Lowering the Cost of Bio-energy Feedstocks while Providing Environmental Services – A Win-Win Opportunity

A proposal submitted to Xcel Energy in response to:

The Renewable Development Fund

3rd Funding Cycle

July 12, 2007

By

The University of Minnesota

Rural Advantage

In collaboration with:

Koda Energy (Rahr Malting and the Shakopee Mdewakanton Sioux Community)

Minnesota Department of Natural Resources (DNR)

Institute for Agricultural and Trade Policy (IATP)

Section 1. Project Administration

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Grant Application Form – Xcel Energy Renewable Development Fund

Research & Development Project

Applicant Information

Name and Title of Applicant: University of Minnesota

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(Street number and name) (Suite number)
Minneapolis, MN 55455
(City, state, zip code)

Lead Organization / Prime Contractor: University of Minnesota

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Project Information

Project Title: Lowering the Cost of Bio-energy Feedstocks while Providing Environmental Services – A Win-Win Opportunity

Project Work Site Location(s): Minnesota River Basin

Technology Type (check one(s) that apply)

Wind ☐ Solar PV ☐ Hydroelectric ☐ Biomass **X** Biofuel ☐

Other ☐ *(please describe)* _____

Funding Request

Total RDF funding requested: $ 992,989

Funding from other sources: $ _____

RDF Funds requested by year: 2008: $ 145,791

2009: $ 227,684 2010: $ 287,318 2011: $ 205,259

2012: $ 126,937 2013: $ _____ 2014: $ _____

2015: $_____ 2016: $ _____ 2017: $ _____

Project Duration

Estimated Project Start Date April 1, 2008 Estimated Project End Date March 31, 2013

Technology / Application Pairs (refer to page 21 in RFP for instructions)

Please indicate which pair(s) the proposed project addresses. Example pairs are shown on page 23 of the RFP, but applicants can identify any additional pairs that are not contained on the list.

Technology Type	Application
Combined heat and power	Locally produced feedstocks
Electricity and CHP from biofuels with environmental benefits	

Project Team

UMN	Dean Current – Program Director
(Prime Contractor)	(Name & Title of Principal Investigator)
Rural Advantage	Linda Meschke – Executive Director
(Sub Contractor)	(Name & Title of Principal Investigator)
Institute for Agriculture and Trade Policy	Jim Kleinshmit – Rural Communities Director
(Sub Contractor)	(Name & Title of Principal Investigator)

Prime Contractor Number of Employees: 18,470 Year Established: 1851

Legal Form or Ownership (check one)

☐ Sole Proprietorship	☐ Limited Partnership
☐ General Partnership	☐ Corporation
☐ Sub-Chapter S Corporation	**X** Other (identify) University

Standard Grant Contract Terms and Conditions Acceptance

I am authorized to act on behalf of the applicant in this matter, and I have received, reviewed and do hereby accept the Standard Terms and Conditions of the Grant Contract included as Appendix C of the Xcel Energy Renewable Development Fund RFP.

YES ☐ **NO X** (If "No", complete Appendix D)

I hereby authorize Xcel Energy to make any inquiries and obtain any financial information necessary to evaluate my organization's capability to implement the proposed project. I also authorize Xcel Energy to make any necessary inquiries to verify the information I have presented.

YES X **NO** ☐

I hereby certify to the best of my knowledge and belief that I have read and understand the terms and conditions contained in the Xcel Energy RFP and that the information contained in this proposal is correct and complete.

Signature of Authorized Representative Date

Typed Name Title

Grant Application Narrative

This project represents a unique collaboration between the University and public and private sector partners with each participant bringing their particular expertise and resources to bear on the problem of environmentally and economically sustainable renewable biomass production for the generation of electricity, with an important by product being environmental benefits on working lands. The University, Rahr Malting, Rural Advantage, the Institute for Agricultural and Trade Policy (IATP) and the Minnesota Department of Natural Resources (DNR) have an established and successful track record working together.

We are proposing this as "advanced stage" research. This project builds upon past research by all partners and moves that research into new areas using a systems approach with the aim of increasing the market penetration of renewable energy resources at a reasonable cost to energy facilities, providing a fair price to landowners producing biomass, and generating environmental benefits. Our focus will be on addressing the current constraints and barriers to producing, processing and delivering biomass to energy facilities and specifically lowering the costs of the feestock. Koda Energy will provide a real world example for developing the system to provide biomass for renewable energy. The technologies to be researched are those necessary to produce and deliver biomass for energy, a key area which limits the market penetration of renewable energy. The combustion /conversion technology is not a focus of this project although it will figure into the life cycle analysis. Irrespective of the combustion /conversion technology, an effective production and delivery system for biomass feedstocks will be required.

The University of Minnesota will be the primary contractor with a subcontract with Rural Advantage. Collaborators include Koda Energy, the Institute for Agricultural and Trade Policy (IATP), and the Minnesota DNR. Koda Energy is a joint effort between Rahr Malting Co. and the Shakopee Mdewakanton Sioux Community set up to produce 16.5 MW of base load renewable electricity from biomass feedstocks. Koda Energy will collaborate but receive no funding from the project. Project partners and collaborators will meet on a quarterly basis to evaluate progress.

We are requesting a total of $ 992,989 for the project that will be carried out over a period of 5 years. The project period of 5 years was selected to allow sufficient time for new plantings to be established and monitored as well as to provide sufficient time to monitor wildlife, water quality and initial carbon sequestration impacts.

1.1 Executive Summary

Minnesota has become a leader in renewable energy. The Governors signing of a new energy bill in early 2007 requiring that 25% of the electricity produced in the state be from renewable sources by 2025 (30% for Xcel Energy) is fueling interest in sources of renewable energy. Both woody and herbaceous biomass will be important parts of the feedstock mix considered throughout the state to meet that mandate. Minnesota has a history of producing process heat and electric energy from biomass sources but primarily from agricultural, wood, and manufacturing wastes that, in the past, have been readily available. To meet the growing demand for renewable feedstocks those sources will not be sufficient. There is a growing interest and need for dedicated biomass production to provide feedstocks to help meet that demand.

Much of the interest in renewable energy has been driven by environmental concerns. Evidence linking increasing levels of carbon dioxide in the atmosphere to global warming has led to greater interest in renewable energy as a carbon neutral source of energy that can also sequester carbon under appropriate management. Dedicated perennial crops for biomass production, if targeted planting is undertaken, can provide a number of environmental services including carbon sequestration, improved water quality, wildlife habitat as well as increases in biodiversity. Increasingly the environmental services that could be provided by dedicated energy crops are being valued and payments are already available to Minnesota landowners who plant trees through the Chicago Climate Exchange's carbon credit trading program. A clean energy option as part of the Reinvest in Minnesota conservation easement program is being proposed which would provide payments to landowners producing clean energy crops. The availability of payments for environmental services will help spur the adoption of dedicated energy crops and lower the cost of those crops as an energy source.

The interest in the production of dedicated biomass crops as a feedstock for energy production as well as the environmental services they provide has lead to initial research on those crops. Nonetheless, since many of the energy crops under consideration are relatively new and do not have the large research base associated with commodity crops, there is a need for research on their production, processing and delivery to energy facilities. Basic agronomic research is needed to determine the most cost effective cultural practices required to produce crops at a price competitive in the market and which provides good income potential for landowners. Research is needed on establishment practices, optimum planting and harvesting dates as well weed control practices. As those management practices are better understood both productivity and cost effectiveness will improve providing one avenue for lowering the cost of feedstocks for biomass energy.

Another promising area of research which can help lower the cost of biomass feedstocks to energy facilities are the emerging markets for environmental services. Targeted plantings of perennial crops for bioenergy can have very significant environmental benefits. Plantings can: 1) sequester carbon in the soil as well as in the aboveground biomass left after harvest; 2) improve water quality by taking up excess nutrients and providing a continuous cover protecting the soil from wind and water erosion particularly in environmentally sensitive areas and at times of the year when soil is normally exposed; 3) improve habitat for songbirds and small mammals when compared to traditional annual commodity crops; and 4) provide a more favorable energy balance compared to other feedstock alternatives.

Payments for environmental services are already becoming available to landowners through programs like the Chicago Climate Exchanges carbon credit trading program. The USDA, DOI and Association of Fish and Wildlife Agencies have just signed a Habitat Credit Trading Agreement which will allow

landowners to be paid to establish wildlife habitat to mitigate losses in other areas. The USDA announced in April, 2007 that they are working on market based options for conservation which include payments for environmental services.

By combining improvements in cost effectiveness of feedstock production, processing and transport with the emerging markets for the environmental services provided by perennial feedstocks should lead to a significant reduction in the purchase price of biomass feedstocks for energy production and make renewable energy production a more viable option. Beyond cost reductions, this provides a unique and innovative way to promote significant environmental improvements while providing a reasonably priced renewable energy feedstock with its inherent environmental benefits associated with replacing non-renewable fuels for energy production.

We are proposing to look at the entire system from production of feedstock to address current constraints in developing a biomass feedstock supply chain that is able to effectively deliver biomass to an energy producing facility addressing issues of pre-processing, storage and transportation of a low density feedstock. The analysis will include a life-cycle analysis component carried out by an expert in that field to specifically address issues of energy balance and integration of diverse environmental benefits. Throughout the supply chain we will measure costs to be able to estimate the delivered cost of bioenergy feedstocks. To that cost analysis will be added a component for a system of payments for the diverse environmental services provided by plantings.

Following is an outline of the major research areas:

1. Biomass crop production field to farmgate
    - Optimum planting and harvesting dates
    - Weed control strategy
    - Fertilizer replacement value of biofuel ash
2. Moving biomass from road/farmgate to facility
    - **NOTE**: This will be undertaken by Koda Energy, will be initiated prior to project start date, and **will not require Xcel funding** as this is part of their commercial operations.
3. Measure and value environmental benefits
    - Carbon sequestration benefits as well as benefits related to substitution of a non-renewable fuel with a renewable feedstock based on MN Terrestrial Carbon Project
    - Water quality and storage benefits will be estimated using a modeling approach; the model will be calibrated with field data.
    - Wildlife benefits will be measured and monitored
    - Environmental benefits will be valued based on existing information
    - A Life Cycle Assessment will be undertaken
4. An integrated assessment of multiple environmental commodity market options
    - Farmers will be surveyed to determine what would be required for them to adopt dedicated biomass crops.
    - Complete an integrated assessment of multiple ecological services markets currently being used.
    - Identify potential buyers of ecological services provided by biomass energy crops.
    - Based on existing and potential payment options for environmental services and the landowner survey we will develop an integrated ecological services payment package.

1.2 Project Approach and Work Plan

1.2.1 Goals and Objectives

Goal:
Develop an efficient system for the production, pre-processing and delivery of biomass feedstocks for energy production that minimizes feedstock cost for energy facilities while maximizing landowner income and the environmental benefits of biomass production.

Objectives:

- Establish, research cultural practices, and estimate costs and potential cost savings for the establishment, management, pre-processing and transport of perennial biomass feedstocks from field to energy facility;
- Estimate potential energy, wildlife, water quality, carbon and soil health benefits from targeted perennial biomass feedstock plantings;
- Value environmental benefits for potential payments to landowners who provide environmental commodities;
- Complete an integrated assessment of multiple ecological services markets currently being used; identify potential buyers of ecological services provided by perennial biomass energy crops; develop an integrated ecological services payment package; and
- Develop a model for the production, pre-processing and delivery of perennial biomass feedstocks to energy facilities including a life-cycle assessment of the system from field to facility.

1.2.2 Schedule

Task	2008			2009				2010				2011				2012				13
	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
Biomass Crop production component																				
Exp. 1.1 Weed control- establishment																				
▪ Establishment of study	X				X															
▪ Data collection: biomass yield			X				X				X				X					
▪ Statistical, economic analysis.																X	X			
Exp. 1.2 Planting date																				
▪ Establishment of study			X	X	X		X	X	X											
▪ Data collection:biomass yield							X					X								
▪ Statistical and economic analysis															X	X				
Exp.1.3 Harvest date																				
▪ Establishment of study			X	X	X		X	X	X											
▪ Harvest trt appl. Biomass yield						X	X			X	X			X	X					
▪ Data collection: stands					X	X			X	X			X	X						
▪ Statistical and economic analysis															X	X				
Exp. 1.4 Ash evaluation																				
▪ Preliminary analysis			X	X	X															
▪ Field experiments initiation						X			X											
▪ Data collection: biomass and soil								X			X				X					
▪ Statistical and economic analysis																X	X			
Deliverables (Reports)																				
▪ Progress reports			X				X				X				X				X	
▪ Cost effective strategy for producing biomass (draft)																		X		
▪ Cost effective strategy for ash recycling (draft)																		X		
▪ Final report																				X

Moving biomass from road/farmgate to facility:

Research area 2 will be carried out by Koda Energy LLC and that information provided to the project for the systems/Life Cycle Assessment. That work will be initiated in 2007 by Koda Energy. The research will be part of the Koda Energy plan for developing their energy generation facility and will look at options for gathering biomass of various types from the area surrounding their facility, identifying storage and pre-processing staging areas and the timely delivery of that material to the facility to reduce the need for on-site storage and guarantee a constant supply of biomass as required for the facility. The information generated by Koda will be incorporated into the Life Cycle Assessment of feedstock production and delivery system.

Schedule (continued)

Task	2008			2009				2010				2011				2012				13
	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
Measure and value environmental benefits																				
Wildlife impacts																				
▪ Grassland Songbird Surveys				X	X			X	X			X	X			X	X			
▪ -Annual reports						X				X				X				X		
▪ -Final report																			X	
Water quality/quantity impacts																				
▪ Monitoring of instrumented watersheds	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
▪ Develop hydrologic model									X	X	X	X								
▪ Interim report													X							
▪ Final report																				X
Integrated assessment of ecological service markets																				
▪ Assessment of ecological services market opportunities	X	X	X	X																
▪ Identify potential buyers				X	X	X	X	X	X											
▪ Survey of landowners							X	X	X	X										
▪ Develop ecological services payment model								X	X	X	X	X								
▪ Draft reports				X					X			X								
▪ Final report																X				
Life Cycle Assessment																				
▪ Goal and scope definition				X	X															
▪ Life Cycle Inventory						X	X	X	X											
▪ Life Cycle Impact Assessment										X	X									
▪ LCAs for alternatives												X	X	X	X					
▪ Life cycle interpretation																X	X	X	X	
▪ Database development						X	X	X	X											
▪ Draft reports					X				X		X				X				X	
▪ Final integrated report																				X

X – Monitoring during this period would be covered by matching funding sources

Schedule (continued)

Task	2008			2009				2010				2011				2012				13
	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1
Economic Assessment of biomass production and delivery system																				
Analysis of Costs and Benefits																				
▪ Develop plan with project team	X	X																		
▪ Gather financial/economic data			X	X	X	X	X	X	X	X	X	X	X	X						
▪ Data analysis													X	X	X	X				
▪ Interim and final reports																X				X
Valuation of Ecological Services																				
▪ Develop plan with project team	X	X																		
▪ Gather financial/economic data			X	X	X	X	X	X	X	X	X	X	X	X						
▪ Data analysis													X	X	X	X				
▪ Interim and final reports																X				X
Project Coordination																				
▪ Quarterly meetings	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
▪ Progress reports		X		X		X		X		X		X		X		X		X		
▪ Final project report																				X

1.2.3 Project Performance

Project performance will be measured by various means. Reports and deliverables are addressed briefly in the schedule. Below is a more detailed list of milestones an deliverables by each project task area:

Task	Milestones and deliverables
Biomass Crop production component	
Exp. 1.1 Weed control- establishment	
▪ Establishment of study	Study plan – June 30, 2008
▪ Data collection: biomass yield	Progress report – Dec. 30, 2008, 2009, 2010, 2011 Milestone – Data collected
▪ Statistical, economic analysis.	Final report - June 30, 2012
Exp. 1.2 Planting date	
▪ Establishment of study	Progress report – June. 30, 2009, 2010 Milestone – Research plots established
▪ Data collection: biomass yield	Dec. 30, 2009, March 30, 2011
▪ Statistical and economic analysis	Report – March 30, 2012
Exp.1.3 Harvest date	
▪ Establishment of study	Progress report – June. 30, 2009, 2010 Milestone – Research plots established
▪ Harvest trt appl. Biomass yield	Progress report – Dec. 30, 2009, 2010, 2011
▪ Data collection: stands	Harvest complete - Dec. 30, 2009, 2010, 2011
▪ Statistical and economic analysis	Analysis complete - March 30, 2012 - Report
Exp. 1.4 Ash evaluation	
▪ Preliminary analysis	June 30, 2009 – complete – progress report
▪ Field experiments initiation	Sept. 30, 2009, 2010 – experiments initiated.
▪ Data collection: biomass and soil	Mar. 30, 2010, Dec. 30, 2010, Dec. 30, 2011 – Biomass and soils data collected – Progress report.
▪ Statistical and economic analysis	June 30, 2012 – Report completed.
Deliverables – Integrated reports	
▪ Progress reports	Dec. 30, 2008, 2009, 2010, 2011, 2012 – Integrated report
▪ Cost effective strategy for producing biomass (draft)	Draft complete – Sept. 30, 2012
▪ Cost effective strategy for ash recycling (draft)	Draft complete – Sept. 30, 2012
▪ Final reports	Final Report complete – Mar. 30, 2012

Task	Milestones and deliverables
Measure and value environmental benefits	
Wildlife impacts	
▪ Grassland Songbird Surveys	Survey complete –June 30, 2009, 2010, 2011, 2012
▪ -Annual reports	Report - Sept. 30, 2009, 2010, 2011, 2012
▪ -Final report	Report – Dec. 30, 2012
Water quality/quantity impacts	
▪ Monitoring of instrumented watersheds	Continuous – Annual monitoring report – Dec. 30, 2009-12
▪ Develop hydrologic model	Model complete – Mar. 30, 2011
▪ Interim report	Report – June 30, 2011
▪ Final report	Report – Mar. 30, 2013
Integrated assessment of ecological service markets	
▪ Assessment of ecological services market opportunities	Assessment complete – Mar. 30, 2009 – Report
▪ Identify potential buyers	Identification complete June 30, 2010 - Report
▪ Survey of landowners	Survey complete Sept. 30, 2010
▪ Develop ecological services payment model	Complete with report – Mar. 30, 2011
▪ Final report	Mar. 30, 2012
Life Cycle Assessment	
▪ Goal and scope definition	June 30, 2009 - Report
▪ Life Cycle Inventory	June 30, 2010 - Report
▪ Life Cycle Impact Assessment	Dec. 30, 2010 - Report
▪ LCAs for alternatives	Dec. 30, 2011 - Report
▪ Life cycle interpretation	Dec. 30, 2012 - Report
▪ Database development	June 30, 2010 - Report
▪ Final integrated report	Mar. 30, 2012 - Report

Task	Milestones and deliverables
Economic Assessment of biomass production and delivery system	
Analysis of Costs and Benefits	
▪ Develop plan with project team	Work plan – Sept. 30, 2008
▪ Gather financial/economic data	Annual progress reports – Dec. 30, 2009-12
▪ Data analysis	Finish analysis – Report – Mar. 30, 2012, Final Mar. 30, 2013
Valuation of Ecological Services	
▪ Develop plan with project team	Work plan – Sept. 30, 2008
▪ Gather financial/economic data	Annual progress reports – Dec. 30, 2009-12
▪ Data analysis	Finish analysis – Report – Mar. 30, 2012, Final Mar. 30, 2013
Project Coordination	
▪ Quarterly meetings	Meeting – end of every quarter
▪ Progress reports	Progress report every 6 months
▪ Final project report	Report – Integrated – Mar. 30, 2013

1.3 Project Team

Project Management: This project will be carried out over a five-year period. The project team will work together to complete the various components with each component being led by one of the team members. Team members have a strong history of working together and each brings a strong network of colleagues to the project goals. The team will meet at least quarterly to coordinate, collaborate and evaluate progress toward project objectives.

1.3.1 Project Team

Task/Research Topic	Member	Organization	Role
Agronomic research			
	Donald Wyse	UMN	Perennial crop production
	Craig Sheaffer	UMN	Perennial crop production
	Carl Rosen	UMN	Soils – ash application
Hydrology research			
	Ken Brooks	UMN	Water quality/storage impacts
	John Nieber	UMN	Hydrologic modeling
	Bruce Wilson	UMN	TMDL's, erosion issues
Ecological Services payments	Linda Meschke	Rural Advantage	Environmental payment scheme
	Jim Kleinschmit	IATP	Existing ecologic service markets
	Dean Current	UMN	Carbon credit trading
Wildlife impacts			
	Todd Arnold	UMN	Songbird impacts
	Tim Bremicker	DNR	Coordination research and plantings
Life Cycle Analysis			
	Sangwon Suh	UMN	Life Cycle Analysis/Systems – Energy balance
	Nick Jordan	UMN	
Economics research			
	K. W. Easter	UMN	Valuation of environmental benefits
	Dean Current	UMN	Crop production economics
Farmgate to facility			
	Paul Kramer Jesse Theiss	Koda Energy	Both will coordinate Rahr Malting work on farmgate to facility delivery systems
Coordination			
	Dean Current	UMN	Overall project coordination. These individuals will be the representatives from their respective organization for project coordination
	Linda Meschke	Rural Advantage	
	Mark Lindquist	MN DNR	
	Paul Kramer	Koda Energy	
	Jim Kleinschmit	IATP	

1.3.2 Key Project Personnel:

Dean Current, Research Associate and Co-Director of the Center for Integrated Natural Resources and Agriculture Management [CINRAM] at the University of Minnesota. Dr. Current will serve as Project Director, coordinate the project team, and complete the project reporting. Dr. Current has extensive experience leading multidisciplinary project teams in Latin America and Minnesota. He is on the steering committee of the MN Terrestrial Carbon Project and will help lead and coordinate the integrated assessment of existing environmental services markets and the non-market value survey. He has over twenty years of experience in natural resource based rural development and has been a leader in working with interdisciplinary teams of local land owners and researchers to develop markets for woody biomass and other alternative and multi-benefit crops.

Linda Meschke, Rural Advantage, has over 18 years of experience in developing, leading and managing innovative water quality improvement projects that result in changes on the land. Coordination with local, state and federal agencies, University of Minnesota, non-profits, and private partners has been an important component of Rural Advantage's success. Meschke will work with participating landowners, identify farmers to supply feedstocks to the renewable energy facilities and co-coordinate the environmental services and outreach components.

James Kleinschmit, Rural Communities Director, Institute for Agriculture and Trade Policy [IATP] will lead the component to identify potential environmental services buyers and sellers from within the regional/ local energy sheds. Kleinschmit's work focuses on promoting working landscapes and sustainable rural development in both the U.S. and abroad.

Don Wyse, Professor in the Department of Agronomy and Plant Genetics at the University of Minnesota, Co-Director of the Center for Integrated Natural Resources and Agricultural Management, founding Executive Director of the Minnesota Institute for Sustainable Agriculture, and founder of the University of Minnesota Regional Agricultural and Natural Resources Sustainable Development Partnership Program. He currently leads a multi-college integrated research approach to landscape, human, and animal health issues. Dr. Wyse is the leader of a research program that focuses on the development of diversified agricultural systems that are productive and also provide ecosystem services. His project has provided leadership on perennial crop breeding and selection, management of invasive species, biological weed management, native plant seed production, plant biochemistry, and perennial cropping system design.

Craig Sheaffer, Professor in the Department of Agronomy and Plant Genetics at the University of Minnesota works with: research and education; alfalfa and forage management; sustainable cropping systems; and is the director of the sustainable agriculture graduate program. Dr. Sheaffer has extensive experience developing and managing forage crops, grasses and native perennials and works closely with and interdisciplinary group of faculty, students and non-profit organizations in exploring alternative crops for more sustainable agricultural systems. Dr. Sheaffer will work closely with Dr. Wyse and the project team to research appropriate management practices for perennials for biomass production

Carl Rosen, Professor in the Department of Soil, Water and Climate at the University of Minnesota. Dr. Rosen conducts research on improving nitrogen use efficiency in potato to reduce nitrate leaching losses; genotypic variation in nitrogen acquisition and utilization by plants; nitrogen mineralization characteristics of organic wastes and compost; and effects of municipal and industrial waste application on soil quality and crop production. Dr. Rosen has extensive experience working with the application of ash from alfalfa stems to agricultural crops and will lead the effort researching the application of ash to perennial cropping systems for biomass for energy.

Ken Brooks, Professor in Forest Resources at the UMN. Dr. Brooks will provide leadership and coordinate the hydrology/ flow research with a graduate student and project partners. Dr. Brooks brings extensive experience in studying perennials, associated hydrologic systems and their impact on the landscape and water quality and quantity. Dr. Brooks' research under this project will build upon research conducted by Dr. Brooks and other members of the project team on the impacts of perennial crops on water quality and storage in the Minnesota River Basin.

Todd Arnold, Associate Professor in the Department of Fisheries, Wildlife and Conservation Biology. Dr. Arnold will be responsible for the research on the impact of perennial cropping systems managed for biomass production on wildlife and particularly songbirds. Dr. Arnolds' research interests focus on the ecology and conservation of wetland- and prairie-dependent wildlife, particularly waterfowl. For the last several years I have worked with a team of scientists from Ducks Unlimited Canada on several long-term studies of factors limiting productivity of dabbling ducks in the Canadian Prairies. One outcome of this research has been the development of spatially explicit models that predict the abundance and reproductive success of waterfowl as a function of landscape attributes. These models then become important planning tools for the delivery of future conservation programs.

Sangwon Suh, Assistant Professor in the Department of Biobased Products and Biosystems Engineering is an expert in Life Cycle Analysis with specific experience and interest in Life Cycle Assessment (LCA); Input-Output Analysis (IOA) and hybrid applications; Environmental database developments; Eco-industrial developments; Materials and energy flow modeling; and Integrated Product Policy (IPP). Dr. Suh will lead the Life Cycle Assessment component of the project

Bill Easter, Professor in the Department of Applied Economics in the University of Minnesota. Recent research includes a study of water markets and the transaction costs of sectoral and intersectoral water exchanges, an economic analysis of agricultural pollution of groundwater, a study of the transaction costs of alternative methods for providing urban water supplies in developing countries, and an evaluation of the secondary economic impacts of interbasin water transfers. Dr. Easter will assist with the valuation of environmental services and the elaboration of payment schemes for payments for environmental services.

Mark Lindquist, Biofuels Program Manager at the Minnesota Dept. of Natural Resources. Mr. Lindquist will be responsible for coordination of the DNR involvement in the project which will include providing areas for perennial plantings as well as cooperating with the wildlife studies to be carried out by the project.

1.3.3 Coordination

Because of the integrated nature of this project coordination between members of the project team will be important to meet the goals and milestones set out for the project. Project meetings with researchers and students will be held, at a minimum, on a monthly basis to coordinate activities and sharing of data as well as to make any adjustments to project management that are required. In addition specific meetings will be set up between team members who will need to integrate their research and analyses. For example, input from the agronomy team on management will be required by Dr. Suh to carry out the life cycle assessment. There will also be a team set up for overall coordination with representatives from the University, Rural Advantage, IATP, Koda Energy, and the Minnesota DNR.

Section 2. Technical Aspects

2.1 Project Description

2.1.1 Project Overview

The research and development proposed has a goal with four major components: 1) Develop an efficient system for the production, pre-processing and delivery of biomass feedstocks for energy production; 2) minimize feedstock cost for energy facilities; and 3) maximizing landowner income: and 4) maximize the environmental benefits of biomass production. The project explores options for providing a low cost source of fuel that, in the process, can generate income for landowners and rural communities and provide ecological services to society. The project further explores the opportunity for landowners to be compensated for the ecological services they provide which should lead to lower feedstock prices to energy facilities. Although there are several components, they are all integrated under a Life Cycle Assessment which will allow the project to estimate the true costs and beneficial impacts of the production and utilization of rentable energy biomass feedstocks in both economic and environmental terms.

What technical issue is the proposed project trying to solve?

Development of a feedstock production and delivery system that minimizes the cost of feedstocks to energy facilities while generating sufficient income to make production an option for landowners and with the ability to generate positive environmental benefits. Much of current research on renewable energy has been dedicated to the technologies needed to process biomass into energy. This research is important and necessary but there has been a relative lack of research on both production systems for the dedicated crops that would provide feedstocks for renewable energy and the pre-processing and delivery of a high volume feedstock to an energy facility. This project intends to address that issue.

What technical, cost, or other market barriers is it trying to overcome?

The technical barrier to be addressed is the ability to produce, pre-process and deliver renewable energy feedstocks to an energy producing facility at a price that makes those crops attractive to farmers/landowners and keeps those feedstocks cost-competitive with other land use and feedstock options. These are both technical and cost barriers that need to be addressed. In addition, through landowner surveys we hope to determine how address and overcome the social and economic barriers that might limit the adoption of dedicated perennial biomass crops by landowners.

Why is the work important; how will it advance science or technology?

The proposed work is important primarily due to the lack of research currently underway to address these issues. In addition, it allows us to explore the synergies that exist between the production of energy crops and provision of ecological services. We currently have commodity crops that have benefited from generous, long-term research support. In contrast we have seen great interest develop in support of perennial polyculture crops for which we have very little knowledge on how to produce, harvest and process to maximize farmer success in establishment, harvest and transport to an energy facility while, at the same time, optimizing potential environmental services. Including the production or environmental/ecological services has rarely been addressed as an integral part of crop development in past research other than best management practices.

What is the current status of the technology and of relevant R&D?

There has been research undertaken in the past on perennial crops like switchgrass and alfalfa with significant research on alfalfa. Nonetheless, with the exception of alfalfa, very little information exists on the specific production methods for perennials and especially polycultures that would make these options viable production options for landowners. This work will contribute to that work as well as incorporate the research into a systems approach including a Life Cycle Assessment.

What is the proposed effort's relationship to R&D being conducted by other organizations?

This work essentially builds off of, complements and is the logical next step in research initiated by project team members in the last 10 years. This proposal builds upon research results that have been generated by team members in the areas of: perennial crop production with an emphasis on natives; water quality and quantity impacts of targeted perennial cropping systems; work on the economics of perennial crop production. This proposal adds the ability to integrate result from past research with the research proposed under a systems approach to address issues based upon a real case in Minnesota. This also complements the research program of the University's Initiative for Renewable Energy and the Environment (IREE).

What is the expected contribution to bringing the technology to market readiness?

This research really looks at how we can move the production of perennial crops for biomass energy production beyond research plots into the level of production agriculture and the application of research to a real situation under a comprehensive systems approach.

2.1.2 Applications

This research will contribute to quickly developing field of renewable energy production from biomass. Due to the current mandates for renewable energy production in Minnesota, utilities are searching for real options to produce renewable energy from biomass and will be under pressure to do than in an environmentally sustainable fashion. The research we are proposing would be applicable to any technology requiring the delivery of biomass to an energy facility and, in that sense, is somewhat "technology neutral". The results would be equally applicable to gasification, direct firing, co-firing, as well as combined heat and power facilities other than the specifics of the feedstock that each technology might require. To develop our model we are using the Koda Energy facility.

Some of the products of the proposed research will be immediately applicable upon completion of the research particularly due to the participation of Koda Energy in the project. The systems model that is developed as a result of the project will be ready to applied with adaptations to the development of other renewable energy facilities. Programs for payments for environmental /ecological services are being developed and results of this project can contribute to and inform the development of those payment strategies. Crop production research will need to be ongoing but this will provide preliminary information for production of perennial energy crops and help direct future research.

Note: Koda Energy is used as an example for developing the feedstock production and delivery system but energy production is not a key element of this research other than the Life Cycle Assessment.

The principal waste generated by this project is ash and the research will be exploring the use of that ash as a soil amendment. Water use will not be an issue other than water needed to produce perennial crops.

2.1.3 Specific Project Objectives

Measuring project progress and success: The following metrics will be used to measure project progress and success:

- Completion of project reports and milestones listed in sections 1.2.2 Project Schedule and 1.2.3 Project performance.
- Quarterly meetings of the project team will be used to evaluate progress and make any adjustments to project planning to meet stated objectives.
- A project report will be prepared biannually in July and January to evaluate and report project progress.
- Success will be measured by the extent to which project results are applied to the operations of Koda Energy and other biomass energy facilities.

2.1.4 Project Task Plan

The project Schedule (Section 1.2.2) lays out the timeline for completion of the following tasks

2.1.4.1 Agronomic Aspects of Biomass Production

Production of biofuels from herbaceous native plants is an emerging industry. We need additional information to reduce the production costs of these crops. Our overall goal is to develop biologically and economically based management guidelines for establishing and maintaining profitable stands of native perennials for use in energy production.

Experiment 1. Establishment strategies for weed control

How will native plants be established so as to maximize short-term and long-term productivity? Unfortunately, native plants are challenging to establish in the upper Midwest because of poor seedling vigor of the native plants and significant competition with annual and perennial weeds. With the existing approaches that involve seeding and mowing for weed control, two or three years are required for high levels of production from native plantings and the desired botanical composition cannot consistently be predicted. This adds a significant overall cost to production. New establishment strategies are greatly needed.

Objectives: Develop new approaches for weed control in establishing native perennial grasses and grass-forb polycultures.

Experimental design: Randomized complete block with 4 replications. Treatments will be in a split plot arrangement.

Whole plot treatments will be native plant species: 1) Switchgrass grown alone, 2) a native grass tertiary mixture of switchgrass, big bluestem, and indiangrass, and 3) a mixture of switchgrass, big bluestem and indiangrass with four native forbs and four native legumes.

Subplot treatments within the whole plots will be 1) allelopathic mulches (winter rye, black oats, and oil seed radish; 2) herbicides specific for weed control in native grasses or forb mixtures, 3) a cool season native grass with high seedling vigor (Canada wildrye), and 4) a mowed control.

Specific methods:

<u>Establishment</u>

Whole plots will be established in 50 by 300 ft blocks using a commercial no-till drill; they will be subdivided by the sub plot treatments (minimum size of 50 by 40 ft. Seeding rates of all species as per recommendation of the University of Minnesota. All treatments will be seeded in June, except mulch treatments that will be seeded in fall of the previous year. Grass plots will be fertilized with 80 lb N/acre each year beginning in the year following establishment

Data collected

1) Plant populations of all treatments in June and September of the year of seeding and in spring of the year following seeding by counting all plants in a 3 ft^2 area.

2) Biomass yield in the late fall of the seeding year; in the fall for three years after establishment. Biomass yield will be determined by harvesting a 10 by 10 ft^2 area to a 3 inch height within each plot. A subsample of 2000 g will be collected to a 3 inch height. Botanical composition (weeds, native grasses, and forbs) and contribution to dry weight will be measured. The subsample will be dried and yield expressed on a dry matter basis. The energy value of the biomass will be determined using bomb calorimetry..

.Statistical analysis

All data will be subject to an analysis of variance. Treatment means will be separated using LSD (0.05)

Experiment 2. Optimum planting dates for native perennial biomass crops

Typically, native perennial biomass crops are dormant seeded in the late fall or are seeded in the spring. Both scenarios present challenges to timely and successful establishment. The success of the late fall seeding is dependent on freezing and thawing action during the winter. The spring/ June seeding is dependent on favorable moisture levels in the spring. Both systems appear to be vulnerable to competition form cool and warm season weeds. Establishment strategies need to be developed on soils within the microclimate of the fuels shed for the plant.

Objectives: Determine the effect of planting date on the establishment of native perennial grasses and grass-forb polycultures.

Experimental design: Randomized complete block with 4 replications. Treatments will be in a split plot arrangement.

Whole plot treatments will be native plant species: 1) Switchgrass grown alone, 2) a native grass tertiary mixture of switchgrass, big bluestem, and indiangrass, and 3) a mixture of swithchgrass, big bluestem and indiangrass with four native forbs and four native legumes.

Subplot treatments within the whole plots will be three dates of seeding: Early December before snowfall; January-March; and June.

Specific methods:

Establishment

All plots will be 10 by 10 ft and will be broadcast seeded.. Seeding rates of all species will be based on recommendation of the University of Minnesota. Weeds will be controlled best management practices including herbicides.

Data collected

1) Plant populations of all treatments in September of the year of seeding and in spring of the year following seeding by counting all plants in a 3 ft^2 area.

2) Biomass yield in the late fall of the seeding year; in the fall for three years after establishment. Biomass yield will be determined by harvesting a 10 by 10 ft^2 area to a 3 inch height within each plot. A subsample of 2000 g will be collected to a 3 inch height. Botanical composition (weeds, native grasses, and forbs) and contribution to dry weight will be measured. The subsample will be dried and yield expressed on a dry matter basis. The energy value of the biomass will be determined using bomb calilormetry.

.Statistical analysis

All data will be subject to an analysis of variance. Treatment means will be separated using LSD (0.05)

Experiment 3. Optimum harvest dates for native perennial biomass crops

For most biofuel systems in more moderate climates, dormant harvests in the late fall and are recommended. This necessitates costly year round storage of biofuel crops. An alternative approach is to harvest throughout the year. The influence of diverse harvest times on biofuel yield and composition and stand persistence is unknown.
Objectives: Determine the effect of harvest date on the yield, energy content, ash content, and persistence of native perennial grasses and grass-forb polycultures .

Experimental design: Randomized complete block with 4 replications. Treatments will be in a split plot arrangement.

Whole plot treatments will be native plant species: 1) Switchgrass grown alone, 2) a native grass tertiary mixture of switchgrass, big bluestem, and indiangrass, and 3) a mixture of switchgrass, big bluestem and indiangrass with four native forbs and four native legumes.

Subplot treatments within the whole plots will be four dates of harvest: September, December, March, May (before greenup)

Specific methods:

Establishment

We will utilize stands of natives established in Experiment 1.

Data collected

1) Biomass yield at each target harvest date for three consecutive years Biomass yield will be determined by harvesting a 10 by 10 ft^2 area to a 3 inch height within each plot. A subsample of 2000 g will be collected to a 3 inch height. Botanical composition (weeds, native grasses, and forbs) and contribution to dry weight will be measured. The subsample will be dried to allow yield expression on a dry matter basis. The subsample will be analyzed for nitrogen and mineral (P, K, Mg, MN, B, S, Si, Na) concentration. The energy value of the biomass will be determined using bomb calorimetry.

2) Plant populations of all treatments will be measured each spring in June during green-up of the stands. All plants will be counted in a 3 ft^2 area.

.Statistical analysis

All data will be subject to an analysis of variance. Treatment means will be separated using LSD (0.05)

Experiment 4. Fertilizer replacement value of biofuel ash

The combustion of herbaceous biofuels will generate a significant amount of ash that potentially could have value as a fertilizer. Recycling of this ash to the soil will be an environmentally sound practice.

Objective: The overall objective isanswer fundamental questions related to the agronomic use and potential environmental impacts of ash generated from combustion of herbaceous native perennial biomass at the Rahr Malting facilities.

This research has two phases: 1) In a laboratory ash characterization study, we will measure the concentration and chemical form of the elements in the ash. 2) In the field, we will determine crop response when ash is returned to the soil. The solubility of various compounds in the ash will be regulated by the chemistry of soil.

Sub-objective 1): Chemically characterize the ash.

Ash generated from the combustion of native perennial plants will be subject to chemical analysis. Chemical composition will be determined using several methods because different instruments are required to determine certain elements or groups of elements. Additional analyses will be conducted following leaching experiments to determine the relative solubility of individual components and elements in the fly ash material. Total elemental analyses of the ash will be conducted by inductively coupled plasma—mass spectrometry (ICP—MS). Samples are first fused with lithium metaborate and then dissolved in a hydrochloric/citric acid solution. ICP—MS analyses provide total elemental concentrations for approximately 60 elements, including most heavy metals. They are also very sensitive and can easily detect these elements even when they occur at trace levels. Because they were introduced in the fusion process, lithium and boron cannot be determined by ICP-MS. Boron is a common constituent of fly ash produced by standard methods (Mattigod et al., 1990; Eary et al., 1990). These elements will be determined by inductively coupled plasma—atomic emission spectrometry (ICP—AES) on samples that have been digested by a combination of strong acids, thus avoiding lithium and boron contamination of the samples. These analyses will also provide data for arsenic, and will serve as an independent check on the accuracy of the ICP—MS analyses. Mercury cannot be determined by normal ICP—MS or ICP—AES methods. Consequently, analysis of samples for mercury will be performed by cold vapor atomic fluorescence after the method of Bloom and Fitzgerald (1988). Samples will be digested in concentrated nitric acid in high pressure digestion bombs in a microwave. Water-soluble anions (chloride, fluoride, sulfate, nitrate, nitrite, phosphate) will be determined by ion chromatography.

Sample pH will be determined on a 1:5 sample:water mixture. Electrical conductivity will be determined on the same mixtures using a conductance meter. Calcium carbonate equivalent (a measure of liming potential) will be determined by standard methods (Johnson, 1990a). Fertilizer P and K value of the ash will be determined using methods described by Johnson (1990b).

Sub-Objective 2 - Crop response to ash amendment. We will conduct experiments on two soils on farms within 20 miles of the ash generating facility. We have chosen corn (stover) as well as switchgrass, the native grass mixture, and or the native grass-forb mixture as the test crops because of their importance to the biofuel industry in the Midwest. (Experiment 1

Experimental design: Randomized complete block with treatments in a split plot arrangement. Whole plot treatments will be the three native plantings mentioned above and corn will be used as a control. Sub plot treatments will be 6 rates of ash applied to each crop.

Specific methods

Plot size will be 20 by 20 feet. The experiment will be conducted in the field. Ash will be spread and incorporated into established stands of switchgrass, the native grass mixture, or the native grass-forb mixture (experiment 1) in early spring before resumption of growth.. It will also be applied prior to corn seeding. Ash will be added at six rates, ranging from very low rates to rates approximating "fertilizer"

additions (based on estimated P and K availability from laboratory extractions), to a high rate that might be used in disposal operations. Appropriate fertilizer and lime control treatments will be included. The ash will be mixed with the upper 6 cm of soil.

Data collected

Biomass yield will be determined by harvesting a 10 by 10 ft^2 area of the herbaceous native biomass crops and the corn to a 3 inch height within each plot. Botanical composition (weeds, native grasses, and forbs) of the native plant mixtures will be measured Corn grain and stover yield will be measured .A subsample of 2000 g of herbaceous biomass or corn stover will be collected. The subsample will be dried to allow expression of yield on a dry matter basis and saved for analysis. The energy value of the biomass will be determined using bomb calilormetry. Soil subsample will be collected from 0-6 and 6-12 inch depth from all treatments.

The subsamples of the whole herbage of the biomass crops as well as the corn stover will be analyzed for:

1) total N by semi-micro Kjeldahl digestion followed by colorimetric flow injection analysis;
2) total Cl by the mercuric thiocyanate-ferric nitrate procedure in which ferric thiocyanate is formed proportionally to the original Cl concentration; and
3) other elements (P, K, Ca, Mg, Na, Al, Fe, Mn, Zn, Cu, B, Pb, Ni, Cr, Cd, Si, and S) by ICP-AES after wet digestion.

Total accumulation of all measured elements will be calculated from shoot dry mass and elemental concentration.

Analysis of soil samples will include:

1) 1 *M* HNO_3-extractable metals (Fe, Al, Mn, Cu, Zn, Cd, Ni, Pb, and Cr);
2) DTPA-extractable metals (Cu, Zn, Fe, Mn, Cr, Cd, Ni, and Pb);
3) extractable P by Bray and Kurtz P-1 (acid soil) or Olsen and Sommer $NaHCO_3$ (alkaline soil);
4) SO_4-S by extraction with 0.008 *M* $Ca(HPO_4)_2$;
5) exchangeable K, Na, Ca, and Mg by 1 *M* ammonium acetate;
6) inorganic N as NH_4+ and NO_3- by 2 *M* KCl extraction and colorimetric flow injection analysis;
7) hot water soluble B;
8) pH (1:1 soil:water); and
9) soluble salts.

The two metal extraction procedures reflect estimates of sorbed (HNO_3) and plant available (DTPA extractant) forms of these elements. The two extractable P tests were designed for soils with different pH. Tests 3 through 7 are used in standard soil testing laboratories to predict likely response of crops to fertilizers.

Statistical analysis

We will use a combination of analysis of variance and regression analysis to analyze this data. Regression analysis will allow prediction of responses based on ash application rates.

2.1.4.2 Wildlife Impacts

To examine potential wildlife benefits of a diversified perennial cropping system, we will document grassland songbird communities inhabiting perennial biomass production systems and contrast them with communities of similar-sized study plots in a traditional corn-soybean rotation. In addition, we will determine nesting success of birds in these systems in relation to predation and timing of agricultural operations. Research in Iowa has shown that bird species abundances are lowest in tilled row crops and small grains, but reach their peak in narrow strips of perennial vegetation such as rights-of-way and wooded fencerows (Best et al. 1995).

Converting local landscapes from a simple annual cropping system to a diversified system that includes annual and perennial crops can lead to 1.5 to 3-fold increases in bird species diversity (Arnold 1983, Best et al. 1995), and we anticipate similar responses by Minnesota birds. We will use territorial mapping to assess grassland songbird abundance (International Bird Census Committee 1969) in 8-ha study plots (200 $\times$ 400 m, approx. 20 ac.). Locations of singing male songbirds will be plotted on air photos of study plots to facilitate recognition of individual territories. Species richness and species abundances will be compared between diversified perennial cropping systems and traditional row-crop systems. In addition, we will explore correlates of individual species abundances to discern particular habitat requirements (e.g., an association between song sparrow territories and clumps of woody vegetation).

Nesting success is one of the most important determinants of population growth rates (and hence persistence) in grassland birds (Fletcher et al. 2006). Two potential drawbacks to diversified perennial cropping systems are that habitat patches are usually small and they are often harvested during the nesting season, and both of these factors can contribute to low nesting success for grassland songbirds (Kirsch et al. 1978, Johnson and Temple 1990). We will locate and monitor songbird nests on each study plot to determine Mayfield nesting success (Johnson 1979), the proportion of nests fledging at least one offspring. We will monitor nests immediately after mowing operations to identify nest mortality associated with farming operations, as opposed to predation, and we will compare rates of nesting success between perennial cropping systems and traditional row-crop systems (Patterson and Best 1994).

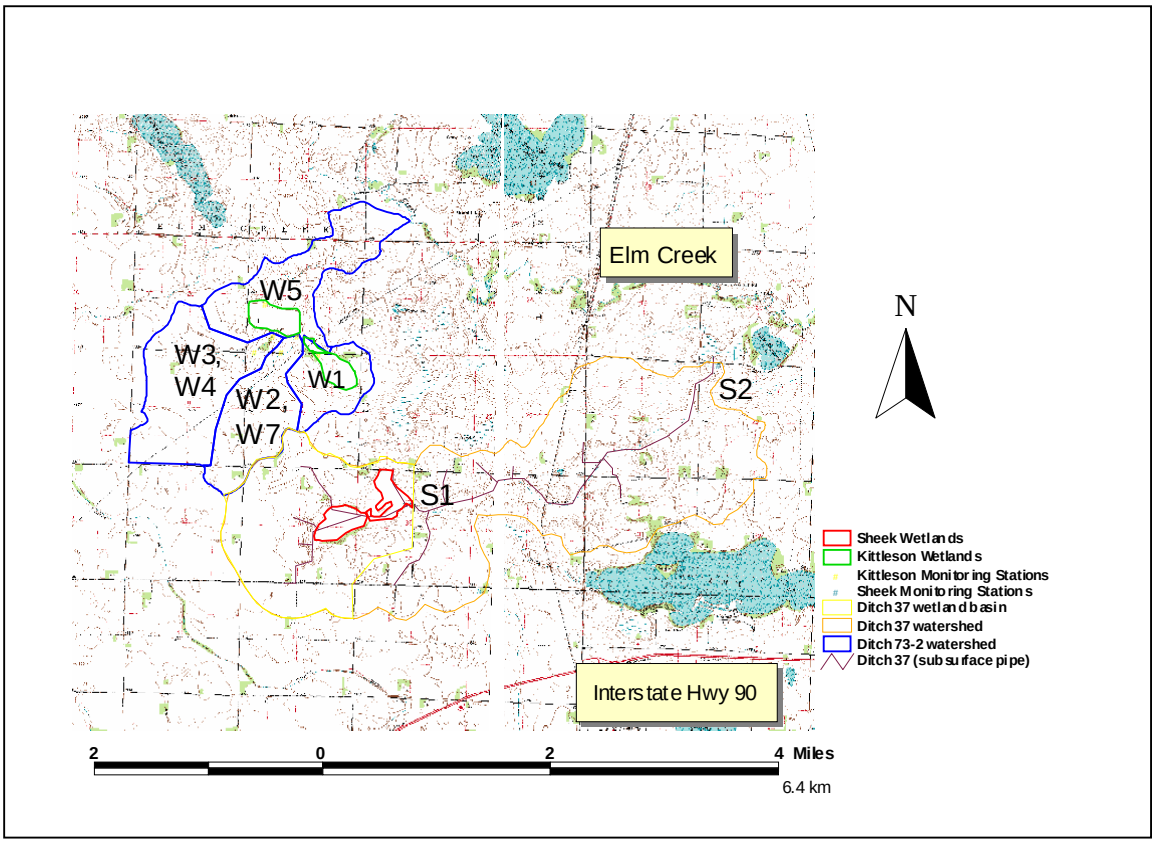
2.1.4.3 Hydrologic and Water Quality Attributes of Perennial Crops in Contrast to Corn:

The extent of agricultural non-point-source pollution from corn-soybean cropping in the Minnesota River Basin (MRB) is well documented (Leach and Magner, 1992; Magner et al., 1993; MPCA, 1994; Randall et al., 1997; Quade, 2000; Brooks et al. 2006). The MRB has also experienced frequent damaging floods and many of the tributary streams and sections of the main stem river channel are degraded. With increasing emphasis on ethanol production from corn, these impacts will be exacerbated.

Energy production from perennial crops offers a viable alternative to corn that has the potential to improve watershed conditions that can improve water quality and restore hydrologic function of many tributaries in the MRB (Ennaanay, 2006; Lenhart, 2007 (forthcoming)).

We propose to use an existing monitoring of subwatersheds with perennial herbaceous bioenergy crops in wetland complexes and compare these data with that from subwatersheds of corn crops in the Elm Creek watershed, a tributary of the Blue Earth Basin. Three years of monitoring have produced flow and water quality data on surface runoff and tile flow from corn-soybean subwatersheds and from subwatersheds that have significant percentages of herbaceous vegetative cover. We will use these data to calibrate a hydrologic model and apply it to larger scale systems. One of the corn crop subwatersheds could be converted to herbaceous perennial crops (switchgrass and other native species) to validate the model. Through a modeling approach we can examine the potential water quality benefits that can be generated through converting from corn to perennial bioenergy crops. Not only will such changes help mitigate TMDLs, they can potentially provide added environmental benefits that can make perennial biofuels more sustainable and economically viable than 100% corn cropping.

Figure 1. Location of study sites in Martin County, southern Minnesota.



The monitoring study that will provide the necessary data is ongoing at two adjacent watersheds of Elm Creek, the SHEEK watershed that is defined as the drainage associated with Ditch 37 and the Kittleson watershed that is defined by Ditch 73-2; both subsurface drainage pipe networks in western Martin County, Minnesota located at latitude 43˚ 42′N and longitude 94˚ 47′W. The sites are located in the prairie pothole region of southwestern, Minnesota where wetlands and lakes covered 30% of the land area prior to European settlement in the late 1850s (Quade, 2000; Perrine and Meschke, 2006).

Today, the Elm Creek watershed has 86% coverage of corn-soybean agriculture with 2% wetland and 1.7% lakes with the rest consisting of grassland, pasture, roads and a small urban area (Quade, 2000). Most of the agricultural land is now drained by privately-installed subsurface pipes that connect to the public ditch system. The 474 ha upper SHEEK watershed and the 527 ha Kittleson watershed contain 72.5 and 86% annual row-crops, 8.8 and 10.3 % wetland area and 16.7 and 3.7% perennial vegetation, respectively. The Kittleson subwatersheds, W2 and W4 contain 91 and 94 % row-crop agriculture, respectively (Table 1 and Figure 1). Tile outlet sites, W7 and W3 contained the subsurface outlets for the same corresponding subwatersheds; i.e. (W7 + W2) and (W4 + W3) represented the cumulative water discharge from each subwatershed.

Monitoring stations in the Kittleson watershed were selected to compare the response from croplands with the outflow response of watersheds that have a cropland-wetland-perennial vegetation complex. The SHEEK watershed is currently being monitored that has 70%, 7% and 23 % row-crops, wetlands, and perennial vegetation respectively. This study permits a nested watershed approach to examine effects of wetland-perennial vegetation components across different scales.

2.1.4.4 An integrated assessment of ecological service market options:

Integrated assessment of multiple ecological services market opportunities

An integrated assessment of multiple ecological services market opportunities will be undertaken by Rural Advantage, the University of Minnesota and the Institute for Agriculture and Trade Policy [IATP]. This will be completed in the first year of the project. Potential ecological services markets and related market elements to be considered include carbon, water quality trading (flow, N, sediment and P), habitat, sustainability standards, aquifer recharge/water storage, and air quality trading. Evaluation methods used to develop existing market structures, how payments are facilitated, values for various environmental commodities, reporting/validation/certification methods and requirements specific to each implemented program will be summarized. Special attention to what has worked elsewhere and not worked in robust or limited markets, and what are the identified key factors of success or limitations will be defined in the context of the project area. For habitat and other developing markets, the team will conduct a survey on Non Market Valuation (NMV) for those environmental commodities that are only concepts or emerging interests. NMV describes how value is assigned to features and services provided (i.e., higher species of water fowl or song birds, recreational uses such as hunting and fishing, quality of life interests such as camping scenic byways and trails, etc.). The project will identify what values and functions have majority agreement or are highly desirable, capture opinions on who should pay for the services, identify the value, what services are valued higher, and determine what a buyer is willing to pay.

Identify potential buyers of ecological services provided by perennial biomass energy crops;

Identification of potential biomass purchasers in the project area and local regions of Minnesota will be led by the Institute for Agriculture and Trade Policy with collaboration by the University and Rural Advantage. The search will consider facilities already in place and those that will be operating within the time frame of this project or shortly thereafter. The criteria for including a facility on the potential purchaser list will include consideration of transportation and storage costs of the biomass fuel. This task will be completed by the end of the second year of the project.

Survey of landowners to identify barriers to adoption of perennial biomass energy crops

The University of Minnesota in collaboration with Rural Advantage and IATP would undertake a survey of farmers/landowners to gauge factors that increase their interest in producing perennial biomass cropping systems as well as the constraints that might limit their adoption of those systems. To undertake the survey, initially the target group of landowners would be identified which would include owners currently farming but also others such as absentee landlords and renter/farmers who may make or influence the decisions that are made in terms of land management. The survey would be applied in the fuelshed area (the area from which Koda Energy might purchase dedicated feedstocks) of the Koda Energy facility but would be structured in such a way that it could be adapted and used throughout the state.

Develop an integrated ecological services payment model

Rural Advantage, with collaboration of other team members, will develop an integrated ecological services payment package model that can provide perennial biomass growers with a payment directly related to the ecological services they provide. The model would be built upon the research results of the preceding three tasks.

2.1.4.5 Life Cycle Assessment (LCA)

Overview

LCA is a tool to quantify environmental impacts of products and services taking their entire life-cycles, from "cradle to grave" – including raw material extractions, energy acquisition, materials production, manufacturing, use, recycling, ultimate disposal, etc. Environmental impacts considered in an LCA includes climate change, stratospheric ozone depletion, tropospheric ozone (smog) creation, eutrophication, acidification, toxicological stress on human health and ecosystems, the depletion of resources, water use, land use, and noise.

LCA provides an overview of environmental costs and benefits of the product system in question and helps identify key bottle necks and prioritize improvement options. LCA is widely used as a decision-support tool for choosing raw and ancillary materials or for evaluating alternative production practices.

ISO 14040 series by the International Organization for Standardization (ISO) lays out a baseline framework of conducting an LCA study. The International Standards distinguish four phases of conducting an LCA. They are briefly described in the following paragraphs [Dean, if this and what follows is too detail, you can simply delete them].

Goal and Scope Definition of an LCA provides a description of the product system in terms of the system boundaries and a functional unit. The functional unit is the important basis that enables alternative goods, or services, to be compared and analysed. The functional unit is not usually just a quantity of material. Practitioners may compare, for example, alternative types of packaging on the basis of 1 m3 of packed and delivered product – the service that the product provides. The amount of packaging material required, termed the reference flow, can vary depending on the packaging option selected (paper, plastic, metal, composite, etc.).

Life Cycle Inventory (LCI) is a phase for estimating the consumption of resources and the quantities of waste flows and emissions caused by or otherwise attributable to a product's life cycle. The processes within the life cycle and the associated material and energy flows as well as other exchanges are modeled to represent the product system and its total inputs and outputs from and to the natural environment, respectively. The total inputs and outputs are then related to the functional output of the entire product system, e.g., kWh of electricity, so that the LCI result shows the inputs and outputs from and to the natural environment to provide the function.

Life Cycle Impact Assessment (LCIA) is a phase where the LCI results are related to quantifiable environmental impacts. For instance, the amount of CO_2 and CH_4 emission quantified during the LCI phase are converted into Global Warming Potential (GWP), and, if necessary, further aggregated into a single indicator through normalization and weighting between different impacts.

Life Cycle Interpretation occurs at every stage in an LCA. If two product alternatives are compared and one alternative shows higher consumption of each material and of each resource, an interpretation purely based on the LCI can be conclusive. A practitioner, however, may also want to compare across impact categories, particularly when there are trade-offs between product alternatives, or if it is desirable to prioritize areas of concern within a single life cycle study.

Research plan

Although traditional manufacturing industries are the main users of LCA, LCAs have been conducted for biomass-based energy production systems, mainly corn starch-based ethanol production. LCAs for corn starch-based ethanol generally confirms that there is no to little benefit for climate change, while there are significantly higher impacts on other environmental impact categories such as eutrophication and

human and ecosystem toxicological impacts as compared to those by fossil fuel alternatives that provide same function. There are only handful of studies on cellulosic biomass-based energy production systems, main focuses being on corn stover-based ethanol and biomass co-firing. Most of these studies were conducted using figures from literatures and the results are thus preliminary in nature. Furthermore, relatively little attention has been paid to the crop production practice, and the consequences of various cultural practices on life-cycle environmental impacts of biomass energy systems have not been successfully addressed.

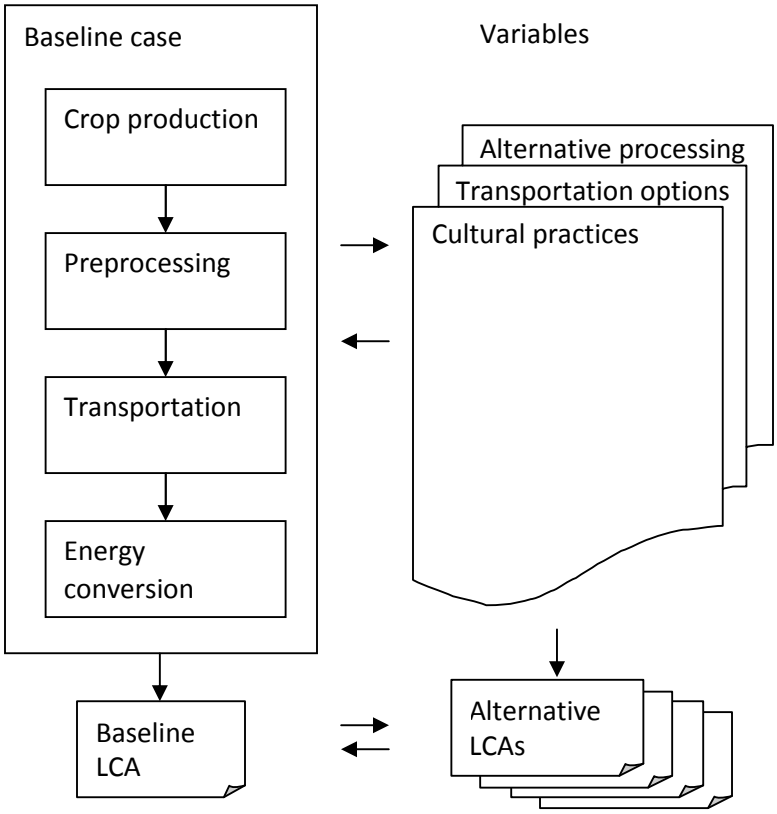


Figure XX. Parametric LCA framework for evaluation of alternative practices in biomass-based energy production system

With the proposed research, we will first draw a baseline LCA case, which will serve as a reference for comparison as well as the default scenario to which various cultural variables can be easily attached (see figure XX). In this way, information on shared processes are preserved for later uses, and LCAs for alternative practices can be easily performed by changing relevant variables of the baseline case and/or adding/subtracting relevant unit processes. This approach is generally referred to as a parametric LCA approach.

We will utilize the Comprehensive Environmental Data Archive (CEDA) 3.0 database developed by one of the co-PIs of the proposal. CEDA 3.0 is an LCA database that contains information on 1344 types of environmental emissions generated by 500 goods and services produced in the US throughout their life-cycles. The life cycle inventory data is connected to over 90 different life cycle impact assessment methods. CEDA 3.0 will be used as a background LCA database for the project.

Section 3. Project Economics

3.1 Economic Development Benefits

Since this project concentrates on the production and delivery of perennial feedstocks to energy producing facilities, the economic benefits from those technologies are generally local providing jobs and income to landowners and others producing the crops as well as those involved in pre-processing and delivery to a facility. Beyond that, the technology being used by an energy facility will determine additional benefits.

3.1.1 Likely Cost Effectiveness

Combining the evaluation of production options for perennial crops with payments for environmental/ecologic services should make options developed by this project **much better or somewhat better than alternatives**, and particularly when comparing biomass production options for renewable energy. Use of biomass for energy is a relatively low value use for biomass although the market for energy will determine that value in the future. In situations where you may be able to extract a higher value product from a crop and use the residue as an energy source, that alternative might be more cost effective. But, if you include environmental/ecologic benefits and the payments for those services, dedicated perennial crops would have increased cost effectiveness for energy production.

3.1.2 Potential Size of Market

The potential market for perennial feedstocks for renewable energy will largely be determined by the market but here I will refer to calculations made for a community energy facility in Madelia, MN. [1] Madelia is a community of members in South Central Minnesota. They calculated productivity of biomass at roughly 4 tons per acre producing around 60 M Btu's per acre considering that a ton of biomass is roughly equivalent to 15 M Btu's. According to the findings of the study the energy demand of 47 trillion BTU's of energy for thermal, electrical and transportation fuels could not be met by the potential production of biomass from the land base. Based on the Madelia findings there is sufficient demand for renewable energy from biomass as the percentage of renewable energy required by the Minnesota legislature has increased.

3.1.3 Other Benefits

The production technologies proposed here have the potential to provide a number of environmental and ecological benefits. The table below provides an initial estimate of some of the benefits of the production of perennial crops in the Minnesota River Basin. This data was generated by a model developed by project partners that would be expanded and improved through this project.

Benefit category	Unit	Low	Best	High
Flood control	$/acre	11.66	35.06	100.36
Income generation (net)	$/acre	<0.00	--	587.56
Savings in dredging costs	$/CY	--	6.5	--
Savings in ditch cleaning	$/foot	--	--	65
Recreational benefits	$/h'hold	--	11.8	59.87
Cost savings TMDL	$/kg.	<0.00	--	7.89

[1] Madelia Bio-Based Eco-Industrial Assessment. Rural Advantage. 2/15/07

3.2 Use of Project Funds

A project budget is included in section 4.4 in the Appendices. This project requires an interdisciplinary effort to be able to perform the systems analysis required to look at the production, processing and delivery of biomass feedstocks to an energy facility at a price which helps keep the price of energy reasonable and also produces the potential environmental benefits. The project unites the basic analyses required to persons highly trained in their area of expertise but also allows for the integration of that information into the final analysis. Through this project we plan to be able to:

- Provide recommendations for cost effective production methods for perennial crops for biomass energy effectively working to lower the cost of the feedstock.
- Provide guidelines for payments for environmental/ecosystems services which will provide additional income from perennial plantings and again lowering the effective cost of the feedstock for energy production.
- Provide recommendations for strategies for promoting biomass energy plantings to landowners that will facilitate adoption and the plantings at a scale that they can effectively provide a consistent feedstock for energy production.
- Develop a model for the production, pre-processing and delivery of biomass to energy production facilities that can be applied, adapted and improved upon throughout the region.
- We will address research issues that need to be addressed but have not been due to a greater emphasis on combustion or processing technologies.
- We will have better estimates of the positive environmental and ecological benefits of perennial cropping systems that could receive payments for the services they provide.

The project will be receiving in-kind support from Koda Energy and the Minnesota DNR as indicated in their letters of support. Koda Energy will be providing information for the Life Cycle Assessment as well as costs of the field to facility staging and transport systems. The DNR has offered to allow us to work on some of the lands they manage and may be providing assistance with plantings that will be monitored. The time of researchers at the University will also be provided to the project as an in-kind contribution.

We will require quarterly reimbursement as we do not have funding to carry us over from one quarter to the next. This arrangement has been worked out with the University in the past and we will provide quarterly milestones to justify the reimbursement.

3.2.1 Itemized Project Costs

Budget Item	Description/Justification
Agronomic Aspects of Biomass Production	
RA polyculture research (.50 FTE) + fringe	The project will hire a half time graduate student to work with project researchers to set-up, register data and perform data analysis and write-up of experiments.
RA water quality/hydrology (.50 FTE) + fringe	The project will hire a half time graduate student to work with project researchers to set-up, register data and perform data analysis and write-up of water monitoring experiments.
Two undergrad. assistants ($10/hr x 800 total hours/year)	The undergraduate students will assist project personnel in maintaining research plots and taking data

Travel To research sites	We have research sites in Martin County, Waseca and will be establishing new sites with the DNR. Travel to the sites will be required
Water quality/hydrology Supplies & analyses	The water quality work will require the purchase of supplies to maintain field measuring stations as well as for the analysis of water samples.
Soil analyses (included in budget as other direct costs	Soil samples will be taken that will require analysis periodically. Funding is requested for those analyses.
Environmental Services	
Research Associate (15% FTE) + fringe	Dr. Dean Current will coordinate the project and work on the economics and survey work for the Payments for Environmental/Ecologic Services.
RA Wildlife Assessment (.50 FTE) + fringe	The project will hire a half time graduate student to work with project researchers to set-up, register data on bird counts and perform data analysis and write-up of bird population experiments.
RA ecological services (.50 FTE) + fringe	The project will hire a half time graduate student to work with project researchers to research environmental payment schemes as well as assist with the economics analyses of the crop production and delivery systems.
Subcontracts	
Rural Advantage	Rural Advantage will be contracted to provide services related to the work on environmental services and payment options. She will work 800 hours over the first three years of the project.
IATP	Jim Kleinschmit who has specific expertise in sustainable cropping systems and payments for environmental services will be subcontracted. He will put in 320 hours over a 3 year period@62.50/hour
Travel to project areas & consultation with other researchers	We will need to travel to project areas to work with interviews and focus groups related to get landowner input into payment schemes for environmental services. This is an emerging field of work that may also require travel to consult with other researchers.
Life Cycle Analysis	
RA Life cycle analysis (.50 FTE) + fringe	The project will hire a half time graduate student to work with project researchers to set-up, register data and perform data analysis and write-up of water monitoring experiments.
Indirect costs (49.5 %)	This is the negotiated rate between the University of Minnesota and Xcel Energy

Section 4. Appendices

4.1 Appendix 1 – Project budget

4.2 CV's for principal project personnel

February 2007

KENNETH N. BROOKS
Professor of Forest Hydrology and Director of Graduate Studies
in Natural Resources Science and Management,
Department of Forest Resources, University of Minnesota, St. Paul, MN.
Telephone: (612) 624-2774; FAX: (612) 625-5212; e-mail: kbrooks@umn.edu

Education:

University of Arizona	Ph.D.	Watershed Management	1970
University of Arizona	M.S.	Watershed Management	1969
Utah State University	B.S.	Range & Watershed Science	1966

Professional Experience:

1985-Present	Professor, Department of Forest Resources, since 1987, Director of Graduate Studies in Natural Resources Science and Management (formerly Forestry), College of Natural Resources, University of Minnesota, St. Paul
1995-Present	Co-Director of the Center for Integrated Natural Resources and Agricultural Management (CINRAM), University of Minnesota
1979-1985	Associate Professor, Department of Forest Resources, University of Minnesota
1975-1979	Assistant Professor, Department of Forest Resources, University of Minnesota
1973-1975	Hydrologist, Hydrologic Engineering Center, Davis, California
1971-1973	Hydrologist, North Pacific Division, Corps of Engineers, Portland, Oregon

Publications (10) Related to Proposal:

Brooks, K.N., D. Current and D. Wyse. 2006. Restoring Hydrologic Function of Altered Landscapes: An Integrated Watershed Management Approach. Pp 101-114 in: Tennyson, L. And P.C. Zingari (eds.). *Water Resources for the Future*, Conference Proceedings, Porto Cervo, Sassari, Sardinia, Italy; 22-24 October, 2003, Watershed Management & Sustainable Mountain Development Working Paper 9, FAO, United Nations, Rome.

Riedel, M.S., E.S. Verry and K.N. Brooks. 2005. Impacts of land use conversion on bankfull discharge and mass wasting. *Journal of Environmental Management 76:326-337.*

Bryne, M. And K.N. Brooks. 2005. Soil moisture regimes under annual and perennial crops as components of agroforestry systems. In: Brooks, K.N., and P.F. Ffolliott. 2005. (eds.) *Moving agroforestry into the mainstream*. The 9th North American Agroforestry Conference Proceedings, June 12-15, CINRAM and Dept. of Forest Resources, University of Minnesota, St. Paul, MN.

Brooks, K. N., P. F. Ffolliott, H. M. Gregersen, and L.F. DeBano. 2003. *Hydrology and the Management of Watersheds.* Third Edition. Iowa State Press, Ames, Iowa, 502 pp.

Ffolliott, P.F. and K.N. Brooks. 2002. Watershed management: a rational approach to producing, conserving, and sustaining natural resources. *Annals of Arid Zone* 41(3&4):217-232.

Ffolliott, P.F., K.N. Brooks and M.M. Fogel. 2002. Managing watersheds for sustaining agriculture and natural resource benefits into the future. *Quarterly Journal of International Agriculture* 41 (No. 1/2):23-40.

D. Shuhuai, Geng Zhihui, H.M. Gregersen, K.N. Brooks and P.F. Ffolliott. 2001. Protecting Beijing's municipal water supply through watershed management: an economic assessment. *J. American Water Resources Association* 37(3):585-594.

Lu, S.Y., J. Cheng and K.N. Brooks. 2001. Managing forests for watershed management in Taiwan. *Forest Ecology and Management.143:77-85.*

Perry C.H., R.C. Miller and K.N. Brooks. 2001. Impacts of short-rotation hybrid poplar plantations on regional water yield. *Forest Ecology and Management* 143(1-3):143-151.

Brooks, K.N. 1996. Watershed management project planning, monitoring and evaluation. *Journal of Soil and Water Conservation (Taiwan)* 28(3):87-96.

Synergistic Activities

2006

- Member, Committee on Hydrologic Impacts of Forest Management, Water Science and Technology Board, The National Academies, Washington, DC
- Watershed management specialist, Panel for 3rd External Programme and Management Review of the World Agroforestry Center (ICRAF), headquarters in Nairobi, Kenya, Science Council, Consultative Group on International Agricultural Research (CGIAR).

2005

- Co-editor of Proceedings, 9th Association for Temperate Agroforestry Conference, Moving Agroforestry into the Mainstream, Rochester, MN June 12-15, 2005.

2004

- Training course "Hydrologic role of agroforestry practices as integral components of watershed management in Central America," K.N. Brooks and B. Ramakristna, March 24, as part of "White Water to Blue Water Conference," Miami, Florida.

Collaborators/graduate and postdoctoral advisees

Current, Dean, Streed. Erik, Josiah. Scott, Jones, Jeff, Ffoiliott, Peter F., Gregersen, Hans M., DeBano, Leonard F., Magner, Joseph, Verry, E.S., Isebrands, Jud, Wyse, Donald, Tolbert, Virginia, Baskfield, P.J., Kaster, A.R., Perry, C.H., Lu, S.Y., Christner, William, Christopherson, Jeff, Fall, Ahmed, Kaster, Anthony, Quinn, Robert, Rorer, Michelle, Shank, Brett, Wall, Scott, Miller, Ryan, Nguyen, Luke, Robinson, Dale

Dean A. Current

Program Director
CINRAM
University of Minnesota

Office (612) 624-4299
FAX (612) 625-5212
E-Mail: curre002@umn.edu

PROFESSIONAL PREPARATION

2000	Ph.D. Natural Resource Economics	University of Minnesota
1997	M.A. Anthropology	University of Minnesota
1985	M.S. Forest Economics	University of Minnesota
1975	B.S. Forest Management	University of Missouri

APPOINTMENTS

Sept, '02 – Present: Program Director – Center for Integrated Natural Resource and Agricultural Management (CINRAM) College of Food Agriculture and Natural Resource Sciences - University of Minnesota

- Managing a portfolio of interdisciplinary projects involving University researchers, local watershed groups, state and federal agency representatives as well as international researchers and organizations dealing with market-based approaches to integrated watershed management for environmental and economic benefits as well as market based approaches to forest and ecosystem conservation.

- CINRAM and its University and outstate partners have been awarded a total of approx. $3,000,000 in funding from Federal, State and International funding sources since 2002.

- Memorandum of Understanding between the University of Minnesota and the Tropical Agricultural Center for Research and Higher Education in Costa Rica. MOU has resulted in the preparation of a joint course and a funded Pilot Watershed Management project.

- Teaching "Role of Natural Resources in Sustainable International Development" as well as a 2 week course in Costa Rica entitled "Emerging Issues in Tropical Agriculture and Forestry".

- Coordinated two projects with the North American Commission for Environmental Coordination: 1) "The potential market and market and certification mechanisms for palms of the Genus Chamaedorea (Xate) in North America"; and 2) "Market mechanisms to promote the adoption of lead-free pottery in Mexico.

July '01-Oct. '01: Consultant – Programme for Belize – Evaluation of Conservation based forestry projects in Belize, Southern Mexico and the Peten of Guatemala

Feb. '01-Mar. '01: Consultant – USDA-USAID – Hurricane Mitch Reconstruction Project – Policy analysis and review

Oct. '00-Mar. '01: Consultant – Irland Group Minnesota Forest Resource Council study on information adequacy and needs in the Minnesota Forest Sector

June '97-Dec. '99: Project Leader – Center for International Forestry Research C(IFOR)-CATIE Secondary forest management in Humid Tropical Lowlands Project. (Brazil, Nicaragua and Perú).

REFEREED PUBLICATIONS AND REPORTS

Gregory A. O'Neill, I. Dawson, C. Sotelo-Montes, L.Guarino, M. D. Current, and J. C. Weber. 2001. Strategies for genetic conservation of trees in the Peruvian Amazon.. Biodiversity Conservation 10 pp. 837-850.

Scherr, S. and Dean Current. 1999. Incentives for Agroforestry Development:Experience in Central America and the Caribbean. In Enters, T. 1999. Incentives in Soil Conservation.

Smith, Nigel, Jean Dubois, Dean Current, Ernst Lutz, and Charles Clement. 1998. Agroforestry Experiences in the Brazilian Amazon: Constraints and Opportunities. Pilot Program to Conserve the Brazilian Rain, Brasilia, Brazil.

Current, Dean. 1997. ¿Los sistemas agroforestales generan beneficios para las cominidades rurales? Resultados de una investigacion en America Central y el Caribe. Agroforesteria en las Americas 4(16).

Scherr, Sara and Dean Current. 1997. What makes agroforestry profitable for farmers? Evidence from Central America and the Caribbean. Agroforestry Today 9(4):10-15.

Current, Dean, Ernst Lutz and Sara Scherr (Eds.). 1995. Costs, Benefits and Farmer Adoption of Agroforestry: Project Experience in Central America and the Caribbean. World Bank Environment Paper Number 14. Washington, D.C.: World Bank. 212 p.

SYNERTISTIC ACTIVITIES

Dr. Current is a Natural Resource Economist with training in Anthropology. He has coordinated region wide projects in Central America which included development of methodology and training of consultants for data gathering related to the costs and benefits and adoption of agricultural and agroforestry systems. He contintues his work on social and economic dimensions of technology adoption in Minnesota and the Upper Midwest. He has extensive experience working on and coordinating interdisciplinary teams in the US as well as overseas.

COLLABORATORS & OTHER AFFILIATIONS

Collaborators and co-authors:

Dr. Kenneth Brooks, Forest Hydrologist, UMN, Dr. K. William Easter, Natural Resources Economist, UMN, Dr. Michelle Schoeneberger, National Agroforestry Center, Dr. Donald Wyse, Agronomy and Plant Genetics, UMN, Dr. Craig Sheaffer, Agronomy and Plant Genetice, UMN, Dr. Roger Ruan, Biosystems and Agricultural Engineering, UMN, Dr. Paul Chen, Biosystems and Agricultural Engineering, UMN, Dr. Driss Enaany, Hydrologist, University of Arkansas, Dr. Michael Demchik, Silviculturalist, Uninveristy of Wisconsin, Stevens Point, Dr. Jeffrey Jones, GIS Specialist, Tropical Agricultural Center for Research and Higher Education, Turrialba, Costa Rica, Dr. Thomas Burk, Forest Management Information Systems, UMN, Dr. Lee Froelich, Forest Ecologist, UMN, Dr. Roy Rich, Forest Ecologist, UMN, Dr. James Anderson, Soil Scientist, UMN, Dr. Stephen Polasky, Ecological Economics, UMN, Dr. Ed Nader, Soil Scientist, UMN, Dr. Gregg Johnson, Souther Research and Outreach Center, UMN, Dr. Joseph Magner, Minnesota Pollution Control Agency, Dr. Diomides Zamora, Agroforester and Bioenergy Extension Specialist, UMN, Dr. Hans Jung, USDA/ARS, UMN, Dr. David Zumeta, Minnesota Forest Resources Council, Dr. Jeffrey Gillman, Horticulture, UMN

Thesis Advisees: At the University of Minnesota:

Dalia Abbas, PhD Candidate, RaeLynn Jones-Loss- MS , AnnaLisa Holtebeck-MS, Alex Gehrig-MS, Cordelia Eastridge-MS, Jeri Peck-PhD – Committee member

4.2.1.1.1.1 PROFESSIONAL ORGANIZATIONS & ACTIVITIES

- Current President, Association for Temperate Agroforestry
- Soil and Water Conservation Society
- NRCS State Technical Committee
- Minnesota SARE Advisory Committee
- Rock-Tenn BioEnergy Advisory Committee
- WesMin RC&D Productive Conservation Technical Advisory Committee
- Guest Editor, Special Edition of Agroforestry Systems, Springer

Linda Meschke

President and Founder, Rural Advantage
1243 Lake Avenue, Suite 222
Fairmont, Minnesota 56031
507.238.5449 Phone
507.238.4002 Fax
linda@ruraladvantage.org

Employment:

2003 – Present	**President,** Rural Advantage I formed Rural Advantage, a MN nonprofit corporation with 501[c][3] status, to continue my work with water quality, 3rd Crops and rural vitality. Through Rural Advantage I am interested in working on initiatives that enhance the interconnections of agriculture, the environment and rural communities.
2007 to Present	Martin Soil and Water Conservation District [SWCD] Supervisor
1996 – 2006	**Executive Director**, Blue Earth River Basin Initiative [BERBI] Responsibilities included administration of the organization under the direction of a five member Board of Directors; the development of new and innovative projects; collaborating with project partners; securing funding for a variety of projects; and coordinating and implementing all projects. In 2006, BERBI received the statewide Minnesota Environmental Initiative Award for Innovation and Partnership in Land Use for their 3rd Crop Initiative. I have been involved in securing over $4,500,000 in grant funding and reduced the pollution loading from the Blue Earth River System, to the Minnesota River system, by an estimated 9% through my work with BERBI. BERBI ended in 2006.
1980 – 2005	**Farm Partner** in 540 acre Crop/ Livestock operation in Martin County raising corn, soybeans, swine, beef and hay.
1988 – 1997	**Agricultural Inspector/ Water Planner/ Wetland Administrator**, Martin County, Minnesota
1985 – 1989	**Loan Servicing**, Farmers Home Administration, Fairmont, Minnesota
1978 – 1983	**Vocational Agriculture Instructor and FFA Advisor**, Fairmont High School, Fairmont, Minnesota

Education:

Graduate School [18 Credits toward] University of Minnesota- St. Paul
Masters of Science in Vocational Technical [Agricultural] Education

Bachelor of Science – Agricultural Education
University of Wisconsin – River Falls 1978

Associate of Applied Science Degree- Meat/ Poultry Science
University of Minnesota- Crookston 1976

Leadership Activities/ Recognition:

2005 -- 2008 1992 – 1998	University of Minnesota Southern Research and Outreach Center -- Waseca, Advisory Committee Member
2005 – 2006 Pre 2005	President, Soil and Water Conservation Society, Minnesota Chapter Commendation Award, Local Arrangements Committee – 2004 International SWCS Conference, Southern Rep, Membership Committee
1998 – Present	Coalition for a Clean Minnesota River [CCMR] – Board Member
1999 – Present	Water Management Advisory Committee, University of Minnesota Southern Research and Outreach Center, Waseca, Minnesota
2003 – Present 1999-	Minnesota Rural Futures Board of Directors Minnesota Rural Futures "Futures" Award
1993 – 2003	Alternate Member of the State Pesticide Applicator Education and Examination Review Board
1996-	Minnesota Water Planner of the Year
1983 – 1996	Master Gardener Volunteer
1989 – 1992	Minnesota State Horticultural Society Board

Activities/ Membership:
Soil and Water Conservation Society
21 Year 4-H Adult Leader
Fairmont Area Chamber of Commerce
Madelia Chamber of Commerce
Minnesota Agri-Growth
American Association of University Women, Fairmont Branch
First Congregational Church United Church of Christ, Fairmont
Heritage Acres [Agricultural Heritage]
Martin County Historical Society
Martin County Preservation Association

CRAIG C. SHEAFFER

Professor, Department of Agronomy and Plant Genetics. Appointment 65% Research 35% Teaching

Education

B.S.	Agronomy	Delaware Valley College, 1971
M.S.	Agronomy	University of Maryland, 1974
Ph.D.	Agronomy	University of Maryland, 1977

Appointments

Assistant Professor, University of Minnesota, 1977-1982
Associate Professor, University of Minnesota, 1982-1986
Professor, University of Minnesota, 1986-present

Graduate School Appointment(s):

Agronomy Graduate Program: 1977- present; Sustainable Agriculture Systems: 1996-present.

Number of APS Graduate Students Advised to Degree completion: 4 M.S.
Current number of APS advisees: 3 M.S.,

Overview of Research and Teaching program.

Research is on the use of perennial native and introduced legumes, grasses, and woody species as biofuels. Research is being conducted on crop rotations, legume management, cover cropping, and legume-grass polycultures. This research also includes measurement of the impact of perennials on water quality and soil erosion. My teaching responsibilities include: an introductory crops course for majors and non-majors (Crops Environment and Society), a graduate level course on sustainable agriculture (Issues in Sustainable Agriculture), and an introductory course on horse management for non-majors (Horse in Your Backyard). I also participate in outreach education programs on forages management.

Awards:

Crop Science Society of America - Young Crop Scientist Award, 1985
American Forage and Grassland Council - Merit Certificate, 1986
Northrup King Outstanding Education Award, 1987
American Society of Agronomy, Fellow, 1994
Crop Science Society of America, Fellow, 2000
College Agric., Food, & Environ. Sci., Distinguished Teaching Award, 2005

Significant Scholarly contributions:

Seguin, P. A.F. Mustafa, and C.C. Sheaffer. 2002. Effects of soil moisture deficit on forage quality, digestibility and protein fractionation of kura clover. J. Agron. & Crop Sci. 188: 260-266.

Seguin, P., C.C. Sheaffer, M.A. Schmitt, M.P. Russelle, G.W. Randall, P.R. Peterson, T.R. Hoverstad, S.R. Quiring, and D.R. Swanson. 2002. Alfalfa autotoxicity: effects of reseeding delay, original stand age, and cultivar. Agron. J. 94:775-781.

DeHaan, R.L., C.C. Sheaffer, D.A. Samac, J.M. Moynihan, and D.K. Barnes. 2002. Evaluation of annual medicago for upper Midwest agroecosystems. J. Agron. and Crop Sci. 188:417-425.

DeHaan,L.R., N.J. Ehlke, C.C. Sheaffer, R.L. DeHaan, and D.L. Wyse. 2003. Evaluation of diversity among and within accessions of Illinois bundleflower. Crop Sci. 43:1528-1537.

Byun, J. C.C. Sheaffer, M.P. Russelle, N.J. Ehlke, D.L. Wyse, and P.H. Graham. 2004. Dintirogen fixation in Illinois bundleflower. Crop Sci. 44:493-500.

Halgerson, J.L.,C.C. Sheaffer, N.P. Martin, P.R. Peterson, and S.J. Weston. 2004. Near-infrared reflectance spectroscopy prediction of leaf and mineral concentration in alfalfa. Agron. J. 96:344-351.

Jung, H.G., and C.C. Sheaffer. 2004. Influence of Bt transgenes on cell wall lignification and digestibility of maize stover for silage. Crop Sci. 44:1781-1789.

Sulc, R. M., K.D. Johnson, C.C. Sheaffer, D.J. Undersander, and E. van Santen. 2004. Forage quality of potato leafhopper resistant and susceptible alfalfa cultivars. Agron. J. 96:377-343.

Sheaffer, C. C., N. J. Ehlke, D. L. Wyse, D. J. Vellekson, D. R. Swanson and J. L. Halgerson. 2004. Forage yield and nutritive value of selected quackgrass. Forage and Grazinglands. Online. doi:10.1094/FG-2004-03XX-01-RS.

Cuomo, G.J., M.V. Rudstrom, P.R. Peterson, D.J. Johnson, A. Singh, and C.C. Sheaffer. 2005. Initiation date and nitrogen rate for stockpiling smooth bromegrass in the north central USA. Agron. J. 97: 1194-1201.

Fischbach, J.A., P.R. Peterson, C.C. Sheaffer, N.J. Ehlke, J. Byun, and D.L. Wyse. 2005. Illinois bundleflower forage potential in the upper Midwestern USA: I. Yield, regrowth, and persistence. Agron. J. 97: 886-894.

Fischbach, J.A., P.R. Peterson, N.J. Ehlke, D.L. Wyse, and C.C. Sheaffer. 2005. Illinois bundleflower forage potential in the upper Midwestern USA: II. Forage quality. Agron. J. 97: 895-903.

Laberge, G., P. Seguin, P.R. Peterson, C.C. Sheaffer, and N.J. Ehlke. 2005. Forageyield and species composition in years following Kura clover sod-seeding into grass awards. Agron. J. 97: 1352-1360.

Laberge, G., P. Seguin, P.R. Peterson, C.C. Sheaffer, N.J. Ehlke, G.J. Cuomo, and R.D. Mathison. 2005. Establishment of kura clover no-tilled into grass pastures with herbicide sod suppression and nitrogen fertilization. Agron. J. 97:250-256.

Lamb, J.F.S., C.C. Sheaffer, L.H. Rhodes, R.M. Sulc, D.J. Undersander, and E.C. Brummer. 2006. Five decades of alfalfa cultivar improvement: impact on forage yield, persistence, and nutritive value. Crop Sci. 46:902-909.

Sheaffer, C.C., J.L. Halgerson, and H.G. Jung. 2006. Hybrid and N fertilization affect corn silage yield and quality. J. Agron. & Crop Sci. 192:1-6.

DeHann, L.R., N.J. Ehlke, C.C. Sheaffer, D.L. Wyse, and R.L. DeHaan. 2006. Evaluation of diversity among North American accessions of false indigo (Amorpha fruticosa L.) for forage and biomass. Genetic Resources and Crop Evolution 1573-5109.

BIOGRAPHICAL SKETCH

Carl J. Rosen
Professor
Department of Soil, Water, and Climate
University of Minnesota
St. Paul, MN 55108
crosen@umn.edu, 612-625-8114

Education and Training

Degree	Major	Institution	Year
Ph.D.	Soil Science	University of California, Davis	1983
M.S.	Horticulture	Pennsylvania State University	1978
B.S.	Horticulture	Pennsylvania State University	1976

Professional Experience

My research focus is on improving nutrient management and nutrient use efficiency in a variety of crops with particular emphasis on nitrogen management. Major efforts in recent years have also focused on land application and beneficial use of municipal and industrial waste products for agricultural use.

1995-present	Professor, University of Minnesota, Dept. of Soil Water, and Climate
1989-95	Associate Professor, University of Minnesota, Dept. of Soil Science
1983-89	Assistant Professor, University of Minnesota, Dept. of Soil Science

Publications with relevance to the project

Zvomuya, F., C. J. Rosen, and S.C. Gupta. 2006. Phosphorus sequestration by chemical amendments to reduce P leaching from wastewater applications. J. Environ. Qual. 35:207-215.

Zvomuya, F., C. J. Rosen, and S.C. Gupta. 2006. Nitrogen and phosphorus leaching from growing season vs. year-round application of wastewater on seasonally frozen lands. J. Environ. Qual. 35:324-333.

Mozaffari, M., M. P. Russelle, C. J. Rosen, and E.A. Nater. 2002. Nutrient supply and neutralizing value of alfalfa stem gasification ash. Soil Sci Soc. Amer. J. 66:171-178.

Mozaffari, M., C.J. Rosen, M.P. Russelle, and E.A. Nater. 2000. Chemical characterization of gasified alfalfa stem ash: Implications for ash management. J. Environ. Qual. 29:963-972.

Mozaffari, M., C.J. Rosen, M.P. Russelle, and E.A. Nater. 2000. Corn and soil response to application of ash generated from gasified alfalfa stems. Soil Science 165:896-907.

Mamo, M., C.J. Rosen, and T.R. Halbach. 1999. Nitrogen availability and leaching in soil amended with municipal solid waste compost. J. Environ. Qual. 28:1074-1082.

Mozafarri, M., C. Rosen, M. Russelle, and E.Nater. 1998. Developing agricultural uses for byproducts of energy production from biomass: The Minnesota experience. Proceedings: BioEnergy 98: Expanding BioEnergy Partnerships Conference, Madison, WI. pp. 168-177.

Bierman, P.M., C.J. Rosen, P.R. Bloom, and E.A. Nater. 1995. Soil solution chemistry of sewage sludge incinerator ash and phosphate fertilizer amended soil. J. Environ. Qual. 24:279-285.

Bierman, P.M. and C.J. Rosen. 1994. Phosphate and trace metal availability from sewage sludge incinerator ash. J. Environ. Qual. 23:822-830.

Rosen, C.J., P.M. Bierman, D. Olson 1994. Swiss chard and alfalfa responses to soils amended with municipal solid waste incinerator ash: growth and elemental composition. J. Agric. Food Chem. 42:1361-1368.

Donald L. Wyse

Professor
Department of Agronomy and Plant Genetics
University of Minnesota, St. Paul, Minnesota, 55108
wysex001@umn.edu, 612 625 7064

Education and Training

The Ohio State University, 1970, B.S., Agronomy
Michigan State University, 1972, M.S., Crop Science (Weed Science)
Michigan State University, 1974, Ph.D., Crop Science (Weed Science)

Professional Experience

Director, Minnesota Institute for Sustainable Agriculture, Univ. of Minnesota, 1992-2000
I was the founding Executive Director for MISA and provided leadership for the program for 8 years. MISA is a joint venture between the University of Minnesota and the sustainable agriculture community and facilitates research and education programs to enhance the sustainability of agriculture.
Professor, Department of Agronomy and Plant Genetics, Univ. of Minnesota, 1986-present
I lead a research program that focuses on the development of diversified agricultural systems that are productive and support ecosystem services. My research has focused on perennial crop breeding and selection, management of invasive species, biological weed management, native plant seed production, plant biochemistry, and perennial cropping system design.
Associate Professor, Department of Agronomy and Plant Genetics, Univ. of Minnesota, 1980-1986
Assistant Professor, Department of Agronomy and Plant Genetics, Univ. of Minnesota, 1974-1980

Publications

Byun, J., C.C. Sheaffer, M.P. Russelle, N.J. Ehlke, D.L. Wyse, and P.H. Graham. 2004. Dinitrogen fixation in Illinois bundleflower. Crop Sci. 44: 493-500.

Sheaffer, C. C., N. J. Ehlke, D. L. Wyse, D. J. Vellekson, D. R. Swanson and J. L. Halgerson. 2004. Forage yield and nutritive value of selected quackgrass. Forage and Grazinglands. Online. doi:10.1094/FG-2004-03XX-01-RS.

Grossman, J.M., C.C. Sheaffer, D. Wyse, and P.H. Graham. 2005. Characterization of slow-growing root nodule bacteria from *Inga oerstediana* in organic coffee agroecosystems in Chiapas, Mexico. Appl. Soil Ecol. 29: 236-251. On-line. doi:10.1016/j.apsoil.2004.12.008

Grossman, J.M., C. C. Sheaffer, D. Wyse, B. Bucciarelli, C. Vance, P.H. Graham. 2005. An assessment of nodulation andnitrogen fixation in inoculated Inga oerstediana, a nitrogen-fixing tree shading organic grown in Chiapas, Mexico. Soil Biology & Biochemistry 20:1-16.

Wiersma, J., C. Sheaffer, G. Nelson, D. Wyse, and K. Betts. 2005. Intercropping legumes in hard red spring wheat under semi-arid conditions. Plant management network: Crop Management doi:10.1094/CM-2005-0119-01-RS.

Fischbach, J.A. P.R. Peterson, C.C. Sheaffer, N.J. Ehlke, J. Byun, and D.L. Wyse. 2005. Illinois bundleflower forage potential in the upper Midwestern USA: I. Yield, regrowth, and persistence. Agron.

J. 97: 886-894.

Fischbach, J.A., P.R. Peterson, N.J. Ehlke, D.L. Wyse, and C.C. Sheaffer. 2005. Illinois bundleflower forage potential in the upper Midwestern USA: II. Forage quality. Agron. J. 97: 895-903.

Mercer, K.L., D.L. Wyse, R.G. Shaw. 2006. Effects of competition on the fitness of wild and crop-wild hybrid sunflower from a diversity of wild populations and crop lines. Evolution 60:2044-2055.

Mercer, K.L., R.G. Shaw, D.L. Wyse. 2006. Increased germination of diverse crop-wild hybrid sunflower seeds. Ecological Applications 16:845-854.

Chen, S., D.L. Wyse, G.A. Johnson, P.M. Porter, S.R. Stetina, D.R. Miller, K.J. Betts, L.D. Klossner, and M.J. Haar. 2006. Effect of cover crops alfalfa, red clover, and perennial ryegrass, on soybean cyst nematode population and soybean and corn yields in Minnesota. Crop Sci. 46:1890-1897.

Miller, D.R., S.Y. Chen, P.M. Porter, G.A. Johnson, D.L. Wyse, S. R. Stetina, L.D. Klossner, and G. A. Nelson. 2006. Rotation crop evaluation for management of the soybean cyst nematode in Minnesota. Agron. J. 98:569-578

Synergistic Activities

I initiated the development of the University of Minnesota Regional Agricultural and Natural Resources Sustainable Development Partnership Program. In this program we have developed settings for social learning on a community-to-regional scale, through a statewide network of five regional sustainable development partnerships. Each is working in a predominantly rural region, and therefore, natural resource-based livelihoods, such as those in agriculture, are central concerns of all of the partnerships. This program will allow us to experiment with methods for convening citizens for the purpose of critically assessing sustainable development in their regions, defining unmet needs for knowledge and action, and organizing regional and statewide resources that can meet these needs. The program is currently providing leadership for community based renewable energy programs state wide.

I organized a multi-college program entitled the Landscape, Human, and Animal Health Initiative. This integrated approach to landscape, human and animal health will create new opportunities in health, veterinary, crop and livestock sciences, while promoting ecological and socioeconomic sustainability. The University faculty that have organized themselves around this program believe that agriculture can contribute greatly to our commonwealth by providing for the health of landscapes and their inhabitants. The cultivation and sustenance of biodiversity provides a guidepost for all of agriculture as it works to fulfill its promise; and for the public universities as they strive to aid that work. I am completely committed to supporting the development of a process for critical thinking about what forms of social organization will help us improve agriculture in an environment of complexity.

ABBREVIATED CURRICULUM VITAE

TODD W. ARNOLD

Associate Professor — Department of Fisheries, Wildlife and Conservation Biology
University of Minnesota — Phone: (612) 624-2220
St. Paul, MN 55108 — E-mail: arnol065@umn.edu

EDUCATION

Ph.D. in Zoology, University of Western Ontario, London, ON, Canada, December 1990. Dissertation: *Food limitation and the adaptive significance of clutch size in American Coots* (Fulica americana). Supervisor: Dr. Dave Ankney.

M.Sc. in Wildlife, University of Missouri—Columbia, August 1986, Thesis: *The ecology of prairie mink during the waterfowl breeding season.* Supervisor: Dr. Erik Fritzell.

B.Sc. in Fisheries and Wildlife, with high distinction, University of Minnesota, March 1983.

EMPLOYMENT

Associate Professor, Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul, Minnesota. Sept 2002 – May 2006 (Assistant); May 2006 – present (Associate).

Senior Scientist; Institute for Wetland and Waterfowl Research, Ducks Unlimited Canada, Stonewall, MB; Nov 1999—Aug 2002.

Scientific Director; Delta Waterfowl Foundation, Portage la Prairie, MB; Sept 1997—Oct 1999.

Assistant Professor of Wildlife Management; Humboldt State University, Arcata, CA; Sept 1994 to Aug 1997.

Post-doctoral Investigator; Institute for Wetland and Waterfowl Research, Stonewall, MB; Jan 1993 to Aug 1994.

Post-doctoral Fellowship; Natural Science and Engineering Research Council of Canada, Canadian Wildlife Service, and The University of Saskatchewan; 1991-1992.

GRANTS (last 5 years)

2006: *Effects of competition and predation on survival of mallard ducklings*. Delta Waterfowl Foundation, $205,000.
2006: *Estimating sightability for waterfowl pair and brood counts*. Delta Waterfowl Foundation, $31,760.
2006: *Effects of competition and predation on survival of mallard ducklings*. University of Minnesota Grant-in-Aid of Research, Artistry and Scholarship, $17,992.
2005: *New Techniques for Assessing Productivity of Prairie-nesting Waterfowl*, UMN Agricultural Experiment Station, $58,000.
2005: *Impact of Helminthic Parasites on Parental Body Condition and Chick Mortality in American Coots*, Delta Waterfowl Foundation, $20,000.
2003: *Mallard Brood Movements and Habitat Selection*, Ducks Unlimited Canada, $40,000.
2003: *Prairie Habitat Joint Venture Assessment Study*, Ducks Unlimited Canada, $10,000.

PROFESSIONAL SERVICE

Journal of Wildlife Management – Associate Editor, waterfowl ecology, 2007-2009
Scientific Program Committee, 4th North American Duck Symposium, Bismarck, ND; 2006.

Chair, Scientific Program Committee, Cooper Ornithological Society, La Crosse, WI, 2004.
Chair, Student Awards, 3rd North American Duck Symposium, Sacramento, CA; 2003.

PROFESSIONAL SOCIETIES

American Ornithologists' Union (since 1984)
Cooper Ornithological Society (since 1984)
The Wildlife Society (since 1982)

PUBLICATIONS (last 5 years)

Arnold, TW, LM Craig-Moore, LM Armstrong, DW Howerter, JH Devries, BL Joynt, RB Emery, and MG Anderson. 2007. Waterfowl use of dense nesting cover in the Canadian Prairie Parklands. Journal of Wildlife Management 71(8): *in press.*

Raven, GH, **TW Arnold**, DW Howerter, and LM Armstrong. 2007. Mallard brood movements in the Canadian Prairie Parklands. Prairie Naturalist 39:1-13.

Raven, GH, **TW Arnold**, DW Howerter, and LM Armstrong. 2007. Wetland selection by mallard broods in the Canadian prairie parklands. Journal of Wildlife Management 71(8): *in press*.

Arnold, TW, and AJ Green. 2007. On the allometric relationship between egg size and composition of avian eggs: a reassessment. Condor 109 (3): *in press*.

Chouinard, MP, Jr. and **TW Arnold.** 2007. Survival and habitat use of Mallard broods in the San Joaquin Valley, California. Auk 124 (3): *in press*.

Carroll, LC, **TW Arnold**, and JA Beam. 2007. Effects of rotational grazing on nesting ducks in California. Journal of Wildlife Management 71: 902-905.

Brasher, MG, **TW Arnold**, JH Devries, and RM Kaminski. 2006. Breeding-season survival of male and female mallards in Canada's prairie-parklands. Journal of Wildlife Management 70: 805-811.

Wells, AM, HH Prince, and **TW Arnold**. 2005. Incubation length in dabbling ducks. Condor 107: 928-931.

Martin, PA, **TW Arnold**, and RJ Forsyth. 2005. Use of agricultural fields by birds during canola planting in Saskatchewan: potential for exposure to pesticides. Canadian Wildlife Service Technical Report Series No. 358.

McPherson, R, **TW Arnold**, L Armstong, and CJ Schwartz. 2003. Estimating the number of nests initiated by radiomarked mallards. Journal of Wildlife Management 67:843-851.

Arnold, TW, MG Anderson, MD Sorenson, and RB Emery. 2002. Survival and philopatry of female redheads breeding in southwestern Manitoba. Journal of Wildlife Management 66: 162-169.

Arnold, TW, DW Howerter, JH Devries, MG Anderson, BL Joynt, and RB Emery. 2002. Continuous laying in mallards. Auk 119: 261-266.

Biographical sketch - SANGWON SUH

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(a) Professional Preparation

Ajou University (S. Korea)	Environmental and Engineering	B.S.	1998
Ajou University (S. Korea)	Environmental and Urban Systems Eng.	M.S.	2000
Leiden University (Netherland)	Environmental Science and Engineering	Ph.D.	2004
Carnegie Mellon University	Industrial Ecology	Postdoc	2005

(b) Appointments

08/05 – present	Assistant Professor, Dept. Bioproducts and Biosystems Engineering, College of Food, Agriculture and Natural Resources Science, University of Minnesota.
08/04 – present	Associate Fellow, Institute of Environmental Sciences (CML), Leiden University, the Netherlands (Dept. Industrial Ecology)
08/04 – 07/05	Postdoctoral Research Associate, Civil and Environmental Engineering, Carnegie Mellon University (supported by BE: MUSES program)
01/02 – 06/04	Research Scientist, Dept. Industrial Ecology, Institute of Environmental Sciences (CML), Leiden University, the Netherlands

(c) Publications (For the last five years, > 30 journal articles and 2 books)

5 most closely related to the proposed project

Hawkins, T., C. Hendrickson, C. Higgins, H. S. Matthews, S. Suh, **2007**: A Mixed-Unit Input-Output Model for Environmental Life-Cycle Assessment and Material Flow Analysis, *Environmental Science and Technology*, 41 (3), 1024-1031.

Suh, S., **2006**: Are Services Better for Climate Change? *Environmental Science and Technology*, 40 (21), 6555 – 6560.

Suh, S., Huppes, H., **2005**: Methods in Life Cycle Inventory (LCI) of a product, *Journal of Cleaner Production*, 13 (7), 687 – 697.

Suh, S., M. Lenzen, G. Treloar, H. Hondo, A. Horvath, G. Huppes, O. Jolliet, U. Klann, W. Krewitt, Y. Moriguchi, J. Munksgaard, G. Norris, **2004**: System Boundary Selection for Life Cycle Inventories, *Environmental Science & Technology*. 38 (3), 657 – 664.

Suh, S., **2004**: Functions, commodities and environmental impacts in an ecological economic model, *Ecological Economics*, 48 (4), 451 – 467.

5 other significant publications

Huppes, G., A. de Koning, S. Suh, R. Heijungs, L. van Oers, P. Nielsen, J.B. Guinée, **2006**: Environmental impacts of consumption in the European Union using detailed input-output analysis, *Journal of Industrial Ecology*, 10 (3), 129 – 146.

Suh, S., **2005**: Developing Sectoral Environmental Database for Input-Output Analysis: Comprehensive Environmental Data Archive of the U.S., *Economic Systems Research*, 17 (4), 449 – 469

Suh, S., **2005**: Theory of Materials and Energy Flow Analysis in Ecology and Economics, *Ecological Modeling*, 189 251 – 269.

Guinée, J.B., M. Gorrée, R. Heijungs , G. Huppes, R. Kleijn, A. de Koning, L. van Oers, A. Wegener Sleeswijk, S. Suh, H.A. Udo de Haes, H. de Bruijn, R. van Duin, M.A.J. Huijbregts, **2002**: *Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards.* Kluwer Academic Publisher, Dordrecht, The Netherlands.

Heijungs, R., Suh, S., **2002**: *The Computational Structure of Life Cycle Assessment*, Springer, Dordrecht, the Netherlands.

(d) Synergistic Activities

Associate Editor, International Journal of Life Cycle Assessment (LCA)

Since 2003, Sangwon Suh is serving as an associate editor of the International Journal of Life Cycle Assessment, the only journal wholly dedicated to the advancement of science and practice of LCA.

United Nations' Environmental Program / Life Cycle Initiative activities

UNEP's life cycle initiative is currently the largest international organization on LCA since TC207 of ISO. The initiative aims at harmonizing LCA methods and data, building capacity for developing world and disseminating life-cycle thinking. Sangwon Suh is among a dozen appointed members of TF3 and TF5, which are responsible for LCI methodological consistency and LCA capacity building, respectively.

Developing public LCA databases

Sangwon Suh has developed CEDA/MIET databases ver. 1.0, 2.0 and 3.0 from 2000 to 2005. CEDA/MIET is a Life Cycle Inventory (LCI) database for the U.S. that utilizes a comprehensive list of environmental statistics and the U.S. input-output table. It contains information on 1344 environmental interventions generated by 500 industry sectors and around 100 different Life Cycle Impact Assessment (LCIA) methods. The latest version of the database has been adopted by a number of commercial/non-commercial LCA software packages including SimaPRO 6 and CMLCA and is being used by thousands of LCA practitioners world-wide.

Services in professional organizations and committees

Sangwon Suh is active in various professional organizations and committees. Listed here are a selection of them that are relevant for the current proposal: Advisory Committee Member of the Eco-Industrial Development Council (EIDC) (2006 – present); an LCA Steering Committee Member of SETAC-Europe (2003 – 2006); an LCA Advisory Group Member of SETAC-North America (2005 – present); Award Committee Member of the International Society for Industrial Ecology (2007 – present); Technical Committee Member of the International Input-Output Association, Istanbul Conference (2007); Chair of the Input-Output Working Group, SETAC-Europe (2003 – 2006).

Invited speaker

Sangwon Suh has been invited by universities and conference organizers as a keynote or a seminar speaker nationally and internationally. Selected invited speaks: International Eco-Industrial Development Conference in Seoul, South Korea (2006); International Material Flow Analysis Workshop in Tokyo, Japan (2005); Yale University (2005); Carnegie Mellon University (2004); NATO Advanced Science workshop, Hungary (2004); Waseda University, Japan (2003); Institute of Advanced Technology (IST), Portugal (2003); Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland (2002); Norwegian Technical University in Trondheim (2003); University of Tokyo, Japan (2002).

(e) Collaborators & Other Affiliations

Collaborators and Co-editors Rokuta Inaba (U Hokkaido), Troy Hawkins (CMU), Chris Hendrickson (CMU), Cortney Higgins (CMU), Scott Matthews (CMU), Reinout Heijungs (CML), Gjalt Huppes (CML), Jeroen Guinee (CML), Helias Udo de Haes (CML), Arjan de Koning (CML), Rene Kleijn (CML), Ester van der Voet (CML), Lauren van Oers (CML), Ayman Elshkaki (CML), Ruben Huele (CML), Anneke Wegener Sleeswijk (CML), Arnold Tukker (TNO), Peter Eder (EC-JRC), Shigemi Kagawa (Kyushu Univ.), Manfred Lenzen (Sydney Univ.), Yuichi Moriguchi (NIES), Olivier Jolliet (UMich), Mark Huibregts (Nijmegen Univ.), Bo Weidema (LCA 2.-0 consultants), Per Nielsen (Univ. Copenhagen), Kun Lee (Ajou Univ.), Sangsun Ha (Samsung Semiconductor Ind.), Ignazio Mongelli (EC-JRC), Gerald Rebitzer (Alcan), Tomas Ekvall (Chalmers Univ.), Rolf Frischknecht (ESU-service), David Hunkeler (Aquatech), Gregory Norris (Sylvatica), Tomas Rydberg (EC), Peter Schmidt (Daimler-Chrysler), David Penington (EU-JRC); Graham Treloar (Deakin Univ.), Hiroki Hondo (Yokohama Univ.), Arpad Horvath (UC Berkeley), Uwe Klann (DRL), Wolfram Krewitt (DRL), Jesper Munksgaard (AKF), Leo Breedveld (EC-JRC), Erik Dietzenbacher (Univ. Groningen), Stefan Giljum (SERI), Klaus Hubacek (Univ. Leeds).

Graduate and Postdoctoral Advisors Kun Lee (Ajou), Gjalt Huppes (CML), Helias Udo de Haes (CML), Lester Lave (Carnegie Mellon), Chris Hendrickson (Carnegie Mellon), Scott Matthews (Carnegie Mellon).

Thesis Advisor and postgraduate-scholar sponsor Yiwen Chiu (UMN), Stephanie Potolka (UMN), Jin-Young Moon (UMN), Junghan Bae (UMN), Michael Wietecki (UMN), Lin Luo (CML).

K. WILLIAM EASTER

Professor of Applied Economics at the University of Minnesota

EDUCATION

B.S., Soil Science, University of California, Davis (1960)
M.S., Agricultural Economics, University of California, Davis (1961) Ph.D., Agricultural Economics, Michigan State University (1966)

EXPERIENCE

Resource Economist for the Bureau of the Budget, Executive Office of the President of the United States (1966-70)
Associate Professor, Department of Applied Economics, University of Minnesota (1970-75)
Worked in India on a University of Minnesota/Ford Foundation research project on rural development (1970-72) and member of the faculty of Agricultural and Applied Economics, University of Minnesota (1970-present)
Visiting professor, Tamil Nadu Agricultural University, India (1978)
Head of University of Minnesota/Colorado University/USAID project on water management and irrigation policy in India, Thailand, Egypt and Pakistan (1979-83)
Sabbatical leave at the East-West Center working on watershed management problems in Asia and the Pacific (1984-85)
Leave of absence from the University of Minnesota at the World Bank, Department of Agriculture and Natural Resources (1991- 93)
Director of Center for International Food and Agricultural Policy (1999-03)
Professor, Department of Applied Economics, University of Minnesota (1975 to present)

RESEARCH EMPHASIS

Water and land management problems and resource pricing and evaluation issues: economics of water management, impacts of soil erosion, both on downstream interests and on-farm productivity, managing groundwater pollution caused by agriculture, costs of municipal waste management, managing surface water pollution from nonpoint sources, non-metropolitan residential demand for municipal water quality improvement, and the effects of government policy on wetlands and water management.

TEACHING RESPONSIBILITIES

APEC 5651 - The economics of natural resource and environmental policy
APEC 3611 - Resource development and environmental economics
APEC 8901 - Graduate Seminar: MS Program

SELECTED PUBLICATIONS

Laura McCann and K. William Easter. "Differences between Farmer and Agency Attitudes Regarding Policies to Reduce Phosphorous Pollution in the Minnesota River Basin." *Review of Agricultural Economics* 21:1 (Summer 1999):189-207.

K. William Easter, M. W. Rosegrant and Ariel Dinar. "Formal and Informal Markets for Water: Institutions, Performance and Constraints." *The World Bank Research Observer* 14:1 (February 1999).

P. L. Brezonik, K. W. Easter, Lorin Hatch, David Mulla and James Perry. "Management of Diffuse Pollution in Agricultural Watersheds: Lessons from the Minnesota River Basin."

Water Science Tech. 39:12(1999):323-30.

Laura McCann and K. William Easter. "Transaction Costs of Policies to Reduce Agricultural Phosphorous Pollution in the Minnesota River." *Land Economics* 75:3(August 1999):404-44.

K. William Easter. "Asia's Irrigation Management in Transition: A Paradigm Shift Faces High Transaction Costs." *Review of Agricultural Economics* 22:2(2000):370-88.

Laura McCann and K. William Easter. "Estimates of Public Sector transaction Costs in NRCS Programs." *Journal of Agricultural and Applied Economics* 32:3(2000):555-63.

Lorin Hatch, A. Mallawatantri, D. Wheeler, A. Gleason, D. Mulla, 3. Perry, K. William Easter, R. Smith, L. Gerlach, and P. Brezonik. "Land Management in the Major Watershed-Agroecoregion Intersection." Journal *of Soil & Water Conservation* 56(1)(2001):44-51.

Cesare Dosi and K. William Easter. "Water Scarcity: Market Failure and the Implications for Markets and Privatization." *International Journal of Public Administration* 26(3)(2003):26590.

Leah Greden-Mathews, Frances R. Homans, and K. William Easter. "Estimating Water Quality Benefits by Combining Revealed and Stated Preference Methods: An Application in the Minnesota River." *J. Amer. Water Resources Assoc.* 38(5)(2002):1217-23.

J. V. Westra, K. William Easter and K. D. Olson. "Targeting Nonpoint Source Pollution Control: Phosphorus in the Minnesota River Basin." *Journal of the American Water Resources Association* 38(2)(2002):493-505.

Jim Perry and K. William Easter. "Resolving the Incompatibility Dilemma in River Basin Management." *Water Resources Research* 40 (2004).

Yongsung Cho, K. William Easter, Laura M. J. McCann and Frances Homans. "Are Rural Residents Willing to Pay Enough to Improve Drinking Water Quality?." *Journal of American Water Resources Association,* 2004, accepted for publication 2005.

Feng Fang, K. William Easter and P. L. Brezonik. "Point-Nonpoint Source Water Quality Trading: A Case Study in the Minnesota River." J. *Amer. Water Resources Assoc.,* accepted for publication in 2005.

K. William Easter and Yoshifumi Konishi. "What Are the Economic Health Costs of Nonaction in Controlling Toxic Water Pollution?" Published in *Journal of Water Resource Development* 22(4)(2006):529-41.

K. William Easter and Slim Zekri. "Estimating the Potential Gains from Water Markets: A Case Study from Tunsia." *Agricultural Water Management* 72(2005):161-75.

K. William Easter and Laura McCann. "Estimating the Transaction Costs of Alternative Mechanisms for Water Exchange and Allocation." *Water Resources Research* 40(9)(July), 2004.

COLLABORATORS/GRADUATE AND PROFESSIONAL ADVISEES

T. Burkhart, F. Homans, Don Wyse, Craig Scheaffer, D. Current, K. Brooks, S. Archibald, M. Demchik, M. Renwick, H. Plusquellec, A. Subramanian, K. Olson, D. Wheeler, A. Gleason, J. Westra, H, Gregersen , K. Palanisami, R. B. Smith, N. Zeitouni, A. Fang, N. Jordan, T. Boyer, R. Johansson, Y. Liu, X Zekri, P. Brezowik, B. Colby, R. Konishi, A. Kasterine, K. Kuperan,

4.3 Letters of support

- **Paul Kramer – Koda Energy, LLC**
- **Mark Lindquist – Minnesota Department of Natural Resources**
- **Linda Meschke – Rural Advantage**
- **James Harkness - Institute for Agriculture and Trade Policy**

4.4 Literature Cited

Arnold, G. W. 1983. The influence of ditch and hedgerow structure, length of hedgerows, and area of woodland and garden on bird numbers on farmland. Journal of Applied Ecology 20:731-750.

Best, L. B., K. E. Freemark, J. J. Dinsmore, and M. Camp. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. American Midland Naturalist 134:1-29.

Brooks, K.N., D. Current and D. Wyse. 2006. Restoring Hydrologic Function of Altered Landscapes: An Integrated Watershed Management Approach. Pp 101-114 in: Tennyson, L. And P.C. Zingari (eds.). *Water Resources for the Future*, Conference Proceedings, Porto Cervo, Sassari, Sardinia, Italy; 22-24 October, 2003, Watershed Management & Sustainable Mountain Development Working Paper 9, FAO, United Nations, Rome.

Ennaanay, D. 2006. Impacts of land use changes on the hydrologic regime in the Minnesota River basin. PhD Thesis. University of Minnesota, St. Paul.

Fletcher, R. J., Jr., R. R. Koford, and D. A. Seaman. 2006. Critical demographic parameters for declining songbirds breeding in restored grasslands. Journal of Wildlife Management 70:145-157.

International Bird Census Committee. 1969. Recommendations for an international standard for a mapping method in bird census work. Bird Study. 16:248–255

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96: 651- 661.

Johnson, R. G., and S. A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. Journal of Wildlife Management 54: 106-111.

Kirsch, L. M., H. F. Duebbert, and A. D. Kruse. 1978. Grazing and haying effects on habitats of upland nesting birds. Transactions of the 43rd North American Natural Resources Conference 43:486-497.

Leach J. and J. Magner. 1992. Wetland Drainage impacts within the Minnesota River Basin. Currents: A Minnesota River Valley Review, Vol. III, (2): 3-10.

Lenhart, C. 2007 (forthcoming) The influence of restored wetland-grassland complexes in mitigating peak flows and water quality of agricultural runoff in southern Minnesota. PhD Thesis, University of Minnesota.

Magner, J.A., G.D. Johnson and T.J. Larson. 1993. The Minnesota River Basin: Environmental impacts of basin-wide drainage. In: Eckstein and Zaporozek (ed.), *Industrial and Agricultural Drainage Impacts of the Hydrologic Environment*. Vol. 5:147-162, Water Environment Federation, Alexandria, VA.

Mickelson, D.L. 2001. The effect of agricultural tile drainage on flood events in the Minnesota River Basin. MS Thesis. University of Minnesota, St. Paul.

Miller, R.C. 1999. Hydrologic effects of wetland drainage and land use changes in a tributary watershed of the Minnesota River Basin: A modeling approach. MS Thesis, University of Minnesota, St. Paul.

Minnesota Pollution control Agency (MPCA). 1994. Minnesota River Assessment Project Report: Executive Summary, Report to the Legislative Commission on Minnesota River Resources.

Patterson, M. P., and L. B. Best. 1994. Bird abundance and nesting success in Iowa CRP fields: the importance of vegetation structure and composition. American Midland Naturalist 135:153-167.

Perrine, R. and Meschke L., 2006. Martin County Water Plan. Fairmont, Minnesota.

Quade, H. 2000. Blue Earth River Major Watershed Diagnostic Report. Blue Earth River Basin Implementation Framework. South Central Minnesota County, Comprehensive Water Planning Project. Joint Powers Board, Water Resources Center, Minnesota State University, Mankato.

Randall, G.W., Huggins, D.R, Russelle, M.P., Fuchs, D.J., Nelson, W.W., and Anderson, J.L.1997. Nitrate losses through subsurface tile drainage in Conservation Reserve Program, alfalfa, and row crop systems. Journal of Environmental Quality, 26:1240-1247.

Appendix D – Proposed Grant Contract Modification Form