES

Collaborators: UW Biological Systems Engineering; UW Agronomy

High yielding cropping systems (e.g., corn, perennial switch-grass, hybrid poplar trees) are proposed to supply feedstock to the latent cellulosic ethanol industry. Assessing the sustainability of these systems requires a better understanding of water, sediment, and nutrient export dynamics when these systems are specifically managed for biofuel production. We will determine how plant diversity and productivity are related at several spatial scales and link these vegetation parameters to water and nutrient dynamics. Specific 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 to be performed on field sites comprising eight different alternative biofuel production systems already established as part of the Sustainability Thrust of the Great Lakes Bioenergy Research Center (GLBRC). Our results 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.

Pleasant Valley Phosphorus Management Pilot Project

J Panuska, AM Thompson, L Ward-Good, P Nowak, KG Karthikeyan, Tom Cox

Funding: USDA CSREES

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 from which the land owners having fields with 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. Atmospheric fallout radionuclides (^{137}Cs and unsupported ^{210}Pb) 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 for six months 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.

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 diary 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.

Environmental Impacts of Pasture Based Dairy

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

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

EXTENSION

Dairy Production

Dairy Production and Profitability

* BJ Holmes, DW Kammel, 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. A full size model, low-cost parlor stall has been built and displayed at many farm shows throughout the state. This exhibit has

attracted much attention to the Dairy Modernization program.

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

- Low-cost milking parlor display;
- Dairy modernization website;
- Design and management options for low-cost, retrofitted milking parlors,
- Dairy producer modernization survey for farms under 100 cows;
- Developing dairy modernization planning teams;
- Dairy modernization planning team training;
- Regional modernization planning workshops;
- Odor control workshop;
- MWPS *Dairy Freestall Housing and Equipment Handbook* revision development;
- Milking technology workshops and CD development;
- Milking parlor management user group;
- Heat abatement in dairy barns;
- Developing dairy modernization planning teams in northern Wisconsin.

Maintaining Forage Quality from Harvest through Storage and Feeding

*BJ Holmes, KJ Shinners, 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.
- Haylage and corn silage inadequately packed and/or covered in bunker silos, piles, and silo bags.
- Haylage 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/teamforage/index.html>. 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.

Research and Extension Grants

*DW Kammel

As a chair of the modernization work group of the UW Cooperative Extension's Dairy Team, I was asked to help coordinate and develop proposals for the Dairy Industry Revitalization Grants as part of a USDA request. I am the primary contact for the following projects.

- A Comparison of Tillage Methods Used within Composting Bedded Pack Barn Systems for Dairy Cattle. WISOM222. UW Consortium Project. S Kelm, L Bauman, P Kivlin, D Kammel. $50,290.
- Regional Dairy Modernization Meetings—USDA $2,168.
- Dairy Modernization Planning Team Support Person—USDA $32, 650.
- Dairy Modernization Planning Team Support—USDA $24,479.

Dairy and Livestock Farm Modernization

DW Kammel

Funding: UW Coop. Ext. Service

Collaborators: UW Biological Systems Engineering, UW Dairy Science, UW Center for Dairy Profitability, MidWest Plan Service, Four-States Dairy Programming Group

Dairy modernization includes facility design and changes to transition the old stall barn dairy system into a more cow comfortable and labor efficient dairy system. This includes presenting and coordinating programs in dairy facilities and feeding systems including low cost milking centers, free stall barns, compost bedded barns, special needs and transition cow barns, and heifer housing. Much of this work has been with family dairy farms in transition from 60-80 cows in a tie stall barn to a milking parlor and freestall or bedded pen housing system. This work has been accomplished through the Dairy Modernization workgroup of the Dairy Team which I am co-chair. We finished a survey of 100 farms that have modernized in the last 10 years and have published a peer reviewed article for the Journal of Extension that explain the impacts of dairy modernization on those farms.

I have also worked with beef quality assurance programs on cattle handling facility design and dairy goat and sheep farm development with the DATCP. I have been invited

to present dairy educational seminars through the Babcock Institute for several groups of Chinese, Phillipino, Finlander, Israeli, Belarussin, Ukrainian visitors to campus. I was invited as speaker by the Western Canadian Association of Bovine Practitioners, Greenbelt Veterinary Service, Chilliwack BC, and Costa Rican Dairy Producers Association. I accepted a volunteer assignment through CNFA funded by USAID to Ukraine and Belarus to work on dairy design with dairy consultants and several dairy farm owners. I was recently awarded the service award from ARS.

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.

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

*DJ Reinemann, TH Passos-Fonseca
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.

Electric Power and Energy Systems

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

Dates: 1-1-2007 to 12-31-2010

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 protential 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.

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 but 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.

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

Pat Walsh, 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:
Curriculum identification and resource collection is complete. Curriculum development is in progress. The eXtension Sustainable Agricultural Energy community of practice is actively involved in program implementation. Short PowerPoint promotional programs have been developed for each of the target areas. Development of evaluation instruments is underway. Webinar will be scheduled for spring of 2011.

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.

Machinery and Harvesting

Wisconsin Annual Farm Technology Days

*RT Schuler
Funding: UW Coop. Ext. Service; Wis. Farm Technol. Days, Inc.
Collaborators: UW Biological Systems Eng.

Wisconsin's annual Farm Technology Days (FTD) provides an opportunity to work with the farm machinery industry to demonstrate field machinery and to reach thousands of farmers. Field demonstrations at FTD allow comparison of machines for tillage and harvesting forage as alfalfa silage and baled hay. In 2008, demonstrations included mower-conditioners, mergers, rakes, forage harvesters, balers, and various tillage implements. Other demonstrations were ride-and-drive for small tractors, utility vehicles, telehandlers, and skid steers and auto guidance systems on a sprayer and tractor.

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, RT Schuler, J Panuska
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.
- Equipment demonstrations and management practices of conservation tillage techniques which have proven effective in reducing soil erosion.
- Work with committees to establish standards for proper management of silage leachate/runoff from feed storage areas,
- A survey of grazier outwintering practices which could affect surface runoff of nutrients.
- Investigation of environmentally friendly cleaning and sanitizing agents.
- Reduction of wastewater volume from milking parlors.
- Demonstration of ground water flow and contaminant transport using sand tank models.
- Development, testing, and teaching how to use field runoff

software models.

Safety and Health

AgrAbility of Wisconsin

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

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

The education priority is done through 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 2010-2011 budget year, on-farm services were provided to 429 farmers with disabilities with 131 new referrals and 175 continuing clients. AgrAbility staff completed 153 farm or worksite assessments. Staff from the FARM program completed 84 assessments for the DVR 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 129 clients whose cases were closed during 2010-2011 grant year were surveyed to estimate the success of the program in meeting their needs. Forty-one farmers completed and returned their surveys, for a response rate of 31 percent. Eighty-two percent of these indicated they do a better job of farming as a result of the program.

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

Youth Education

Tractor and Machinery Operation Certification Program

*CA Skjolaas
Funding: UW Coop. Ext. Service
Collaborator: UW Biological Systems Eng.

Federal child labor laws require specific training relating to tractor and machinery operation for youth ages 14 to 15 working on farms other than those of their parents. In addition, Wisconsin law requires such training for youth 12 to 16 years old who operate tractors or other farm machines on public roads. Training programs are conducted by county Extension agents and agricultural education instructors with help from many volunteers. Greater standardization was brought into the program statewide and help was offered to counties that had not previously offered programs. Supplemental materials, such as an instructor training manual, were developed, and instructor training was offered statewide. These efforts have resulted in more than a thousand youth successfully completing certification programs annually.

Future Farmers of America Agricultural Mechanics Career Development Event

*JW Nelson, CA Skjolaas
Funding: UW Coop. Ext. Service
Collaborators: UW Biological Systems Eng.; Wis. Future Farmers of America

In 2010, 20 teams took part in the Wisconsin Future Farmers of America Agricultural Mechanics event. Each year the top teams from four area Agriculcutural Mechanics contests take part in a statewide event organized by department staff. Guidelines are developed for the four area events. The state event also gets input from faculty at UW-River Falls, UW-Platteville, and the Fox Valley Technical College who direct area events. Biological Systems Engineering Department staff provided training for agricultural educators in Wisconsin.

Awards

ASABE 1/4 Scale Tractor International Student Design

2010 Competition Team won the "Sportsmanship" Award and finished 8th overall at the 13th annual competition held in Peoria, IL.

Hal Bohne received a 2010 CALS Classified Staff Award.

Aicardo Roa-Espinosa received a 2010 Distinguished Achievement Award from the UW-Madison College of Engineering. Aicardo is an internationally recognized expert in specialty polymer development. Specialty polymers are biodegradable materials which can be utilized for dust control, erosion control, water clarification, and solids separation and solidification. They have increasing significance in the management of residuals from the growing international bio-energy economy. His company, Soil Net LLC, markets worldwide.

Cheryl Skjolaas received the UW-Extension/ UW Colleges 2010 Chancellor's Award for Excellence. Cheryl was on the Custom Manure Applicator Subcommittee of the ANRE Nutrient Management Team. The team created several intentional manure spills to demonstrate the proper way to contain, clean up and restore a spill site.

Patrick Walsh received the UW-Extension/ UW Colleges 2010 Chancellor's Career Award. Pat was selected for his work in creating leading-edge educational programs and partnerships that protect Wisconsin's environment.

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