2009

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 105 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 2009 Annual Summary, based on activities underway and completed in 2008. 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 approximately 64 undergraduate and 32 graduate students. The department offers a wide range of courses with options in Machinery Systems Engineering, Food and Bioprocess Engineering, Natural Resources and Environmental Engineering, and Structural Systems Engineering.

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

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

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

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

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Richard J. Straub
Professor and Chair

Table of Contents

Faculty

David R. Bohnhoff, Professor, Ph.D.
Teaching / Research: wood structures
Robin K. Connelly, Assistant Professor, Ph.D.
Teaching / Research: food and bioprocess engineering
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
Director, Center for Dairy Profitability
K.G. Karthikeyan, Associate Professor, Ph.D.
Teaching / Research: natural resources and environment
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: milking equipment and facilities, rural energy, stray voltage
Roger M. Rowell, Professor, Ph.D.
USDA Forest Products Laboratory: wood chemistry, composites
Kevin J. Shinners, Professor, Ph.D.
Teaching / Research: power and machinery
Richard J. Straub, Professor, Ph.D.
Teaching / Research: power and machinery
Chair, UW Biological Systems Engineering Dept. and
Director, Agricultural Programs and Research Stations, 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.
Paul D. Thompson, Adjunct Professor, Ph.D.
Bou-Matic: milking equipment and milk cooling
Junyong Zhu , Adjunct Professor, Ph.D. forestry

Emeritus Faculty

Glen D. Barquest
Theodore J. Brevik
Gary D. Bubenzer
Frederick H. Buelow
James C. Converse
Calvin O. Cramer
Ferencz S. Denes
Marshall F. Finner
Richard G. Koegel
Leonard R. Massie
James O. Peterson
Ronald T. Schuler

Academic Staff

Acronyms of programs/projects with which several of the academic staff are associated:

AAW – AgrAbility of Wisconsin
CASH – UW Ctr. for Ag. Safety and Health
HFHP – Healthy Farmers/Healthy Profits Project
NAP – National AgrAbility Project

Names of associated faculty follow in parentheses for others.

Mary F. Beck, Senior Outreach Specialist, M.S.; NAP
Perry E. Cabot, Ph.D., Research Associate
(K.G. Karthikeyan)
Larry J. Chapman, Senior Scientist, Ph.D.; HFHP
Cally A. Ehle, Associate Outreach Specialist; AAW
Kerem Gungor, Research Associate, Ph.D.
(K.G. Karthikeyan)
Hailin Lin, Visiting Associate Professor, Ph.D.
(S. Gunasekaran)
Brian J. Lepore, Research Associate, Ph.D.
(A.M. Thompson)
Fachuang Lu, Associate Scientist, Ph.D. (X..-J. Pan)
Marcia G. Miquelon, Sr. Outreach Specialist, M.S.; HFHP
Jeffrey W. Nelson, Senior Research Specialist (dept. IT)
and Lecturer (farm equipment and power), M.S.
Astrid C. Newenhouse, Associate Scientist, Ph.D.; HFHP
Mark E. Novak, Senior Outreach Specialist; NAP
John C. Panuska, Faculty Associate, Ph.D.
Kathryn M. Pereira, Outreach Specialist, M.S.; NAP
Scott A. Sanford, Senior Outreach Specialist; Wisconsin Focus on Energy (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
Deanna Duerst, Department Administrator
Debra K. Sumwalt, University Services Program Associate

Graduate Students

Names of major advisor follow in parentheses

Syrym Abylgaziyev (X.J. Pan)
Robert G. Bennett (K.J. Shinners)
Jayne E. Bock (R.K. Connelly)
Colin F. Byrne (K.G. Karthikeyan)
Hyuckjin Choi (S. Gunasekaran)
Matthew F. Digman (K.J. Shinners)
Jeffrey A. Duncan (K.J. Shinners)
Philip D. Gaebler (K.G. Karthikeyan)
Frederick W. Gibbs (D.J. Reinemann)
Kody L. Habeck (K.J. Shinners)
Dan Hoffman (K.J. Shinners)
Thomas J. Hoffman (K.J. Shinners)
Wantida Homthawornchoo (S. Gunasekaran)
Natalie L. Huisman (K.G. Karthikeyan)
James B. Jordan (R.K. Connelly)
Kari A. C. Jordan (R.K. Connelly)
Jacob D. Karlen (K.J. Shinners)
Da E. Kim (X.J. Pan)
Jeannette E. LeBoyer (D.J. Reinemann)
Abiot Legesse-Gemechu (A.M. Thompson)
Aaron J. Lorenz (K.J. Shinners)
Brock M. Lundberg (X.J. Pan)
Jane L. O'Dell (R.M. Rowell)
Asli A. Ozkaynak (K.G. Karthikeyan)
Jose Carlos F. Pantoja (D.J. Reinemann)
Thais H. Passos-Fonseca (D.J. Reinemann)
David C. Powell (S. Gunasekaran)
Timothy F. Radatz (A.M. Thompson)
Vikrant Sharma (K.G. Karthikeyan)
Thomas F. Shevlin (A.M. Thompson)
Li Shuai (X.J. Pan)
Julie C. Sinistore (D. J. Reinemann)
Katherine B. Songer (K.G. Karthikeyan)
Eakasit Sritham (S. Gunasekaran)
Erik L. Storvik (A.M. Thompson)
Thomas Syring (D.J. Reinemann)
Liping Wei (J. Ralph)
Aaron D. Wepner (K.J. Shinners)
Shin Yee Wong (R.K. Connelly)
Xin Xin (R.K. Connelly)
Jiang Yang (S. Gunasekaran)
Dongsheng Zhang (X.J. Pan)
Jinjin Zhou (S. Gunasekaran)

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 about 64 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 32 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, FE Contreras-Govea, DR Mertens, PJ Weimer, GA Broderick

Funding: USDA Agric. Res. Service
Collaborators: USDA Dairy Forage Res. Ctr.; UW Agronomy

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. The objective of this research is to study silage digestion in rumen fluid taken from dairy cows to see if there are any differences in how rumen bacteria utilize silage, whether or not it ahs been inoculated.

Progress: An *in vitro* method was used to study differences in potential ruminal fermentation among alfalfa and corn silages inoculated with different microbial inoculants. Nine trials were completed: five with alfalfa silage and four with corn silage. The inoculants had varied effects on silage fermentation. The largest effects occurred when the natural populations of lactic acid bacteria on the crop at ensiling were lower than inoculants application rates. The effects of inoculation on the *in vitro* digestibility of the silages varied across the five trials. Inoculated silages sometimes produced reduced *in vitro* gas production and increased volatile fatty acid production. The most consistent effects of inoculated silages, however, showed in microbial biomass yield. Silages inoculated with certain inoculant strains consistently produced greater microbial biomass yield during *in vitro* ruminal fermentation than untreated control silages. These results suggest that certain inoculant strains may potentially have a probiotic effect on the cow.

Current efforts on the project are focusing on discovering potential explanations for these effects.

Effects of Additives on the Ensiling of Corn Stover

*RE Muck, JG Coors, KJ Shinners

Funding: USDA; Dept. of Energy
Collaborators: UW Agronomy, Iowa State U.; Pennsylvania State U.

Objectives: One of the keys to using corn stover as a feedstock for biofuel production is storage of the stover until it is ready to process Ensiling has the potential to not only preserve moist stover but also to pre-treat the biomass. The objectives of this study are to investigate the ensilability of various corn stover sources ensiled at different moisture contents with and without various additive treatments.

Progress: In 2007, we ensiled nine cultivars of corn stover to determine if different cultivars were affected similarly by various treatments at ensiling. Treatments included an untreated control, a bacterial inoculant, enzymes and acid as well as inoculant-enzyme and acid-enzyme mixes. Overall, the nine cultivars ranked similarly in ethanol potential compared to the previous year. The treatment that produced the highest ethanol potential was the enzyme-inoculant combination. However, the sulfuric acid treatments likely were the most effective at pre-treating the stovers, but deficiencies in our assay prevented us from accurately measuring their effects. The lack of a treatment by cultivar interaction regarding ethanol potential suggests that ensiling treatments that work well on one cultivar are likely to produce similar effects in others.

A second experiment was initiated in fall 2007 and completed in 2008, comparing laboratory and pilot-scale ensiling of corn stover with and without sulfuric acid treatment. The pilot-scale consisted of high-density bales of chopped stover wrapped with stretch film. Silages were analyzed after 47, 103, and 179 d storage. Storage time did not affect the amount of cellulose or hemicellulose in the bales. Consequently the changes in theses constituents occurred early in the storage period and did not change significantly thereafter. Sulfuric acid treatment produced similar changes in the bales as in previous laboratory studies. The pH was dropped below 2.0 and the only appreciable fermentation product was acetic acid. The sulfuric acid treatment reduced the cellulose content by approximately 30g/kg dry matter and the hemicellulose content 120 g/kg dry matter compared to that of the untreated bales, converting these carbohydrates to sugars.

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 Engineering, UW Dairy Science, UW Soil Science

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 are economically viable and practical.

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

*PL Ruegg, DJ Reinemann, SA Rankin
Funding: Hatch
Collaborators: UW Biological Systems Engineering, UW Dairy Science, UW Food Science

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 eight 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 Engineering, UW Dairy Science, UW Food Science

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.

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

*P Meier, ST Gower, DJ Reinemann
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.

SPORL for Efficient Biochemical Conversion of Woody Biomass

*X Pan
Funding: USDA Forest Service

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.

Cell Wall Structure Analyses for Improved Forage Digestibility and Improved Biomass Utilization

*X-J Pan
Funding: USDA Agricultural. Research Service

Objectives:
1. Provide the plant cell wall and biomass research communities with improved methods for polysaccharide and lignin structural profiling, based on complete cell wall solubilization and NMR;
2. Develop and streamline procedures to allow 20-30 samples/ day to be profiled and develop chemometric methods that allow this profile to predict digestibility and bioconversion efficiency.

Approach: Improvements to the current dissolution/NMR

methods will be sought to:
1. Provide the necessary database, via model compounds and isolated components, to characterize component polysaccharides and lignins in whole-cell-wall mixtures;
2. Optimize milling conditions for the various biomass sample types and seek alternative solutions that require less rigorous milling;
3. Attempt to develop improved rapid dissolution methods that can be performed directly in the NMR tube; determine solvent systems that do not interfere with the correlation contours from polysaccharide and lignin components.
4. Develop NMR methods that allow the crucial 1D-proton and 2D-HSQC NMR spectra to be acquired in less than one hour (on the whole cell wall sample);
5. Develop methods for databasing and quantifying the NMR cell wall spectra;
6) With collaborators, attempt to develop chemometric methods that can be applied to 2D-NMR data.

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

*X-J Pan

Funding: USDA Hatch Fund

The research will emphasize 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 such as lignin-based carbon fibers;
3. Identification and quantification of the mono- and oligosaccharides from hemicellulose and other derivatives from the saccharides, such as furfural, hydroxymethylfurfural (HMF), formic acid, acetic acid, and levulinic acid;
4. Applications of the hemicellulose fraction as livestock feed additives and conversion of the hemicellulose fraction to liquid fuels by aqueous-phase reforming.

Bioconversion of Forest Residues to Fuel Ethanol and Value-Added Co-Products Using Organosolv Biorefining Platform

*X-J Pan

Funding: USDA McIntire-Stennis Fund

This research is to develop a biorefinery technology based on an organosolv process that will allow conversion of forest residues to fuel ethanol and other value-added co-products including high quality lignin, oligosaccharides and other derivatives from lignin and carbohydrate. Forest residues are selected as a feedstock because they are abundantly available in Wisconsin and they have not been widely and extensively utilized.

The specific objectives of this research are:
(1) To optimize the organosolv pretreatment of forest residues for carbohydrate recovery, cellulose hydrolysis and co-product development;
(2) To characterize the substrates prepared from the pretreatment and to evaluate the enzymatic hydrolysability of the substrates;
(3) To characterize the lignin derived from forest residues during the organosolv pretreatment, determine the influence of pretreatment parameters on lignin properties, evaluate the potential application of the lignin and develop co-products from the lignin;
(4) To identify and quantify the mono- and oligosaccharides, degraded low molecular weight lignin, and derivatives from hemicellulose sugars, such as furfural, hydroxymethylfurfural (HMF), formic acid, acetic acid, levulinic acid, etc., and to develop value-added products from these chemicals.

Animal Blood-based Adhesive

*S Gunasekaran, H Lin

Funding: US Egg and Poultry Association

Adhesives were prepared from cow blood via alkali-modification. Their physicochemical and adhesion properties such as the degree of hydrolysis, viscosity, water solubility, curing time, and bonding strength were measured. The degree of hydrolysis increased with increasing basic pH value. The adhesive exhibited shear-thinning viscous behavior. Both viscosity and shear-thinning character showed a remarkable shift at pH 10.2 and at 50°C. The curing time decreased with curing temperature within the 60 to 80°C range. The water solubility of the adhesive was the lowest when sodium silicate, the curing agent, was used during adhesive preparation at a concentration of at least 2.0% (v/v) regardless of the pH value. The adhesive bonding shear strength was independent of the pH and was comparable to that of phenol formaldehyde in the dry condition, but was somewhat lower in the wet condition.

Structures / Construction

Reinforced, Deep End-Notched Wood Members

*DR Bohnhoff, JW Barker, D Rammer, S Cramer

Funding: USDA Hatch; UW Biological Systems Engineering

Deep end-notched wood members are wood members whose ends contain notches that exceed one-fourth of the member's depth, which is the maximum currently allowed by the National Design Specification for Wood Construction. In 2003, deep end-notched wood purlins were used to construct a post-frame building at the UW's Rhinelander Agricultural Research Station. The notches were slightly less than 1.6 inches wide and were located slightly in from the ends of the members so they locked over the trusses they were set on. This use of notched purlins shows how effective they are in increasing construction safety, speed, and accuracy.

Construction safety begins with predrilling holes for fasteners (nails or screws) at the same time the members are notched. Predrilling is possible because notch location dictates fastener location. Safety is enhanced because fasteners can be partially installed before the members are shipped from the manufacturing facility. Safety also results because predriven fasteners help secure lines that are slipped over purlin ends for lighting purposes. Pulling purlins onto a roof with a tag line is considerably safer than having someone toss them up from the ground (a common practice). Reaching for a thrown purlin increases the likelihood of a fall, and a thrown purlin is a dangerous flying object, especially when it doesn't reach its mark. On the roof, notched members are considerably easier to position. The notch also helps hold the purlin in place while the fasteners are driven home. This, and the fact that fasteners are already started, means a worker has one hand free to use for greater personal stability. Also, because of predriving, less energy is expended by workers maneuvering around on the roof framing. It follows that notched purlins and predrilling fastener holes improves construction accuracy. The notches lock in truss spacing. Predrilling fastener holes improves construction accuracy. The notches lock in truss spacing. Predrilling fastener holes ensures that fasteners penetrate the center of rafter/truss top chord. Improved construction speed results because truss spacing is quickly and easily fixed, fastener installation is more rapid, and the use of lifting lines keeps construction smooth and continuous.

Notching enhances the transfer of both tensile and compressive chord forces between purlins in adjacent bays. Since purlins in adjacent bays are both locked to the truss between them, any axial force in one purlin will be transferred via notches and nail connections to the other. Transfer of measurable tensile chord forces is frequently a problem with purlins that rest in joist hangers. Such purlins must generally be tied together over the top of the truss with special metal strapping. Also note that, by decreasing the depth of a purlin at a notch, shorter fasteners can be used to attach the purlin to the truss, and purlin roll forces (forces that work to bend such a connection) are reduced.

During 2006, a series of reinforced and non-reinforced, deep-notched wood members were laboratory tested. Two different methods were used to reinforce the notches so as to reduce shear/tension-perpendicular-to-grain splitting at the inside corner of the notch. In one case, metal plate connectors were pressed into each side of the member alongside the notch. For another set of specimens, a screw was inserted up into the wood member alongside the notch. These test showed that, with minimal reinforcing, strength lost by notching can be easily recovered.

During 2007, work began on an extensive series of laboratory experiments. This work continued through 2008 and is still ongoing in 2009. These experiments began with a series of tests to determine load-slip properties of screw and metal plate connector reinforcement. This was followed by tests of specimens that were reinforced with either screw or metal plate connectors after the specimens were "pre-failed" by slitting the lumber. This phase of the study was conducted to assess analytical procedures that had been developed for predicting assembly behavior. Current tests are being conducted on reinforced and unreinforced notches of four different depths. Half of these tests feature S-P-F, the other half Southern pines.

The ultimate goal of this research is to develop an ASABE Engineering Practice for calculating the design strength of reinforced and non-reinforced deep end-notched members.

Vertically, Mechanically-Laminated Assembly Design

*DR Bohnhoff, AJ Holstein

Funding: USDA Hatch, UW Biological Systems Engineering

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-90s and is 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 need to give equal consideration to ASD and LRFD design formats, and it needs to include information for more commonly used preservation wood treatments, as well as the compatibility of these treatments with various mechanical fastener substrates and coatings.

The bulk of the work on this project involves the development of an equation for calculating repetitive member factors for unspliced, mechanically-laminated assemblies that are a function of mean laminate strength and stiffness, the COVs of laminate strength and stiffness, and the number of laminates. To date, data from the federal government's in-grade lumber testing program has been tabulated along with information from past tests on both glue- and nail-laminated assemblies. This information is now being used to investigate different predictive equations for the repetitive member factor.

Shallow Post and Pier Foundation Design

*DR Bohnhoff

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

During 2008, research concentrated in two areas: revision of the ASABE standard for shallow post embedment, and designing and fabricating a post-to-concrete wall connector.

Revision of the ASABE standard for shall post foundations is a major undertaking. The initial draft of the new standard began in 2007 and should be completed in 2009. 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 (MOE*) hold up, and thus analysis of deeper foundations is not possible. These equations also require that the applied shear force B 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 use: 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.

In 2007, a special bracket for attaching wood-post to cast-in-place concrete stub walls was designed, fabricated and installed in a test building. During 2008, this research was extended with the design, fabrication and installation of a wood post to cast-in-place concrete piers connector. In both cases, the brackets were designed to: (1) maximize moment transfer between the wood post and concrete, (2) minimize fabrication and installation cost, (3) enable accurate post placement, and (4) facilitate anchorage of other building elements in addition to the post. These connections were highlighted in the January 2009 issue of *Frame Building News.*

Bending Properties of I-Post

*DR Bohnhoff, AJ Holstein

Funding: USDA Hatch; UW Biological Systems Engineering

With few exceptions, post-frame buildings are currently constructed with posts featuring identically-sized members that are vertically-laminated by nailing and/or gluing. I-shapes, while standard for columns in steel buildings, have not been used in post-frame construction. Possible reasons for this include: (1) the difficulty of forming a long, straight and non-twisted I-post 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 I-post strength on flange-to-web connections (which makes behavior difficult to predict), and (3) the difficulty of splicing flanges to form longer I-posts.

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, an I-post that exhibits complete composite action (i.e., a post 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 an I-post 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, I-posts 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, I-posts are thermally more efficient. I-posts 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 is to use MLBeam (a special finite element analysis program for horizontally mechanically laminated assemblies) and laboratory testing to optimize the design of an I-post that utilizes a combination of elastomic adhesive and screws to connect flanges. Both LSL and dimension lumber webs will be investigated. Although LSL webs are more expensive, they are also straighter, more dimensionally stable, provide a better contact surface for attachment of flanges, have a more uniform shear strength, and provide a more consistent anchor for mechanical fasteners. In addition, LSL can be manufactured to any width, and thus can be used to easily produce I-posts of any size.

During 2008, all lumber for laboratory testing was obtained. This specific gravity and modulus of elasticity of the lumber was ascertained. A series of load-slip tests were then conducted on the mechanical fasteners and the adhesive that will be used to construct the I-posts. The next step in this project is to use the load-slip data along with MLBeam to optimize I-post design. Assemblies will then be built and tested to determine the accuracy of the analysis method.

Engineering Properties of Clay-Coated Organic Fibers

*DR Bohnhoff

Funding: USDA Hatch; UW Biological Systems Eng.

Based on very limited research, the UW Extension Community Natural Resource and Economic Development program has been constructing and promoting *Northern Light-Clay Straw Buildings* for residential use in Wisconsin. These buildings utilize clay-coated wheat straw as thermal insulation. This process involves adding dry fiber into a mechanical mixer containing a clay slip. The coated straw is then packed into wall forms. The forms are removed, the material is allowed to dry, and the resulting surfaces are plastered. Although fire characteristics of clay-coated straw insulation are unknown, building code officials continue to allow this form of construction because of the fire-resistant plaster wall finishes. It is for this same reason that *straw-bale* home construction is allowed.

Proponents of clay-coated fiber insulation claim that clay preserves and protects the fibers from insects, mice, and fire and absorbs odors. Its use is not new. Centuries-old European heavy timber structures using it are still standing. A variant on the straw-clay technique uses wood chips mixed with clay.

Preliminary tests indicate clay-coated straw has a relatively low thermal resistance. To this end, the attractiveness of clay-coated fiber as an insulation is that it is a very low-impact material as it can be made on-site from local unprocessed earth and waste agricultural fiber. Production is not nearly as energy intensive as other insulating materials. Relative to fiberglass, clay-coated fiber is neither an irritant nor airborne hazard. Although cellulose insulation is an attractive product because of its use of recycled paper, 20 to 25% of its weight is comprised of fire retardant chemicals and, in some products, acrylic binders.

Although it is being used in construction, no research currently exists on the fire resistance of light-clay coated organic fiber material. Additionally, due to its low environmental impact and cost, there is interest in using it as an unprotected insulation (i.e., insulation that does not rely on a fire-resistant plaster covering). This would include use as a blow-in blanket system for walls and loose insulation for open spaces such as attics. Before such uses can be attempted, the material's fire and thermal characteristics must be established. This study, which recently commenced, seeks to determine these characteristics and to ascertain how they are related to such properties as: elemental composition of both the clay and fiber, clay coating thickness, fiber length distribution, specific surface area of the fiber, and dry bulk density. This, in turn, will help answer critical questions regarding quality control associated with on-site production.

Safety and Health

Community Partners for Healthy Farming Nursery Field Crop Growers Intervention Project

*LJ Chapman, AC Newenhouse, MG Miquelon

Funding: US Ctrs. for Disease Control and Prevention; Natl. Inst. for Occupational Safety and Health

Collaborators: UW Biological Systems Eng.; various grower organizations in Wis.; UW Coop. Ext. Service

This project will accomplish three specific aims.

1. Develop or identify existing control technologies for work per-formed by Midwestern nursery operations engaged in bedding and garden plants and nursery crop production. We will reduce hazards (and thereby injuries) by developing or identifying controls that reduce exposure to physical work hazards for musculoskeletal and traumatic injuries. The types of controls we will consider include work practices, tools, labor aids, and administrative controls. We will seek out reports from nursery managers, commercial suppliers, university Extension personnel, and others about emerging production practices that could improve both safety and profits. We will also collaborate with university instructors and their students in design and other engineering courses to accomplish this aim.
2. Conduct field research to evaluate the control technologies from #1 above which show the most promise to determine their impact on production and to verify that musculoskeletal risk factors are actually reduced when the practices are adopted. We will undertake small-scale field studies to quantitatively evaluate the hazard-reducing and profit-enhancing aspects of two to four of the best production practices each year. Comparisons will be made in the field or in laboratory situations between accomplishing work by conventional methods and with the improved control technology. Fewer than six subjects in each condition for less than half a day of work are anticipated. Small-scale field studies will also be undertaken on operations that have adopted practices to verify that musculoskeletal risk factors are really reduced.
3. Conduct and evaluate a large, region-wide intervention to pro-mote the best control technologies from #2 above to the 7,888 nursery operations in seven north central states (WI, MN, MI, IA, IL, IN, OH) that produce bedding and garden plants and nursery crops. Disseminate information about the improved work practices through sources that growers already rely on for information about new production methods (e.g., other growers, trade publications, public events, university Extension agents, other private and public sector resource people, the Internet, etc.) Evaluate the interventions with annual mail questionnaires to separate, population-based, rolling probability samples of the study group (n = 650 nursery growers/yr) and the control group (n = 320 New Zealand nursery growers/yr).

Development and Synthesis of Magnetic, Fluorescent, Carbon-Based Nanoparticles that Display an Array of Antigens 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

Greenhouse Energy Conservation Strategies and Alternative Fuels

*DJ Reinemann, SA Sanford

Funding: USDA-SARE Professional Development Grant
Cooperators: UW Biological Systems Engineering, Michigan State University

Energy costs have been escalating faster than greenhouse growers have been able to raise prices which are putting a squeeze on profitability. Some growers have creased operations or have changed business plans to weather the changes. Many growers are looking for options to reduce their energy costs but they don't always understand which options will provide the greatest return on investment. Alternative fuels, such as wood, are sited as a solution to reducing energy costs but often the total costs of these alternatives are overlooked. A wood lot is often considered low cost or free but the harvest and handling of the wood can be substantial. Many agricultural educators are well versed in greenhouse plant production issues, (propagation, diseases, insect control, plant selection) but lack of knowledge about energy conservation strategies for greenhouse growers.

The objective of this program is to increase the knowledge base and provide agricultural educators with curriculum materials and resources information so they can hold grower workshops about options for reducing energy costs in greenhouses. There are resources available from various sources (NRAES, websites) on energy conservation for greenhouses but there aren't curriculums or presentations available for educators to use for a seminar or workshop on energy conservation. This project is developing extension bulletins and presentation materials on general greenhouse energy conservation, thermal/shade energy curtains, plant production methods to reduce energy use and alternative fuels for heating greenhouses. A professional development workshop will be held in association with the Wisconsin Association of Agricultural Educators on July 1, 2009 and another session in August/September targeted at cooperative extension agents.

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: NRCS Conservation Innovation Grant
Collaborators: UW Biological Systems Engineering, GDS Associates

This project will develop a comprehensive farm energy self-assessment tool and provide an online resource center, so agricultural producers can conduct customized energy analyses. The development of self-assessment tools for dairy farms, greenhouses, irrigation, potato storage, grain drying and lighting 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 self-assessment 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 self-assessment 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.

Focus on Energy - Agricultural Program Technical Support

*DJ Reinemann, SA Sanford, J Kepka, R Hackner, J Brinker, J Schultz

Funding: WI Focus on Energy; GDS Associates
Collaborators: UW Biological Systems Engineering; UW Soil Science

This project will develop and test agricultural energy management assessment support tools and educational materials and provide training and technical support for energy auditors with the Focus on Energy program. Energy audit tools will be developed and supported for energy service providers. Energy presentations will be provided for interest groups including UW Extension. Programs will be offered at Wisconsin Farm Technology Days and at regional seminars.

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.

Development on Novel Micro-Arc Plasma Tool for Localized Surface Functionalization

*FS Denes

Collaborators: UW Material Science;, C-PAM, Biological Systems Engineering; SonoPlot Co.

The plasma-aided technology that is developed using the novel atmospheric pressure plasma tool will allow localized surface functionalization, etching or deposition on the micrometer scale, for the development of high performance biological arrays and microelectronic circuits without using conventional approaches like lithography.

Design, 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

*FS Denes

Funding: UW Center for Plasma-Aided Manufacturing; UW Biological Systems Engineering; UW-Primate Institute

Collaborators: UW Mechanical Engineering

These systems will permit generation of sole and hybrid nanoparticle systems, including magnetic nanoparticles, and the deposition of thin controlled structure macromolecular plasma layers. Potential applications include: development of efficient, localized, targeted drug delivery systems, novel nano-composite materials, and generation of materials with controlled surface characteristics, like low and high surface energy, electrical conductivity, magnetic-skin materials, etc.

Machinery and Harvesting

Engineering and Harvesting

*KJ Shinners, PJ Weimer, RE Muck

Funding: DOE, USDA-ARS, John Deere

Collaborators: UW Biological Systems Engineering, USDA Dairy Forage Research Center

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;
- Assess the storage characteristics of wet and ensiled stover;
- Study the potential of pre-treating the stover during storage.

The grain combine harvester was modified to father, size-reduce and transport the MOG exiting the rear of the combine. The amount of MOG can be altered by the type of head used, either ear-snapper or whole-plant, or the height of the head. In 2008, research focused on improving machine throughput with the single-pass configuration and comparing single- and two-pass harvesting systems. Although improvements were made to the machine in its single-pass configuration, grain harvest is slowed by 25 to 50% compared to conventional harvesting configurations. The simultaneous management of grain and stover handling and transport is also considered a detriment with the single-pass system. The two-pass system involves a unique head which captures stalks and

leaves before they enter the combine and forms a windrow 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. The overall specific fuel use of the two-pass system is greater than the single-pass, but the harvesting capacity is almost double that of the single-pass configuration.

An extensive storage study was conducted in 2008 which compared both aerobic and anaerobic storage of whole-plant and cob/husk stovers. Two different harvest dates were investigated so as to alter the stover moisture into storage. Based on the results of this work, anaerobic storage is the only acceptable storage method. Fermented material not only had low DM loss, but the chemical composition of the material was better than that of the aerobically stored material. Stover at moistures above 40% (w.b.) stored aerobically heated to levels where spontaneous combustion would be a concern.

Novel Technologies for Field Fractionation, Harvesting and Storage of Perennial Bioenergy Crops

*KJ Shinners, PJ Weimer, RE Muck

Funding: USDA-ARS

Collaborators: UW Biological Systems Engineering; USDA Dairy Forage Research Center

Harvest-fractionation involves stripping the leaves from the stem at the time of harvest using a tined rotor. The amount of leaf tissue stripped from the stem is dependent upon the penetration depth of the stripping rotor and the tine to tip speed ratio. For instance, increasing the rotor tip height from 6 to 10 inches decreased yield in the stripped fraction by 37% when stripping lodged alfalfa. Yield of the stripped fraction increased by almost 100% when tine to ground speed tip ratio was raised from 7.3 to 12.8:1. In 2008, harvest fractionation was successfully applied when harvesting alfalfa and reed canarygrass. The moisture of the stripped fraction of the perennial grasses was at satisfactory level for direct ensiling without concerns for clostridia fermentation. Reed canarygrass leaves were below 65% (w.b.) by late June. However, the stripped fraction of alfalfa never reached acceptable moisture for direct ensiling, even when the plants were allowed to reach seed pod maturity. Work on economical and practical methods to directly ensile alfalfa leaves is critical if harvest fractionation of this crop is to be successful. The stem fraction of either fractionated alfalfa or grasses dried very quickly after they were cut and windrowed. Average moisture of this fraction at baling was under 10% (w.b.). Round bales of the stem fractions of alfalfa and reed canarygrass were formed and wrapped with plastic twine, net wrap or plastic film. The bales were stored outdoors on a well drained surface. The DM losses in bales of stems stored out doors were very high after 11 months of storage. Alfalfa stem bales lost 11.8, 16.6 and 21.1% of DM when wrapped with film, net mesh and plastic twine, respectively. Reed canarygrass stem bales lost 7.4, 9.5 and 12.6% of DM when wrapped with film, net mesh, and plastic twine, respectively. Leaves are an important component of a successful thatch on round bales. It has been observed that the twine wrapped bales did not form a good thatch because of the absence of leaves and these bales are experiencing considerable moisture penetration during storage. A new harvest fractionation mechanism was designed and fabricated which combined the leaf stripping and stem cutting steps into a single pass. The mechanism mounted on a self-propelled forage harvester with the stripped fraction being chopped and blown into a trailing wagon and the stem fraction being placed in a windrow under the harvester. Performance of this new harvest mechanism was challenged by lack of capacity and material flow problems. Consideration is being made as to whether using a forage harvester was the appropriate power source for this process given the difficulty achieving adequate clearance under the machine frame for the cut stems.

Storage Characteristics of Ear-Corn as a Biomass Feedstock.

*KJ Shinners

Funding: John Deere Moline Technology and Innovation Center

Collaborators: UW Biological Systems Engineering

With renewed interest in corn cobs as a biomass feedstock and the high cost of artificially drying corn grain, storing ear-corn in a ventilated bag was investigated as an alternative method for naturally drying and preserving both cob and grain. Ear-corn was harvested over three dates in late September and early October of 2007 to achieve different aggregate moistures. Ear-corn was stored in structures with solid plastic tops and bottoms and alternating sections of open mesh and solid plastic on the sides to simulate a ventilated bag. Material was removed from storage after 61, 202 and 292 days in storage. The effect of initial moisture, storage duration and perimeter treatments were quantified through changes in grain and cob constituents and moisture and temperature history. Significant differences in moisture at removal were caused by initial moisture and temperature history. Significant differences in moisture at removal were caused by initial moisture, storage duration, and perimeter treatments. Grain and cob moisture at harvest was as high as 27% and 55% (w.b.), respectively, but dried to below 20% (w.b.) grain moisture after only six weeks in storage. Moisture increased during the winter due to snow penetration into the structure. Grain and cob moisture was generally below 16% (w.b.) over the last two months of the study. Grain and cob constituents generally were not significantly affected by perimeter treatments and generally were unchanged during the storage period, although significant grain and cob decomposition occurred at the bottom of the structure where water collection occurred due to poor drainage.

Evaluation of Robust NIR to Measure Nutritional Composition of As-fed Forages

*KJ Shinners

Funding: John Deere Moline Technology and Innovation Center

Collaborators: UW Biological Systems Engineering

This project deals with real time sensing of nutrient composition for forage crops intended for feeding ruminant animals. The sensor would be applied to a forage-harvester or in a stationary, stand-alone mode for measuring nutrient composition. The sensing technology is near-infrared reflectance (NIR) sensor with InGaAs detectors. This sensor is not commercially available for forage producers to estimate the DM content of their crops and stored forages. This work would extend the sensors on-farm capability so that it could be used to determine in real-time the nutrient composition of these forage crops and feeds. Although NIR has been well established as a means for estimating forage nutrient composition, producers are currently required to send samples to commercial labs where the samples must first be dried and ground before analysis. These procedures create an unacceptable delay in the management information needed to economically balance rations. Should this work prove successful, unprocessed sample at as-fed moistures can be analyzed in real-time. A wide variety of alfalfa haylage and whole-plant corn-silage samples has been collected from over 40 farms in south-central WI and spectral data collected using the John Deere HarvestLab NIR sensor. Both as-harvested and ensiled samples have been used in the development of the database. Analysis of composition was made using conventional NIR techniques (i.e. dried and ground samples). Calibrations for common nutritional constituents will be made using well known NIR calibration techniques.

Natural Resources and Environment

Recycling Agricultural Plastic Films

*BJ Holmes, R Springman

Collaborators: UW Biological Systems Engineering; Genesis PolyRecycling, Inc., Residual Wood Solutions, Inc.); Granulating Solutions, Inc. (AGSI); 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 sile and silage pile covers; silo bags; bale wraps or bags; bale tubes; 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). Those who saw the exhibits expressed strong interest in recycling agricultural plastic film. Their interest encouraged a representative of 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 and have plans to set up a processing facility in Mankota, MN. Residual Wood Solutions, Inc. of Montello, WI has developed a system for forming wood byproducts into fuel pellets using waste plastic as a binder. They, Genesis PolyRecycling and DATCP attended the Farm Technology Days exhibit on Recycling Agricultural Plastics.

Phosphorus and Organic Matter Enrichment in Snowmelt and Rainfall Runoff from Agricultural Fields

*KG Karthikeyan, JC Panuska, RC Lathrop
Funding: US Environmental Protection Agency (STAR Program)
Cooperators: Wisconsin Department of Natural Resources

The physical nature of sediment transport favors the movement of smaller and less dense materials, typically resulting in greater (enriched) sediment total phosphorus (TP) and organic matter (OM) concentrations than those of the parent soil. We compared the dynamics of TP and OM enrichment in rainfall-runoff and snowmelt from corn fields subjected to three contrasting management practices (corn-grain, corn-silage with and without manure addition). In rainfall-runoff, residue cover significantly influenced P enrichment, with the median TP enrichment ratio (TPer) for corn-grain (1.4) being significantly greater (p=0.007) than that for corn-silage (0.8) and manured corn-silage (1.0) fields, which were similar. While greater P enrichment was observed in snowmelt compared to rainfall-runoff, attributable to correspondingly high Omer values, TPer was unaffected by treatment differences (p=0.60). The OM enrichment was much higher (~10x) during snowmelt (9.7) compared to rainfall-runoff (0.97). Low flow rates over frozen surfaces may have favored enhanced transport of OM and clay-sized particles in snowmelt. Corn-grain systems, due to crop residue contributions, also favored greater transport of organic P forms (i.e., low dissolved reactive P/total dissolved P ratios) in rainfall-runoff whereas inorganic P dominance was observed in silage fields. Additional intra-event runoff data generated for fields with difference crop-row orientations (contour vs. up-and-down the slope) provided more insights into the temporal dynamics of the P enrichment process. The TPer values were generally inversely related to flow rate and soil loss and a strong logarithmic TPer-sediment load relationship was obtained uner non-crusted field conditions. This study addresses crucial knowledge/information gaps on the role played by the mode of runoff generation (rainfall-runoff vs. snowmelt) and field roughness conditions (due to crop-residue, crop-row orientations) on P enrichment from row-cropped agricultural systems.

Evaluation of Temporal and Spatial Sediment Dynamics in Agricultural Fields Using Lanthanide Tracers

*KG Karthikeyan, CF Byrne, K Gungor, PD Gaebler, PE Cabot
Funding: USDA-Natl. Research Initiative
Collaborators: UW Biological Systems Engineering; UW Agricultural Research Stations, Case Western Reserve Univ., USDA-Agricultural Research Service

A fully integrated hill-slope scale hydrologic monitoring project is being performed to evaluate sediment transport mechanisms by combining a network of surface runoff sensors monitoring the temporal and spatial occurrence of runoff with lanthanide (rare earth element (REE) oxides) tracer analysis and radiometric (^{7}Be, ^{210}Pb, ^{137}Cs) fingerprinting. These methods have been combined on a hill-slope with a Plano silt loam soil at Arlington, WI under two tillage orientations (contouring and up-and-down the slope) and two corn-harvesting schemes (grain and silage) and multi-year data were collected from a series of natural rainfall-runoff events. The major goal is to determine the spatial patterns of runoff and sediment movement for difference agricultural management systems. To delineate hydrologic active areas (HAAs) and sediment source areas during an event, an array of surface runoff sensors was placed in each plot. The hillslope (40ft) was divided into three segments within which different types of soil-REE (Gd, Nd, Pr)-oxide mixtures were applied. From the edge-of-field REE concentrations, differences in sediment contributing areas were noticed between the two crop-row orientations: in the contoured plots, sediments predominantly originated from the bottom third segment while the entire field contributed in the case of up-and-down slope orientation. Erosion occurred from almost all ridges while deposition often occurred within the furrows of the plots. Movement of Nd (bottom-third segment) was observed throughout the course of the season in the contoured plot indicating that not all eroded sediments were being transported offsite during storm events. However, deposition of Nd was not observed in the lower segment for the up-and-down slope plots, suggesting significant offsite movement of eroded sediments. The ponding sensor data appeared to support the trends observed with the migration of REE-tagged sediments. In the up-and-down row orientation, all three sections (i.e., entire hillslope) were contributing to runoff, while in the contour plot, the middle and upper sections were ponded, but often did not contribute to runoff, while in the contour plot, the middle and upper sections were ponded, but often did not contribute to runoff. Radiometric analysis (^{7}Be) also supported the existence of rills in the contoured plot (preferred transport pathway). This study showed that use of complementary field techniques (REEs, ^{7}Be, and ponding sensors) facilitates gaining a better understanding of the spatial and temporal dynamics of soil erosion from agricultural fields.

Evaluation of Temporal and Spatial Sediment Dynamics in Agricultural Fields Using Naturally-Occurring and Fallout Radionuclides

*KG Karthikeyan, PE Cabot, A Stubblefield, P Whiting, G Matisoff
Funding: USDA-National Research Initiative
Collaborators: UW Biological Systems Engineering, UW Agricultural Research Stations, Case Western Reserve Univ,; USDA-Agricultural Research Service

Sediment yield from scientific erosional mechanisms is difficult to quantify in agricultural settings. However, management and understanding of erosional processes can benefit from improved process description. Novel techniques for tracing and fingerprinting soil movement in response to thunderstorm activity are being tested in agricultural fields. Radiometric fingerprinting using concurrent measurements of

multiple environmental isotopes is being used to determine relative areal extents of the hillslope subjected to interrill vs. rill erosion. Two erosion plot, one with a contour tillage and another with up-down tillage were installed on a hillslope planted to corn on a Plano silt loam soil at Arlington, WI. Within the framework of an erosion plot study, soil depth distributions and runoff concentrations of radionuclides ^{7}Be, ^{210}Pb, ^{137}Cs were determined, lanthanide-tagged soil applied, and a surface runoff sensor network installed. The objectives were to (i) quantify rill and sheetwash erosional mechanisms for different agricultural management techniques, and (ii) investigate the implications of our findings for phosphorus export. Radionuclides have characteristic depth-distributions in surface soils as a result of the time and mechanism of delivery and land-use practices. Thus, the radionuclide concentrations of runoff sediment can be used to estimate from what depth sediment eroded. A strong temporal variation in sediment ^{7}Be activity in relation to storm intensity and sediment yield was observed. ^{7}Be activity varied inversely with sediment yield. We interpret this to indicate periods of peak runoff resulting in rill incision and the access of low ^{7}Be sediment deeper in the profile. Radionuclide data are being modeled using the Simultaneous Rill-Sheet Erosion Model (SiRSEM). The program uses the depth distributions in a mass balance approach to determine the depth and area of rill and sheet erosion on the plot that best matches the sediment and radionuclide yield for each event.

Recovery of Phosphorus in Thin Stillage as a Value-Added Co-Product

*KG Karthikeyan, L Armentano, A Ozkaynak, Aicardo-Roa Espinosa

Funding: USDA Cooperative State Research, Educ. and Extension Service
Collaborators: UW Biological Systems Engineering; UW Dairy Sci.; Soil Net LLC

Ethanol production from corn is a growing industry and has recently garnered considerable interest. As the interest and subsidies for ethanol production continue to increase, more dry distillers grains with solubles (DDGS), the major co-product of dry grind ethanol plants, will be available for use as animal feed. High phosphorus (P) content of DDGS can lead to dietary P levels that are incompatible with P-based nutrient management plans. Of the two components of DDGS, the solubles (thin stillage) are the dominant P contributor. Therefore, the main objective of this study is to reduce the P content of thin stillage while retaining as much mass and nutritive value. A treatment train with centrifugation followed by chemical treatment with coagulants (lime, alum, ACH) and biopolymers was applied. Lime with anionic biopolymers performed best and removed 85% of total P. Total solids reduction was limited as the chemicals used were ineffective in coagulating dissolved solids. Supernatant from lime treatment can be directly fed to the characterization evaporator used in the current corn ethanol plants. The secondary distillers grains can either be added to DDGS or can be used alone as a high crude protein and low P containing animal feed. Reduction in P content of thin stillage would create more opportunities for the use of DDGS in lactating dairy diets.

Manure Solidification and Phosphorus Concentration using Biopolymers

*KG Karthikeyan, V Sharma, A Roa-Espinosa

Funding: Wis. Fertilizer Res. Council
Collaborators: UW Biological Systems Eng.; Soil Net LLC

This project focuses on the use of polymers as flocculants with a more emphasis on the suitability of bio-polymers to concentrate phosphorus (P) and solids in dairy manure. Biopolymers (of varying charge-densities and molecular weights) synthesized from readily available crop sources and fibers prepared from various locally-available residue sources are being tested for their ability to solidify flushed dairy manure. Bench-scale flocculation studies (jar tests) are being employed to determine the effect of polymer dosage, pH, and manure solids content in influencing concentration of P and solids. Results obtained indicate that low- and medium- charge density (CD) polymers are highly effective in concentrating > 90% of both solids and P in flushed dairy manure in a fraction larger than 1-mm in size. These polymers are like large nets after activation in water with molecular weights (MW) of 4000 to 6000 g/mol. The polymer dosage levels had a greater influence on solids/P treatment performance than CD or MW. The optimum dosage for these cationic PAM polymers varied from 20 to 50 mg/L with lower optimum polymer dosage rates (20 mg/L) required for the low-CD polymers compared to those with medium-CD (50 mg/L). However the medium-CD polymer exhibited better dewatering characteristics. Among the cationic formulations, the two best performing polymers were 1000 SAL (CD=5% mole and MW= 6000 g/mol) and 1100AL (CD=10% mole and MW=4500 g/mol). These results are quite encouraging, in terms of highlighting the ability of polymers to function as manure flocculants, considering that > 80% of P was distributed in a size fraction < 0.025mm. The biopolymers derived from corn and potato starch had very low effectiveness for solids and P removal. There was no visible aggregation of the solids using the biopolymers, although they did improve the settling rate. Our treatment system can be expected to produce solidified manure, with high P-content, of sufficient stability to facilitate off-farm transport to P-deficient areas and long-term storage. This treatment technology is expected to result in a flexible, easy-to-adopt, and an economical practice for agricultural producers. A strong linear relationship was obtained between the extent of solids and P removal, which will facilitate broader applicability of findings from this project.

In-Stream Sediment and Phosphorus Dynamics in Agricultural Watersheds

*KG Karthikeyan, NL Huisman, PE Cabot
Funding: USDA CSREES

Suspended sediments originating from agricultural lands are one of the primary agents responsible for the transport of nutrients and other non-point source pollutants. The in-stream sediments, in particular, play a critical role in linking phosphorus (P) transport between the landscape and downstream water bodies. Several experimental techniques, i.e., radiometric ^{7}Be, ^{210}Pb, ^{137}Cs fingerprinting, P update-release, and catchment-scale monitoring, are being concurrently applied to systematically characterize and quantify the in-stream processes controlling sediment and P movement in small agricultural watersheds. Specific objectives are to: (a) determine short- and long- term deposition/resuspension rates, sediment age (residence time), origin, and transport distance in suspended sediments from both rainfall-runoff and snowmelt events; (b) obtain a relationship between sediment age/origin to P uptake and buffer capacity; (c) determine P dynamics (exchangeability, fractionation, bioavailability) in bed and suspended sediments in streams receiving drainage from contrasting animal feeding operation types (small dairy farm vs. regulated large farms), and (d) assess the state of equilibrium of flow from monitored catchments with respect to P status of the sediments. Significant efforts were expended to cultivate relationships with farmers in the study area so that soil cores could be taken on their fields. Runoff was collected from a series of 3 events during a 1-week period in summer 2008: June 5 (0.99 inches, 48 samples), June 8 (3.47 inches; 24 samples), and June 13 (1.61 inches; 53 samples). Soil cores were collected (from upland, streambed and streambank locations) before and after the June 5 storm event to account for changes in the ^{7}Be profile. The cores and dried sediment from the runoff samples are being analyzed for total P (TP) concentration and ^{7}Be, ^{210}Pb, and ^{137}Cs activities. Preliminary soil core TP results indicated that the streambed sites contained the highest amount of TP and the fields contained the lowest amount of TP. These data will be paired with the radionuclide activities for sediment source apportionment. Runoff samples are being analyzed for P distribution in different forms (TP; dissolved reactive P (DRP); total dissolved P (TDP); particulate P (PP)=TP-TDP). In general, it was observed that PP transport increased significantly with the larger storm events while TDP and DRP remained at relatively consistent levels, thus indicating that larger storm events produce significantly more sediment transport through the stream system. TDP typically consisted of nearly 100% DRP regardless of the storm intensity. Results generated would facilitate a better understanding and quantification of nutrient and sediment transport processes as a function of spatial scales and P input characteristics.

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

*KG Karthikeyan, R Jackson
Funding: USDA Cooperative State Research, Educ. and Extension Service
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 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 involved 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.

Value-Added Processing and Phosphorus Recovery from Dairy Manure Using Enhanced Fermentation

KG Karthikeyan, K Gungor
Funding: Wisconsin Fertilizer Research Council
Collaborators: UW Biological Systems Engineering, UW Agronomy

Integrated manure treatment (physical, chemical, and biological) practices are required to obtain a significant reduction in pollutant load from concentrated animal feeding operations (CAFOs). In this context, solid effluents (e.g., separated solids, waste sludge) obtained from manure treatment deserve more attention, since their potential is underutilized via the current end-use routes. These solids are generally recycled as bedding, composted, sold off-farm, and eventually land applied. Enhanced fermentation, which is enhanced hydrolysis of the fibers into simpler sugars and subsequent fermentation of the sugars into readily

biodegradable organics, can improve resource recovery from the separated manure solids and thereby deliver additional economical benefits. We intend to liquefy carbon and phosphorus (P) present in the manure solids by enhanced fermentation and process them into value-added products such as biodegradable plastics and high-grade phosphate minerals. Anaerobic digestion can convert the fermentation products into methane-rich biogas, which will be combusted to generate electricity. A group of bacteria can store the short-chain volatile fatty acids (VFA), generated by enhanced fermentation, in the form of biopolymers called as polyhydroxyalkanoates (PHA). Polyhydroxyalkanoates exhibit similar material properties as the conventional petrochemical plastics such as polypropylene (PP) and polyethylene (PE), but the PHAs are biodegradable while PP and PE are not. Lastly, enhanced fermentation performed under acidic conditions can solubilize P from the manure particulates and the P can be harvested as magnesium or calcium phosphate minerals from the liquid stream. Specific study goals include design of a fermentation reactor to process manure solids and evaluate the probable process configurations in which the fermenter can be used for value-added product generation.

Improved Methods for Identifying P Export Hotspots in Agricultural Watersheds: Strategies for Targeting Mitigation to Maximize Water Quality

KG Karthikeyan, K Songer, P Nowak, LW Good
Collaborators: UW Biological Systems Engineering, UW Soils, UW IES

Agricultural non-point source phosphorus (P) pollution is a leading cause of impairment of surface water bodies in Wisconsin. Mitigation strategies include upland conservation practices as well as installing riparian buffers to reduce the amount of P exported from farms to streams. Most mitigation is performed by county conservation agencies, which work closely with farmers and often provide cost-sharing as an incentive for improving land use practices. Generally, agency resources such as cost-sharing are offered to farmers on a first-come, first-serve basis, but this can mean that farmers who have the highest impacts on water quality choose not to participate in conservation programs. Given limited agency resources, a more effective alternative would be to focus programs on high-impact farms, allowing agencies to build more productive relationships with the farmers who operate them. We are developing a strategy by which conservation agencies wishing to achieve measurable improvements in water quality can predict "hotspots" in a watershed in terms of P export. Through farmer interviews, GIS mapping and soil sampling, 60% of a Driftless Area agricultural watershed was surveyed for farming practices, soil characteristics, and other landscape attributes. The SNAP-Plus model (for nutrient management planning) was used to determine a P Index (PI) value for each of 769 farm fields surveyed. The PI is widely used for farm nutrient management planning in Wisconsin, and represents the estimated lbs P per acre per year reaching the nearest stream the field. A chart of the PI distribution demonstrates that the highest rate of P export comes disproportionately from a few small areas in the watershed. Through multiple linear regression analysis, high PI values were correlated to predictor variables and simple criteria by which agencies can predict P export "hot farms" are being developed – the highest priority farms to work with in a given watershed. Use of these or similar criteria could drastically improve the efficiency of mitigation strategies for improving water quality in agricultural watersheds.

Impact of ENCAP's Movement Control Technology (MCT) on Fertilizer Nutrient Transport

*AM Thompson, BJ Lepore
Funding: ENCAP LLC
Collaborators: UW Biological Systems Engineering, Soil Net LLC

A growing body of research has proven water soluble Polyacrylamides (PAM) are effective at controlling soil erosion and sediment bound Phosphorus (P) transport. However, it has not been determined if and how the application of PAM influences sorption of P to soil, and thus the transport of P with eroded sediment. This study involved a two part approach to investigating the sorption and transport of P with eroded sediment. Sorption isotherm batch experiments were conducted with three levels of PAM (0, low and high; the PAM was applied as ENCAP's MCT product) applied to a silt loam soil. Results indicated minimal influence on this soil's P sorption characteristics at low solution P concentration. There was a slight increase in P sorption at high solution P concentration with the presence of PAM, and no significant differences between low and high PAM rates. This study also included ponded and saturated soil column P flow through experiments, in which PAM was applied to the surface of the soil columns. The same silt loam soil used in the isotherm work was used. No significant differences were observed in dissolved reactive P (DRP) breakthrough times or in absorbed P migration through the soil column. The results of both parts of this study indicated that, for this soil, the potential of PAM to reduce P transport from upslope areas to downslope and downstream regions is primarily related to PAM's ability to stabilize soil particles and aggregates and not in controlling the sorption of P to soil.

Impact of Polyacrylamide Delivery Method on the Effectiveness of Lime and Gypsum as Soil Stabilizers

*AM Thompson, BJ Lepore, A Roa-Espinosa, A Peterson
Funding: ENCAP LLC
Collaborators: UW Biological Systems Engineering, Soil Net LLC

Soil erosion and sediment runoff continue to be important processes leading to non-point source pollution. Lime, gypsum and polyacrylamides (PAM) are all materials used to improve soil quality and reduce erosion. This study

compares the impact of delivering PAM to the soil surface in combination with lime or gypsum using two methods: 1) applying the PAM and lime or gypsum as separate granules or 2) applying a PAM coated prill of lime or gypsum. Laboratory rainfall simulations were conducted, with rainfall rates of 65mm/hr applied for 1 hr to a Plano silt loam soil. All treatements reduced runoff sediment load compared with bare soil and PAM treatments were more effective than lime or gypsum alone. While cumulative sediment and sediment bound P and NH_4 load differences between PAM treatments were not statistically significant ($p<0.05$), the average cumulative loads remained lower for PAM coated prill treatments than separately applied PAM and lime or gypsum granules throughout the duration of the experiments. When compared with 60 minute cumulative sediment load from bare soil, PAM coated lime and gypsum prills reduced the cumulative load by 83 and 69% respectively, while treatments with paper mulch PAM carrying granules applied separately from conditioner granules reduced cumulative load by 67 and 58%, respectively. Cumulative dissolved runoff Ca loads (for lime and gypsum) and S loads (for gypsum) were significantly reduced by PAM coated granule treatments when compared to separately applied PAM and conditioner granules.

Improving Methods for Predicting Runoff from Urban Lawns

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Funding: Wisconsin Department of Natural Resources
Collaborators: UW Biological Systems Engineering, UW Horticulture, USGS, WDNR

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 predicted 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 runoff 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 initiated at the University of Wisconsin O.J. Noer Turf Grass Research Facility. Six turf grass field plots have been instrumented to monitor precipitation, soil moisture, runoff, and meteorologic variables. Data collection began in late summer 2008 and continued through the fall of 2009. The effects of antecedent moisture and slope length on lawn runoff generation for natural rainfall will be evaluated.

Characterizing Thermal Pollution in Urban Landscapes

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Funding: USDA Hatch
Collaborators: UW Biological Systems Engineering; UW Soil Science

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.

A paired asphalt-turfgrass sod plot was constructed to compare the thermal runoff characteristics between asphalt and turfgrass sod surfaces, to identify meteorological variables that influence these thermal characteristics, and to evaluate evaporative heat loss for runoff from asphalt surfaces. Rainfall simulations were conducted during the summers of 2004 and 2005 under a range of climatic conditions. Asphalt surface temperatures immediately prior to rainfall simulations averaged 43.6°C and decreased an average of 12.3°C over 60 minutes as rain cooled the surface. In contrast, pre-simulation sod surface temperatures averaged only 23.3°C and increased an average of 1.3°C throughout the rainfall events. Heat transferred from the asphalt to the runoff resulted in initial asphalt runoff temperatures averaging 35.0°C that decreased by an average of 4.1°C at the end of the event. Sod runoff temperatures averaged only 25.5°C and remained fairly constant throughout the simulations. Multi-variable regression equations were developed to predict: 1) average asphalt surface temperature ($R^2 = 0.90$) and average asphalt run-off temperature ($R^2 = 0.92$) as a function of solar radiation, rain temperature, and wind speed, and 2) average sod surface temperature ($R^2 = 0.85$) and average sod runoff temperature ($R^2 = 0.94$) as a function of solar radiation, rain temperature, rain intensity, and wind speed. Based on a heat balance

analysis, existing evaporation equations developed from studies on lakes were not adequate to predict evaporation from runoff on a heated impervious surface. The combined heat from the asphalt and sod plots was an average of 38% less than the total heat if the total area had consisted solely of asphalt.

A LaGrangian-stochastic model was developed to simulate thermal runoff from impermeable surfaces. The model employs an approach based on the framework of the mass response functions (MRFs) originally developed for non-point source pollutant transport in watersheds. The model is the first attempt to apply MRFs to thermal runoff modeling. The model was applied to the data collected from the asphalt plot and successfully reproduced the temperature of impermeable surface and runoff.

A simple thermal urban runoff model (TURM) was developed for the net energy flux at the impervious surfaces of urban areas to account for the heat transferred to runoff. 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 affecting 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 with the Green-Ampt Mein-Larson rainfall excess method. Pervious runoff temperature is estimated as the rainfall temperature. Field measurements indicate that wet bulb temperature can be used as a surrogate for rainfall temperature and that runoff temperatures from sod average just 2°C higher than rainfall temperatures. Differences between measured and predicted impervious runoff temperature average approximately 2°C, indicating that TURM is a useful tool for determining runoff temperatures for typical urban source areas.

A spreadsheet version of the TURM model is currently being refined. A 30 acre residential development in Sun Prairie, WI was instrumented to monitor rainfall and runoff rates and temperatures during the summer and fall 2009. The model is being evaluated using data collected from this development.

Physical and Hydraulic Properties of Engineered Soil Media for Bioretention Basins

*AM Thompson and NJ Balster

Funding: UW Graduate School; WI Dept. of Natural Resources
Collaborators: UW Biological Systems Engineering; WI Dept. of Natural Resources; UW Soil Sciences

The composition of engineered soil media largely determines the stormwater treatment efficiency of urban bioretention basins. Laboaratory flow-through experiments were conducted to quantify infiltration, bulk density, and moisture holding capacity as a function of different composite mixtures of sand, soil, and compost, and to assess the effect of compaction on bulk density, moisture holding capacity, and saturated hydraulic conductivity. Eleven mixtures were evaluated that varied in volumetric proportions of sad (30% to 70%), sandy or silt loam soil (0% or 20%), and organic compost (20% to 70%). Steady-state infiltration rates were high for all mixtures, ranging from 87 to 178 cm/h, followed the order of mixtures containing sand and compost only > mixtures containing sand, compost, and sandy soil > mixtures containing sand, compost, and silt loam soil. Infiltration rates for mixtures containing sand and compost only and mixtures containing sand, compost, and sandy soil exhibited a significant linear relationship with the ratio of sand to compost. Bulk density of the mixtures was inversely related to the proportion of compost and followed the order of mixtures containing sand, compost, and silt loam soil > mixtures containing sand, compost and sandy soil > mixtures containing sand and compost only. Conversely, moisture holding capacity increased with the proportion of compost and followed the order of mixtures containing sand and compost only > mixtures containing sand, compost, and sandy soil > mixtures containing sand, compost, and silt loam soil. Compaction as a result of an initial wetting process and the infiltration tests led to increases in bulk density and decreases in moisture holding capacity, with mixtures containing a silt loam component showing the greatest resistance to these effects. Bulk Density, moisture holding capacity, and compaction were all linearly related to the ratio of sand/compost in the mixture. Air permeability measurements were used to estimate saturated hydraulic conductivity of four of the mixtures. Reductions of compost and additions of soil decreased saturated hydraulic conductivity. For the same proportions of sand, soil, and compost, the mixture containing silt loam soil was less compactable and incurred greater changes in saturated hydraulic conductivity compared to the mixture containing sandy soil. Although, at least initially, compost controlled the physical density of these mixtures, the textural class of the mineral component appears to help stabilize infiltration and dampen the effect of changing the ratio of sand to compost on the physical and functional characteristics of these mixtures.

Groundwater Mounding and Contaminant Transport Beneath Stormwater Infiltration Basins

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Funding: Wisconsin Department of Natural Resources
Collaborators: UW Biological Systems Engineering; WI Dept. of Natural Resources; University of Alaska-Fairbanks

Increased impervious areas resulting from urbanization cause an increase in stormwater runoff and a decrease in infiltration and recharge to the water table. Infiltration basins are often required to recharge a portion of the pre-development infiltration volume. Localized recharge by these relatively small basins can cause a water table mound to form below the basin. Mount formation is of concern as it may reduce the thickness of the soil available to filter pollutants, and may reduce the infiltration rate of the basin. Therefore, an accurate understanding of water table mound formation is important in the proper design of infiltration basins.

The overall objective of this study was to quantify and document water table mounding and the potential for contaminant transport resulting from recharge beneath stormwater infiltration basins. The specific objectives were to monitor changes in water table levels in response to infiltrating stormwater from an infiltration basin, and to calibrate and test a water table flow model.

A 0.10 hectare (0.25 acre) infiltration basin serving a 9.4 hectare (23.2 acre) residential subdivision in Oconomowoc, Wisconsin, was instrumented for this study. Subsurface strata included sand and gravel material and a water table at approximately 2.3 meters (7.5 feet) below grade. Three storm events with total rainfall of 4.93cm, 2.84cm, and 4.28cm, respectively, were modeled using the two-dimensional variably saturated numerical model HYDRUS. Inverse modeling was performed with HYDRUS to estimate soil hydraulic parameters. A good fit was achieved between modeled and observed data for the timing and magnitude of water table rise for all three storms. Predicted soil hydraulic parameters matched well with both measured and literature values. The model was most sensitive to the thickness of the basin sedimentation layer and the saturated hydraulic conductivity.

The calibrated model was used to evaluate hypothetical basin operation scenarios with parameters obtained from the Wisconsin Department of Natural Resources post-construction stormwater standards 1002 and 1003. HYDRUS was run with various basin sizes, ponding depths, sedimentation layer thicknesses, soil types, and saturated and unsaturated zone thicknesses. Results ranged from the water table mound intersecting the basin floor to no water table response. The mound height was most sensitive to hydraulic conductivity and unsaturated zone thickness.

The three dimensional flow code MODFLOW was used with HYDRUS to determine the effects of regional hydrogeology on the mound underneath the basin. Recharge to MODFLOW was taken from the seepage flux of an unsaturated HYDRUS model. MODFLOW results suggested that recharge from upgradient of the infiltration basin contributed to the prolonged mound recession underneath the basin. The three dimensional saturated fate and transport code MT3D was used to simulate a tracer study and determine the effects of groundwater mounding on contaminant transport. Mounding caused more rapid tracer transport away from the basin compared to the natural gradient.

Results indicate that a variably saturated, three dimensional model would be best suited to predict water table mounding, but that a two dimensional variably saturated model, such as HYDRUS, is capable if the transect is oriented in the direction of groundwater flow. Ideal basin siting conditions to minimize mounding would be in a material with high saturated hydraulic conductivity with thick unsaturated and saturated layers. As mound heights were found to increase more rapidly with ponding depth as the basin size increased, a larger number of smaller-sized infiltration basins would be preferable to one large basin.

Impact of MCT™ on Soil Erosion and Nutrient Transport from DiAmmonium Phosphate Fertilized Silt Loam Soil

*AM Thompson, BJ Lepore

Funding: ENCAP
Collaborators: UW Biological Systems Eng.; SoilNet LLC

Phosphorus (P) and Nitrogen (N) are two of the most common limiting plant macronutrients applied as fertilizer. Excess P and N, when lost to surface and ground waters, are both known to play significant roles in major environmental problems especially, surface and coastal water eutrophication. ENCAP, LLC's (Green Bay, WI) water-soluble polyacrylamide (PAM)-based Movement Control Technology™ (MCT™) has the potential to reduce the risk of N and P losses from soil to surface waters either through modification of nutrient-soil interactions, through sediment stabilization and erosion reduction, or through a combination of the two. Laboratory simulated rainfall experiments were conducted with a simulated rain rate of 2.5 in hr^{-1} for 1 hr at 10 and 36% slopes to test the effectiveness of MCT when applied as a 5 or 10 lb $acre^{-1}$ coating on gypsum or diammonium phosphate (DAP) carriers at reducing DAP-N and -P losses through runoff, erosion and leachate. At 10% slope, all MCT treatments reduced sediment load, with the greatest reduction (82%) provided by the unfertilized gypsum coated with 10 lb $acre^{-1}$ MCT treatment. Compared with a DAP fertilized soil, sediment associated P loads in runoff of fertilized soil were reduced from 39 to 53 percent by 10 lb $acre^{-1}$ MCT depending upon whether MCT was coating the gypsum or DAP and whether gypsum was applied at all. Gypsum coated with 5 lb $acre^{-1}$ MCT reduced sediment bound P loads 44 percent compared with the DAP fertilized control. Also at 10 percent slope, unfertilized soil treated with gypsum coated with 5 and 10 lb $acre^{-1}$ MCT, reduced sediment bound P loads by 62 and 83 percent, respectively, compared with untreated unfertilized soil. At 36% slope, gypsum coated with 5 and 10 lb $acre^{-1}$ MCT applied with uncoated DAP and DAP coated with 10 lb $acre^{-1}$ applied with uncoated gypsum reduced sediment loads 47, 69 and 48%, respectively, compared with bare soil. Gypsum coated with 5 and 10 lb $acre^{-1}$ MCT applied with DAP reduced cumulative sediment P loads by 53 and 34 percent, respectively, although the statistical significance was lower for the lower MCT rate ($p < 0.12$). Under these laboratory rainfall simulation conditions, MCT had little or no effect on fertilizer N losses. In general, MCT coated gypsum treatments (similar to ENCAP's AST™ Gypsum) were more effective than MCT coated fertilizer treatments at reducing sediment and sediment bound P loads.

Identifying a Critical Moisture Condition for Runoff Generation

*AM Thompson, FW Madison

Funding: UW Biological Systems Engineering
Collaborators: UW Biological Systems Engineering; UW Soil Sciences; USGS; UW Discovery Farms

Land application of manure often is the only practical management option for livestock operations yet, if not managed properly, can pose significant risk to surface and ground waters. Antecedent soil moisture is a key factor controlling runoff and subsequent transport of contaminants. If a critical antecedent moisture threshold at which runoff is likely to occur is identified, measurement of soil moisture prior to agricultural field operations could indicate risk for runoff and allow timing of manure application to avoid high risk runoff periods. The goal of this study was to improve our understanding of the factors that influence runoff generation in agricultural watersheds during non-frozen ground periods. The main objectives were to assess variability of soil moisture throughout six agricultural basins in southwestern Wisconsin, evaluate the influence of storm and landscape characteristics on surface runoff generation for the same six basins, determine critical soil moisture thresholds for surface runoff generation for each of the six basins, and utilize a continuous four year monitoring record of precipitation, runoff, and soil moisture in the analysis.

Two farms in the driftless area of southwest Wisconsin have been instrumented by the US Geological Survey to study surface runoff from agricultural fields: 1) a privately-owned farm that is part of the UW-Madison Discovery Farms (UWDF) pro-gram, and 2) the UW-Platteville Pioneer Farm (UWPF). Since 2003, monitoring of three separate basins within each farm has included continuous temporal measurement of precipitation, climatic variables, surface runoff, soil moisture, and field operations (including crop type, planting and harvesting, tillage, and manure and fertilizer applications). While the basins are somewhat similar in terms of size, slope and soil texture, they differ in terms of tillage and crop rotation. The UWDF implements a no-till system with a corn-soybean rotation; the UWPF implements a conditional tillage system (fall chisel plow) with a corn-oats-alfalfa rotation. For the continuous record, soil moisture was measured only at one location (at the meteorological station) on each farm. We developed a sampling procedure to obtain spatial soil moisture measurements over a range of moisture conditions within each basin verify that soil moisture measured at the weather station appropriately reflected basin conditions. The spatial variability of soil moisture within each basin decreased as mean soil moisture increased. Vegetation affected the spatial and temporal distribution of soil moisture. The percentage of precipitation leaving the landscape as surface runoff was two times greater for the conventionally tilled basins compared to the no-till basins. Using breakpoint regression analyses, an antecedent soil moisture threshold of 0.39 cm^3cm^{-3} for runoff generation was determined for all basins. Below this threshold, runoff coefficients were near zero regardless of antecedent soil moisture. Above this threshold, runoff coefficients increased with antecedent soil moisture. Maximum 30 minute rainfall intensity thresholds for runoff generation increased as antecedent soil moisture decreased. Crop cover influenced the 30 minute precipitation intensity threshold for storm events with antecedent soil moisture in the range of 0.35 to 0.40 cm^3cm^{-3}. Avoiding manure application during time periods when soil moisture is near or above a critical threshold could decrease the risk of surface water contamination.

Food Engineering and Processing

Refining and Implementing Multifunctional Management Strategies for Organic Processing Vegetables

*P Mitchell, AJ Bussan, DJ Reinemann, SA Sanford

Funding: USDA, COOP State Research Educational & Extension Service
Collaborators: UW Biological Systems Engineering; UW Department of Agriculture and Applied Economics; UW Department of Horticulture

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.

Material Conditioning and Storage with Saturated Salt Solutions

*DR Bohnhoff, A Kutlgen, BA 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 kernel), 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 involved 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.

Whey Protein-based Nanocomposites

*S Gunasekaran, L Shi
Funding: Hatch Funds

Nanocrystalline zinc oxide (ZnO) particles coated with whey protein isolate (WPI) were fabricated in the weak basic aqueous solution condition at near room temperature. The X-ray diffraction and transmission electron microscopy measurements confirmed the nano-scaled composite structure of ZnO nanoparticles were uniform and monodisperse with an average diameter of 65 nm. In addition, pectin-ZnO nanocomposite were prepared in the aqueous solution condition at room temperature. The Fourier transform infrared, X-ray diffraction, and transmission electron microscope (TEM) measurements confirmed the nano-scaled structure of pectin-ZnO composite. According to the TEM observation, the average composite granules size was about 150nm and the embedded ZnO nanoparticles were uniform with an average diameter of 70nm.

Analysis of Cheese Melt Profile

*S Gunasekaran, S Ko
Funding: Gift Funds

The inverse-Hill model was used to fit the cheese melt profile—the cheese sample height vs. heating time curve obtained using the UW MeltProfiler device. Three process cheeses of different solid fat index (SFI) values were tested. The model fits for all melt profiles were excellent, and the model parameters, *a, b*, and *n*, were used to determine many cheese melt/flow characteristics determined by the graphical method previously used such as the softening point (t_{SP}), end point (t_{EP}), average flow rate (AFR) and maximum flow rate (MFR), etc. The *b* values corresponded to the rapid flow times (T_{RF}), and *n* values correlated well with t_{SP}, t_{EP}, AFR, and MFR. In addition, T_{RF} correlated well with cheese melt spread area and maximum spread diameter measured by a modified Schreiber test. Therefore, the inverse-Hill function simplifies the analysis of cheese melt profile and yields parameters useful to quantify cheese meltability.

Biosensor for Detection of Toxins in Foods

*S Gunasekaran, J Yu, Wantida Homthawornchoo
Funding: Hatch Funds

Work is underway to detect botulinum neurotoxin type A (BoNT/A), one of the most poisonous substances known to humans. Its lethal toxicity makes it potentially suitable as a biological warefare and/or bioterrorism agent. We will develop quartz crystal microbalance (QCM)-based biosensors for detection of BoNT/A in food systems and improve its usefulness by enhancing detection sensitivity by employing nanomaterials (e.g., gold nanoparticles, carbon nanotubes) in the fabrication of the crystal surface. In this study, the established immunoassay and the QCM with dissipation monitoring (QCMD) will be utilized. The effects of different crystal fabrication techniques and the variable food matrices properties on the detection sensitivity will be investigated. Also, the kinetics of interaction between BoNT/A and its specific antibodies and the adsorption isotherm of BoNT/A will also be explored. The QCM results will also be compared with other characterization techniques (e.g., atomic force microscopy (AFM), attenuated total reflectance-Fourier transform infrared (ATR-FTIR).

EXTENSION

Dairy Production

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.

Milking Parlor Management User Group

*DJ Reinemann, K Bolton, PL Ruegg
Funding: UW Coop. Ext. Service
Collaborators: UW Biological Systems Engineering, 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: Association of Equipment Manufacturers

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

Dairy Production and Profitability

*DJ Reinemann, BJ Holmes, DW Kammel
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.

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. Faculty have assumed leadership roles within the Dairy Team. Extension educational programs related to dairy will be 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, RT Schuler, KJ Shinners, RE Muck

Funding: UW Coop. Ext. Service; UW Biological Systems Eng.; 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 a post-Four-States Dairy Management Conference workshop, Forage Field Days, and county extension meetings to encourage producers to improve management in these areas. Articles on these subjects have appeared in conference proceedings, the *Crop Manager* newsletter and on the UW Cooperative Extension Team Forage website, <www.uwex.edu/ ces/crops/ uwforage.htm>. Computer spreadsheets were developed as decision aids and are also available at this website. BJ Holmes conducted 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.

Electric Power and Energy Systems

Energy Conservation and Renewable Energy Education

*PW Walsh, SG Gruder

Funding: Wis. Energy Conservation Corp.

Collaborators: UW Coop. Ext. Service; Wis. Focus on Energy; UW Coop. Ext. Service Solid and Hazardous Waste Educ. Ctr.; Wis. Renewable Energy Network

The Wisconsin Focus on Energy program promotes adoption of energy conservation and renewable energy technology by Wisconsin's citizens, businesses, and governments. In collaboration with public and private sector partners, this program works through UW Cooperative Extension Service offices to deliver energy education to Extension's statewide clientele regarding adoption of improved energy management techniques, technologies to save and generate energy, and incentives available through Wisconsin Focus on Energy, <www.focusonenergy. com>, to stimulate adoption of energy conservation and renewable energy technology.

Farm Energy and Stray Voltage Program

*DJ Reinemann, MA Cook, R Kasper, J Roberts, D Hansen

Collaborators: UW Biological Systems Engineering.; Wis. Public Service Commission; Wis. 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

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 standard companion document for milking center wastewater was worked on this year. Publication expected in 2009.
- 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.
- Home water quality testing and interpretation for students in the Farm and Industry Short Course livestock housing class.
- 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

*RT Schuler, CA Ehle, MF Beck

Funding: USDA CSREES; 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 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. A lecture and a farm visit were provided for the Occupational Therapy Assistant program at Western Technical College and a lecture for the Occupational Therapist program at UW-LaCrosse, UW-Milwaukee, and UW-Madison. Training was provided to WI National Resource and Conservation Service staff and a farm visit was conducted.

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 and 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, and 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 2007-2008 budget year, on-farm services were provided to 429 farmers with disabilities with 161 new referrals and 268 continuing clients. AgrAbility staff completed 153 farm or worksite assessments. Staff from the FARM program completed 106 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 $26,000 for a total of $2,756,000 of assistive technology provided to Wisconsin farmers. Based on DVR data, for each dollar expended on assistive technology, $10 of additional revenue is generated in the community of the disabled person.

The 127 clients whose cases were closed during 2008 were surveyed to estimate the success of the program in meeting their needs. Sixty farmers completed and returned their surveys, for a response rate of 47 percent. Sixty-six percent of these indicated they do a better job of farming as a result of the program.

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

National AgrAbility Project

*RT Schuler, CA Skjolaas, ME Novak, MF Beck, KM Pereira
Funding: USDA CSREES; UW Coop. Ext. Service; contributions from agribusinesses
Collaborators: UW Biological Systems Eng.; Easter Seals Head-quarters

The National AgrAbility Project (NAP) provides training and educational support for the 21 state AgrAbility projects. NAP is a partnership of UW Cooperative Extension staff and staff from a non-profit disability organization, Easter Seals Headquarters in Washington, DC. NAP has the same priorities as AgrAbility of Wisconsin: education, networking, and assistance. The state projects provide education and assistance to farmers and ranchers with disabilities and build service capacity with health, agricultural, and government service providers.

NAP provides training and education through a national training workshop, monthly newsletters, quarterly technical news, teleconferences, and project listerv. Information for stat project staff and the general public is at website www.agrabilityproject.org. This website offers access to an assistive technology database listing close to 1000 products. The monthly newsletter is distributed electronically to project staff only. Four quarterly publications on disability, AT, and agriculture are developed. The 2008 National Workshop, held in Wichita, Kansas, was planned by NAP staff at UW-Madison and Purdue University (newly approved NAP provider), the host state, and a committee of state project staff.

Occupational therapist/physical therapist educational materials about farm culture and the AgrAbility program were developed for post-education. NAP is an “approved provider” of these materials through the American Occupational Therapist Association. State staffs were trained to conduct this training to the OT/PT professionals in their states and to award AOTA continuing educational units when using these materials.

UW-Madison completed the fourth year of the project and received a no-cost, one year project extension. Purdue University has been awarded the NAP program effective August 1, 2008 from USDA CSREES. Evaluations of key aspects of the project are on-going, including collection of demographic data of farmers served by the state projects and impact survey to evaluate changes in ‘quality of life’ as a result of AgrAbility programs.

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 Events

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

In 2008, 22 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.

Mechanical Sciences (Youth Development)

*JW Nelson, CA Skjolaas, JJ Stellato
Funding: UW Coop. Ext. Service; Wis. Rural Insurance
Collaborators: 4-H Youth Development; Natl. Eng., Sci. and Leadership Mgmt. Team; Lincoln Welding; Deere and Co.

In 2008, approximately 20 4-H youth participated in the state mechanical events, which included small engines and aerospace. Many county youth development volunteers and 15 county and agricultural and youth development Extension

agents supported theses events. Winners at the state level advance to the National 4-H Engineering, Science, and Leadership Event held each year in West Lafayette, Indiana.

Approximately 11,000 youth participate in these Mechanical Science projects at the county level. About 1000 volunteers within the various counties direct them. Biological Systems Engineering Department staff provides technical support for the 4-H mechanical science projects including woodworking, tractor, small engine, electricity, bicycle, and aerospace.

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