United States
Department of
Agriculture

**Agricultural
Research
Service**

April 2012

The North Central Soil Conservation Research Laboratory

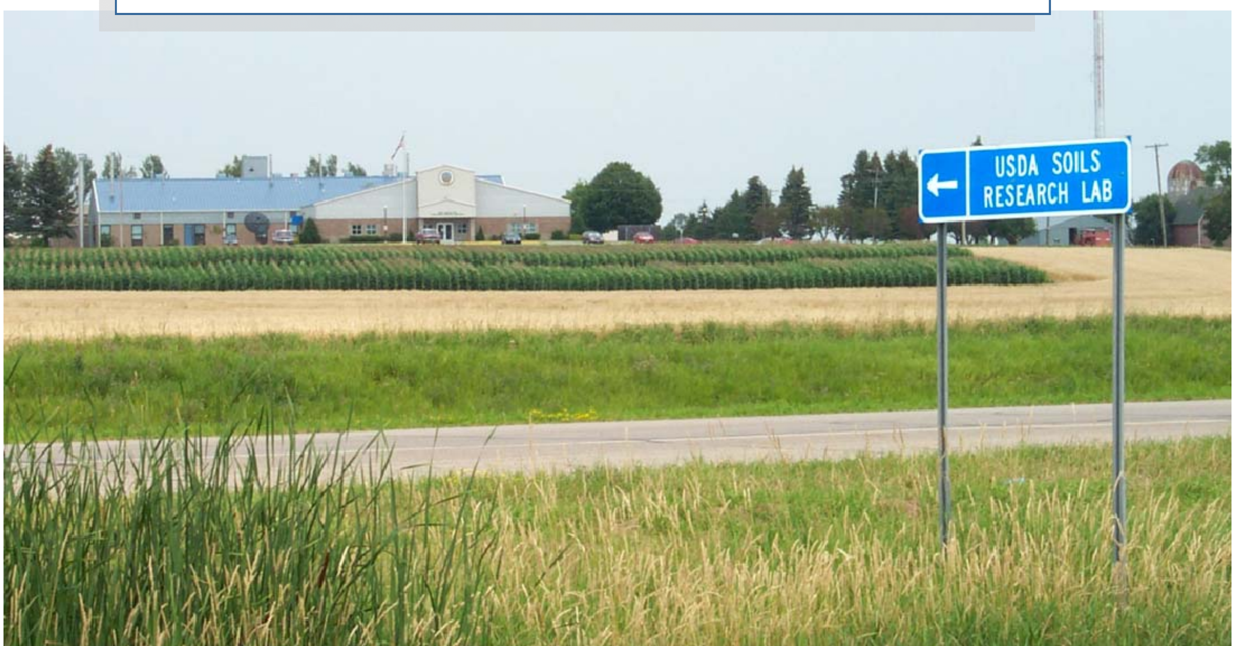
Research Report

U.S. Department of Agriculture - Agricultural Research Service
The North Central Soil Conservation Research Laboratory

ARS Mission

The Agricultural Research Service conducts research to develop and transfer solutions to agricultural problems of high national priority and provides information access and dissemination to:

- ensure high-quality, safe food and other agricultural products;
- assess the nutritional needs of Americans;
- sustain a competitive agricultural economy;
- enhance the natural resource base and the environment; and
- provide economic opportunities for rural citizens, communities, and society as a whole.



Lab Mission

The mission of the North Central Soil Conservation Research Laboratory is to enhance productive conservation of agricultural and natural resources base, improve environmental health, and contribute to national food security through diversified, competitive, and resilient agro-ecosystems in the upper Midwest.

Preface

Abdullah Jaradat
Research Leader

Research scientists and support staff at the North Central Soil Conservation Research Laboratory conducted research and provided services to the farming community and the nation in cooperation with stakeholders, national and international collaborators. During the past year, several developments resulted in new and diverse research outputs. Examples of these outputs are included in this report.

The successful Swan Lake Field Day highlighted on-farm research with farmer, private sector and ARS collaborators. The theme highlighted the ecosystem services provided by the new crops and management practices being developed at the Lab. Several of our collaborators and Lab scientists presented during the Field Day. George Boody, executive director of the Land Stewardship Project, presented on landscape diversity and multiple ecosystem services as a part of our joint Chippewa River Watershed Project. Christi Heintz, executive director of Project Apis m (Pam), a non-profit organization interested in bees, and Jeff Hull, a bee-keeper, along with Frank Forcella presented the benefits provided by new oilseed crops to maintain healthy and abundant bee populations and their economic importance. Bill Berguson, program director of Applied Forestry, University of Minnesota-Duluth, along with Sharon Weyers talked about the environmental and economic benefits of adding perennials to cropping systems. Mike Edgerton, Monsanto Technology Lead for corn ethanol quality traits, and Alex Dubish, USDA-Farm Service Agency, along with Jane Johnson spoke about the environmental and economic benefits of properly managed ethanol production from corn biomass. The day-long activities were attended by the local community and highlighted in the local press.

During the year, scientists and support staff were involved in a number of outreach activities, some of which are highlighted at the end of this report. The Lab's display at the Stevens County Fair, Community Connections Summit, West Central Research and Outreach Center (WCROC) and University of Minnesota-Morris (UMM) celebrations, WCROC Summer Field Day and WCROC Horticulture Night attracted hundreds of visitors who learned more about our research and role in advancing the rural economy.

The Lab's stakeholders continued to support the research and outreach program so that we could better serve our expanding and diverse customer base and chart the Lab's future direction. Also, Lab scientists and their collaborators continued or initiated several research projects in support of the mission of the Lab. A number of these projects are highlighted in this report.

My colleagues and I will do our utmost to keep our stakeholders informed of our progress and achievements. We welcome your initiatives, suggestions and inquiries in order to enhance the quality of our research program.

Soils Lab Scientists

Abdullah Jaradat
Supervisory Research Agronomist
Abdullah.Jaradat@ars.usda.gov

Research Focus: *Modeling genotypic growth, development, biomass partitioning and yield responses of traditional and alternative crops to environmental, cropping systems and management factors*

Jane Johnson
Research Soil Scientist
Jane.Johnson@ars.usda.gov

Developing and assessing management strategies to provide sustainable food, feed and fuel while enhancing environmental quality and mitigating greenhouse gas emission

Russell Gesch
Research Plant Physiologist
Russ.Gesch@ars.usda.gov

Research Focus: *Identifying and characterizing biological factors in crops and management strategies for improving tolerance to environmental stress, and developing new/alternative crops*

Sharon Weyers
Research Soil Scientist
Sharon.Weyers@ars.usda.gov

Research Focus: *Soil biology in relation to soil quality and land management issues*

Frank Forcella
Research Agronomist
Frank.Forcella@ars.usda.gov

Research Focus: *Weed and crop ecology, management, and modeling with the goal of achieving "right-input" agriculture*

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Advancing sustainable and resilient cropping systems for the short growing seasons and cold, wet soils of the Upper Midwest

Jane Johnson (Lead Scientist), Abdullah Jaradat, Sharon Weyers and Frank Forcella

Problem to be addressed:

An expanding population, global climate changes, and need for sustainable energy resources are serious interrelated issues facing society. Agriculture can contribute to solving these problems by protecting and improving the soil resource for producing food and fuel. Moving atmospheric carbon through plants and increasing soil organic matter provides many benefits, including reducing atmospheric greenhouse gas concentrations, improving soil quality and increasing resilience against erosive forces to safeguard productivity and protect water quality. Another aspect to solving the problem is finding adaptive cropping strategies for coping with environmental stresses, which are anticipated to be exacerbated by climate change.

The overall goal of this project is to develop soil and crop management systems that sustain agricultural production, readily adapt to climate change, minimize GHG emission, sequester carbon, and safeguard soil productivity while protecting environmental quality in the upper Midwest.

1. Determine crop residue needs to protect soil resources and identify management strategies that enable sustainable production of food, feed, and biofuel.

2. Develop options for managing crop systems to reduce GHG emissions and increase C storage.

3. Evaluate impacts of environmental changes (water, CO_2, temperature) on traditional, biofuel and alternative crops to develop a model-based risk assessment of crop production under the most likely medium-term (10-30 yr) climate change scenario for the upper Midwest.

2011 progress highlights:

Bioenergy and climate change

Local efforts:

Corn stover is the material (leaves, stalk, and cobs) that remains after the corn is harvested. In the Northern Corn Belt, corn stover is to be used as a non-food, bio-energy feedstock for production of ethanol or as a fossil fuel substitute.
However, enough stover needs to be returned for soil cover, to build new soil organic matter, and for erosion control. Indicators of soil organic matter and soil biology were used to assess if stover harvest compromises yield potential of high quality soils within a corn-soybean rotation. The results suggest that on higher quality soils one or two stover harvests did not reduce corn or soybean yield. However, using maximum harvest rates may decrease long-term yield potential of soils. As a consequence, short-term gains need to be balanced against potential long-term losses. The third of five cycles of residue harvest was completed in the fall of 2011.

Measuring residual stover return rate after corn harvest.

In a collaborative study with the University of Iowa, University of Minnesota-WCROC, and area farmers, cobs or corn stover were harvested at the same time as grain using a one-pass prototype combine.

A study was completed that compared greenhouse gas and crop productivity between two cropping systems. The largest nitrous oxide emission occurred during spring thaw in both systems, with additional emissions detected shortly after applications of nitrogen containing amendments. Yield-scaled greenhouse gas emission expressed as CO_2 equivalents was 1.6- to 5-times greater in the organically-managed system compared to the conventionally-managed system because of decreased crop yield. Organic systems are viable strategies to mitigate greenhouse gas (GHG) emission when they do not compromise crop productivity. Study results highlight the importance of assessing emission and crop production when evaluating GHG mitigation strategies.

The fall of 2011 marked the 10-year anniversary for long-term plots designed to compare soil carbon sequestration, greenhouse gas emission and productivity of several cropping strategies including perennial grasses, extended crop rotations, and inclusion of cover crops in conjunction with residue harvest. Numerous soil parameters are being measured on samples collected to 1-meter. These samples will be used to assess the effectiveness of the cropping strategies based on collections obtained in the first and tenth year.

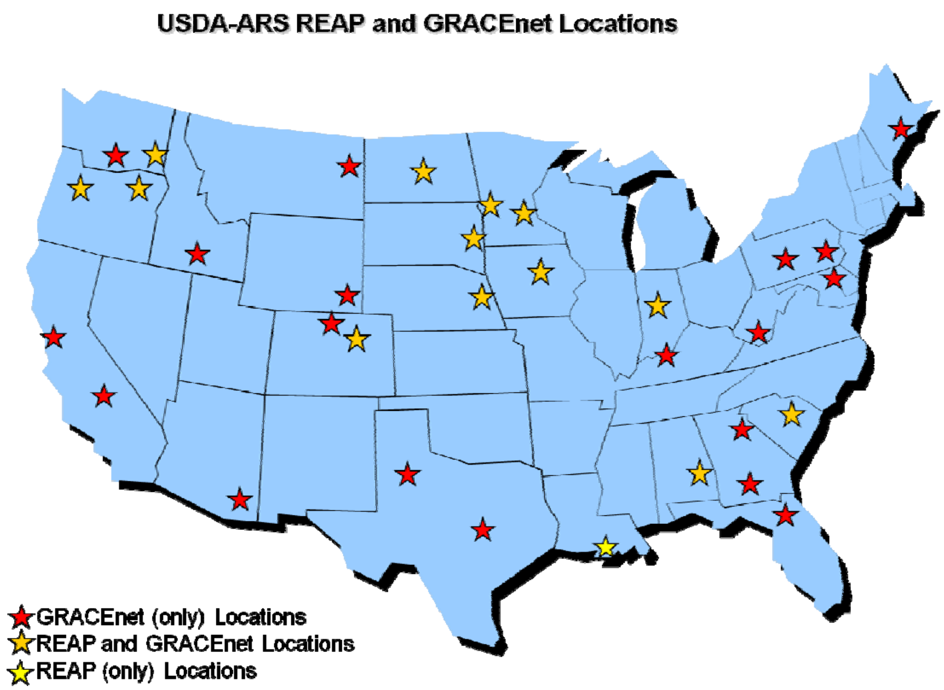
National Projects

REAP (Renewable Energy Assessment Project) – A multi-location project to ensure the soil resource indefinitely meets the demands for food, feed, fiber and fuel.

Morris scientists are actively contributing to this REAP project. One of the projects is system development for collecting and collating data from two dozen sites across the country which will facilitate science-based management guidelines for the emerging non-food bio-energy industry. A demonstration of the early version of the REAP database was conducted at a workshop held at the ARS facility in Ames, IA.

GRACEnet (Greenhouse gas Reduction through Agricultural Carbon Enhancement network). A research program to assess soil carbon sequestration and greenhouse gas mitigation by agricultural management.

Morris continues to be an integral player in GRACEnet. A new book, "Managing Agricultural Greenhouse Gases," summarized and synthesized research data into clear recommendations from land-based agricultural systems. Morris scientists contributed several chapters to this ARS-GRACEnet publication.



Modeling Seed Weight Under Environmental Resource Limitations as a Function of C, N, and C:N Allocation

A. A. Jaradat, Jana Rinke and Steve Vankempen

WHY?
"Anticipated" climate change will require directed adaptations of crop species on an unprecedented magnitude in order to sustain agricultural production.

Start with a seed!!

- Last yield component to be determined by crop plants.
- Resists variation due to external factors
- Inverse relationship with seed number per "fruit" [e.g., corn ear, chickpea pod, wheat spike, safflower capitulum, etc.]
- Correlation with yield is not always strong or positive.
- Importance of quantitative and qualitative nutritional value
- Importance of seed vigor for a vigorous seedling and for stand establishment.

Resource limitation – consequences of climate change:

- Climate changes (e.g., temperature, CO_2, water, nutrients, etc.) impact agriculture
- Agriculture affects climate change (e.g., greenhouse gas emissions, C-sequestration, etc.)
- Is there a critical balance so that farmers can produce enough food, feed, fiber and fuel from agricultural lands, while protecting the environment and natural resources?

Crops:

- Corn (three open-pollinated varieties, OPV Michael Fields Agricultural Institute breeding program; starch) and Wheat (bread and durum varieties; starch and Protein)
- Chickpea (Desi and Kaboli varieties USDA breeding program; and Soybean (Organic and Roundup ® varieties; protein and oil)
- Safflower (two high Omega-3 varieties, Montana State University breeding program; oil)

Resource limitations:

- No resource limitations (optimum planting date and population density)
- Competition for resources I- 125% population density, optimum planting date for each crop
- Competition for resources II- shorter growing season (~ 100 growing degree days after normal planning date), optimum population density
- Competition for resources III- Shorter growing season and high (125%) population density

Why Model Seed Weight?

- To increase our knowledge of single plant and population responses to climate change factors.
- To develop crop coefficients – as crop stress indicators, and to quantify response and dry matter partitioning and its relationship with grain yield.

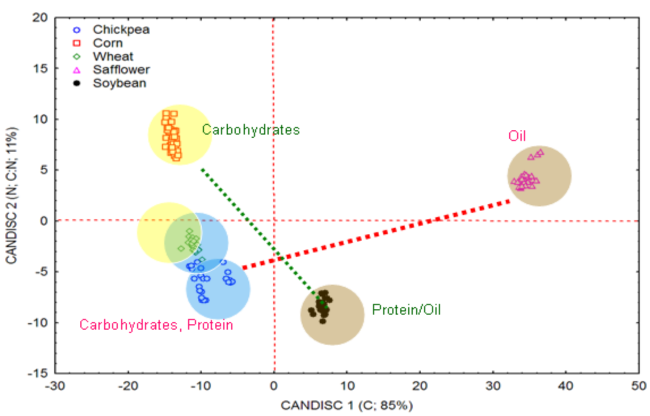
Why C, N, and C:N ratio?

- C & N – most common nutrient elements in provisioned seed.
- Globally-optimum C:N provisioning ratio?
- Impacted by seed-related traits:
  - seeds/fruit,
  - nutrient density,
  - seed “packaging cost”

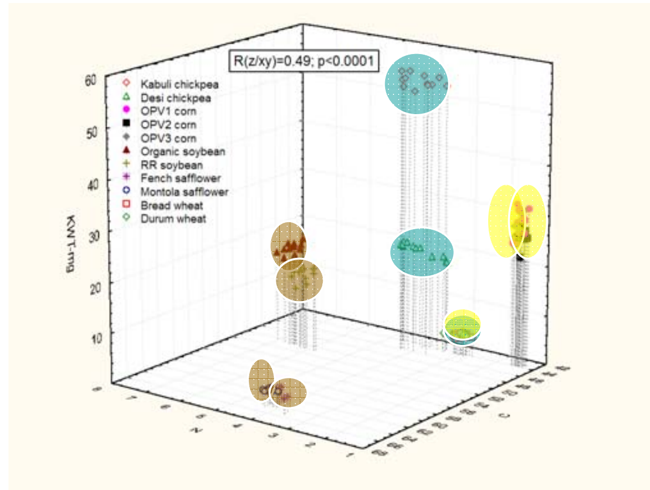
Large and significant differences in kernel weight, and carbohydrate, protein and oil content were found between the five crops.

Summary composition (min-max carbohydrates, protein and oil content, cited from literature) of seeds of five crops.

Species	variety	Kernel weight mg (C.V.=82%)	Carbohydrates $g\ kg^{-1}$	Protein $g\ kg^{-1}$	Oil $g\ kg^{-1}$
Corn	OPV1	2.5-3.4	640-685	80-102	35-55
	OPV2	2.2-3.8	635-670	83-95	35-60
	OPV3	2.4-3.2	640-665	82-103	40-60
Wheat	Bread (HRS)	2.9-3.2	760-785	140-160	
	Durum	3.9-4.8	740-750	170-185	
Soybean	Organic	3.7-4.2	210-260	370-410	150-180
	Roundup ®	2.7-3.3	200-230	360-390	160-200
Chickpea	Desi	1.8-2.2	610-660	220-290	
	Kabuli	5.2-5.6	600-610	210-270	
Safflower	Montola	2.7-3.1	300-320	115-170	350-400
	Fench	2.8-3.3	295-315	125-165	370-410



Carbon content was a major factor separating crops from each other. All crops were 100% separated from each other on the basis of their C, N contents and C:N ratio in their seeds.



Variable relationships across species and varieties were found between kernel weight and C and N content in the seed. However, a strong relationship was found between kernel weight and both C & N ($r=0.49$, $p<0.0001$). High-yielding corn has the largest C content in its seeds; whereas organic soybean has the largest N content.

Implications for Climate Change

- Length of cropping seasons can be manipulated to optimize kernel weight as a major, but not easily adjusted, yield component, especially under resource limitations.
- Species, variety [genotype] x stress factor interactions were most important in explaining large portions of variation in C, N and C:N, and, consequently, kernel weight. Minimizing the level of its impact may lead to larger N, C, N:C in the kernel, and consequently larger kernel weight.
- Population density can be adjusted in relation to length of the growing season in order to optimize utilization of renewable and non-renewable resources.
- Genotypic selection and adjusted population density to fit length of growing season will optimize the production of carbohydrates, proteins, or/and oils under potential Climate Change scenarios.

CROP PRODUCTION

New crops and management strategies to improve cropping efficiency in sort-season high-stress environments

Russ Gesch (Lead Scientist) and Frank Forcella

Problem to be addressed:

Cropping systems in the northern U.S. are highly productive but agricultural diversity is minimal. Intense management of only a few commodity crops (e.g., corn, soybean, and wheat) has led to economic and environmental concerns due to rising input (e.g., fertilizer and pesticides) costs and negative effects from overuse of those inputs on soil, water, and air quality and pest resistance to control tactics. There is now the additional strain on U.S. agriculture to produce bioenergy without sacrificing food security or the environment. These concerns potentially jeopardize long-term sustainability of cropping systems in this region.

The goal of our research is to develop new and alternative crops and timely crop and weed management strategies to increase agricultural diversity and overall cropping efficiency in northern climates. Our intent is to provide producers and other clientele with new knowledge, crops, and management tools to increase cropping efficiency and diversity in northern climates.

2011 Progress Highlights:

This past year our ever-shrinking, but highly efficient, research team participated in the development and writing of several research grant proposals with various government, industry and academic collaborators. This year a grant was awarded for $115K by the North Central Sun Grant Initiative to fund work on double-cropping winter camelina with various food and forage cops. Our team also received an additional $20K from Aveda Corporation and $9.5K from Technology Crops International to continue and begin new work on new oilseed crops such as cuphea and echium. We also have a continuing (December 2010) grant from NC-SARE ($175,000) that we use to support a graduate student in Agricultural and BioSystems Engineering at SDSU. The student, Corey Lanoue, is developing a field-scale demonstration model of an abrasive grit applicator for in-row weed control.

New oilseed crops and cropping systems research

Improved planting management for cuphea production. Cuphea is a new oilseed that our team has been instrumental in developing for the northern Corn Belt region. It can serve as a domestically produced source of oil similar to tropical plant oils that are presently imported into the U.S. for chemical manufacturing. We experimented in the field with various seeding rates and row spacing to optimize seed yields.

- We found that cuphea has very good yield compensation over a range of row spacings and seeding rates.
- However, we determined the optimum seeding rate was about 8 lb/acre and row spacing of 15 to 22 inch to maximize cuphea seed yield while minimizing a farmer's input costs related to planting.
- This knowledge will ultimately help farmers to more successfully manage cuphea production and increase their net economic returns.

Climate and soil environment influence cuphea seed oil characteristics. Certain plant oils can serve as highly efficient, renewable and biodegradable feedstock for advanced biofuels such as aircraft fuel. Cuphea is one of only a few plant sources of such oil that can be grown in the U.S., but its oil yield and quality are affected by growth environment. In collaboration with other ARS scientists and scientists from the University of Western Illinois, Iowa State University, and North Dakota State University we tested various cuphea species across the Midwest to determine the effects of soil-type and climate on seed yields and seed oil characteristics.


Combining cuphea

- We discovered that certain species native to Mexico and South America actually performed quite well in the upper Midwest.
- We also found that the seed oil quality necessary for efficient biofuel production increased the further south that cuphea was grown in the Midwest, but that total oil yield was actually greater the further north that it was grown.
- This information will further help to determine where best to grow cuphea for the purpose of biofuel and provides information that may help efforts to develop better agronomic varieties.

Additional highlights include preliminary work on, echium (pronounced "ek-ee-um"), a new oilseed crop that grows well in west central MN. Echium seeds are a rich source of gamma linolenic acid (GLA) that is highly valued for health supplements and cosmetic products (e.g., anti-wrinkle creams). Also, a second year of field research was completed on developing a double-crop system using fall-seeded winter camelina followed by soybean. Using a method called relay cropping, we were able to consistently produce a viable camelina crop in addition to soybean yields of 35 to 40 bu/A in a single season.

Double cropping soybean and camelina

Weed emergence modeling and new weed control strategies

Controlling weeds with organic fertilizer. Efficient weed control is vital for profitable crop production, especially organic farming. Weed control options available to organic farmers are restricted. In collaboration with New Zealand scientists, we tested using corn gluten meal, an organically approved fertilizer, propelled under pressure by a sand blaster to abrade and kill weeds.

- We discovered that when nozzle applicators were within 2 ft of a weed and a pressure of greater than 75 psi was used, the technique was highly effective at controlling foxtail, a weed of worldwide economic importance.
- This new technology developed by our team potentially allows for nitrogen fertilization and weed control to be done simultaneously in organically-produced crops.
- This technology will be of interest to agricultural machinery manufacturers as well as organic farmers who grow crops in widely spaced-rows such as corn, grapes, and blueberries.

Efficient, cost effective method to predict weed seedling emergence. Small 3' x 3' sheets of clear plastic when placed on the soil surface in very early spring act like tiny greenhouses. Sunlight passes through them, heats the underlying soil, and promotes early germination of annual weed seeds. This simple low-cost technique can allow crop scouts or farmers to monitor these early-emerging weeds and make decisions regarding weed control (e.g., herbicide selection and rate) before the crop is even planted. What isn't known, however, is how many of these plastic sheets should be used in large fields to accurately assess weed emergence. Our team in collaboration with scientists from Argentina conducted the same study in both MN and Argentina to determine the number of small plastic sheets necessary to accurately predict weed seedling emergence.


Plastic sheet used to predict weed emergence

- We discovered that 1 sheet per 11 acres was needed to predict crabgrass emergence, while 1 sheet per 5 acres was needed for lambsquarters and green foxtail.
- The use of this technique may be especially valuable in small fields of high-value crops.
- This information will help crop scouts and growers make better decisions regarding the choice and rate of herbicides to be applied.


Weeds in amongst crop plants

Additional highlights include hosting two visiting scientists in 2011 from the University of Lleida in Spain, Dr. Aritz Royo Esnal and Addy Laura Garcia, a Ph.D. graduate student. These scientists came to the Soils Lab to learn our modeling techniques and collaborate on model-construction for two weed species that grow in Spain and the USA.

Technology developed by our team during 2011-2012 was transferred to clientele and other interested parties through several venues including professional meetings, field days, industry and grower meetings, and popular press articles as well as several peer-reviewed scientific publications and through downloading of usable software from our Web site for modeling and predicting soil microclimate and weed phenology/ecology.

Research on weed control in 2011 emphasized two very different systems. The first emphasis was on non-chemical means of controlling weeds, as would be needed in organic crops. We continued our work on an abrasive grit applicator. Through a SARE grant, the Soils Lab is sponsoring a graduate student in agricultural engineering at SDSU to build a prototype four-row implement that uses compressed air to propel corn cob grit (or any other type of grit) through pairs of nozzles aimed at either side of a row of corn or soybean. The prototype will be available for on-farm trials in 2012. The grit abrades small weed seedlings within the crop row and leaves the crop plants essentially unscathed. Two timely applications of grit (for instance at the 1- and 5-leaf stages of corn) provides season-long weed control within the crop row. For between-row weed control, growers can use a cultivator or a winter cover crop, such as winter rye. Growth of the winter cover crop has to be terminated in late spring with a roller-crimper when the rye is heading. The resulting rye mulch controls nearly 99% of weeds between rows. Its only drawbacks are that summer-growing row crops, like soybean, must be planted somewhat late, which reduces soybean yield potential.

Calendula flower with pollinator

Calendula is related to sunflowers. It is an annual plant whose seed oil is a valuable substitute for tung oil in paints and varnishes. Tung oil and calendula oil are considered the best of the plant-based "drying oils," which are expected to be in high demand in the near future as petroleum-based paints and varnishes are banned in developed countries. Calendula grows quite well in cool climates like Minnesota (whereas tung trees are tropical), and acreage is anticipated to increase in the next decade. Because little is known about how to control weeds in calendula, we embarked on several studies to explore herbicides and herbicide rates that could be tolerated by calendula but still kill weeds that commonly grow in Minnesota. Two post-emergence herbicides can be used in calendula; these are the active ingredients found in Betamix (desmedipham + phenmedipham) and Assert (imazamethabenz). Although Betamix will damage calendula plants, if it is applied after the 4-leaf stage, the plants recover and produce plentiful seeds. Calendula completely tolerates Assert. Calendula also tolerates soil-applied active ingredients found in Dual (metolachlor), Prowl (pendimethalin) and Treflan (trifluralin). Thus, growers have a small but useful number of products with which to control weeds if they choose to try calendula in Minnesota or adjacent states.

Another aspect of calendula agronomy that lacked experimental verification was planting depth and sensitivity to spring-time soil temperatures. Consequently, extensive experimentation in 2010 and 2011 in conjunction with a visiting graduate student from Ecole Supérieure d'Agriculture in Angers, France, documented that calendula should be planted at 1/3" depth and that about 190 growing degree days (base temperature = 42°) at that depth must elapse for 50% emergence to occur. On average, 190 GDD corresponds to 7 days after planting in May. We also found that as soil temperature at (1/3" depth) reaches 104° for even just a few hours, calendula seeds thereafter fail to germinate. This means that early planting is important for successful calendula establishment, as the probability of soils in southern and central Minnesota reaching that critical temperature rises sharply in late May and early June, respectively. In contrast, soils in northern Minnesota almost never reach such high temperatures. Indeed, calendula may be a more reliable crop in northern Minnesota than farther south.

Soils Lab staff also worked closely with scientists who spent the summer of 2011 visiting Morris. Two projects involved modeling the dynamics of weed seedlings in fall and spring. The first project was for ripgut brome, which is a weedy grass of winter wheat and other winter-growing crops. The second project was for prostrate knotweed, which is a nuisance weed in lawns for Minnesotans, but a significant crop weed in warmer areas. Both projects were conducted in conjunction with visiting scientists from the University of Lleida, which is one of the largest agriculturally-oriented universities in Spain. The Spanish researchers desired training on STM^2 software developed at the Soils Lab so that they could estimate soil temperature and soil moisture (that is, growing degree days affecting buried weed seeds) to develop models that accurately predict seedling emergence of these weeds in Spain, in the USA, and anywhere else on earth where these weeds are troublesome. The models are in the final states on completion during winter 2012.

Work on numerous oilseed crops over the years by Soils Lab personnel has led us to suspect that poor yields at some sites sometimes can be attributed to lack of insect pollinators. This suspicion stimulated our interest in promoting pollinators throughout the region. As it happens, Minnesota and adjacent states are the primary suppliers of transient honey bees to California and other southern states during winter.

Bee hives from Minnesota and North Dakota are moved seasonally for most almond pollination in California.

The honey bees are sent south in November and return in April. Many bees die overwinter because of, in part, poor nutrition while in Minnesota during spring, summer, and fall. We hypothesized that a broad suite of bee-friendly oilseed crops that begin flowering in late April (e.g., winter camelina) and finish flowering in late October (e.g., calendula) may provide continuous supplies of the protein-rich pollen and energy-rich nectar that bees need to thrive.

Demonstration experiments in 2011 with a wide variety of such crops and observation of nearby beehives convinced us of the validity of our hypothesis.

Subsequently, we wrote and submitted an exhaustive grant proposal ($500,000) in conjunction with the USDA-ARS lab in Brookings, SD, to thoroughly investigate the connections among oilseed crops in Minnesota, bee nutrition, bee health, and overwinter bee survival in California.

Pollinator crop plots

Agricultural system competitiveness and sustainability

Abdullah Jaradat (Lead Scientist), Sharon Weyers, Jane Johnson and Russ Gesch

Problem to be addressed:

The sustainability of current crop management practices is questionable. Land use in the upper Midwest is currently centered on large-scale corn and soybean production systems, but emerging markets have driven the recent increase in alternative crop and livestock production systems. Land use supporting corn-ethanol production is also growing, and grain-based biofuels are expected to dominate and remain significant until 2030. We anticipate that long-term sustainability of agricultural production in the upper Midwest can be enhanced to include both environmental and economic perspectives in evaluating productivity. The research project on "Agricultural Competitiveness and Sustainability" addressed two interrelated components to identify the impact of diverse land use systems on system level productivity at large (landscape), medium (field) and small (plot-level) scales. The first two parts are being implemented in collaboration with farmers and the plot-level results are being used to provide basic information for the field-scale research activities. Scientists are evaluating nitrogen dynamics across the landscape to develop economically-based nitrogen budgets; and are determining the impact of multiple biomass production strategies of soil and crop productivity. The data generated will be used to develop energy budgets for biomass and bioenergy feedstock production systems. The nitrogen and energy budgets will support the identification and development of economically-viable agricultural practices that protect the environment and integrate into a diverse landscape.

2011 Progress Highlights:

The following are some of the 2011 achievements to demonstrate the scale and coverage of research activities of the project.

ARS Long-Term Agro-Ecosystem Research (LTAR) Network

During the last part of 2011, the Soils Lab in Morris, in addition to sister Labs in MN, WI and IA, were successful in becoming part of the Agricultural Research Service's ***Long-Term Agro-Ecosystem Research Network***. These Labs are located within watershed within the Upper Mississippi River Basin (**See Map in Figure 1**) and will engage in synergistic, network-wide research to address questions related to the condition, trends, and sustainability of agricultural systems and resources on large scales of space and time. Sustainable agricultural systems that provide a safe, nutritious, ample, and reliable food supply; produce bioenergy; provide essential ecosystem services; and mitigate climate change are needed for the well-being and welfare of future generations. The participating labs were selected based on several criteria; these were: productivity and the track record of the current ARS research team; infrastructure capacity; data richness and availability on long-term field experiments —the length, breadth, depth, and overall quality of the existing data record; geographic coverage at various scales (The Soils Lab and its partners represent the Chippewa River Watershed in the LTAR; **See map in Figure 2**); strength of existing external partnerships with producers, other stakeholders, and local universities, including the potential for education; and institutional commitment to support the continued operation of the location.

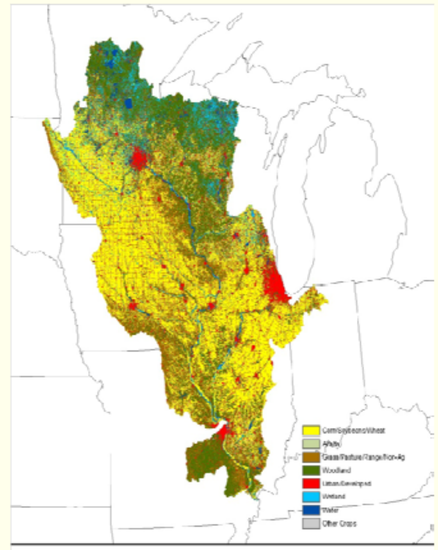


Fig. 1 The Upper Mississippi River Basin land use (Assessment of the effect of conservation practices on cultivated cropland in the Upper Mississippi River Basin, USDA-NRCS)

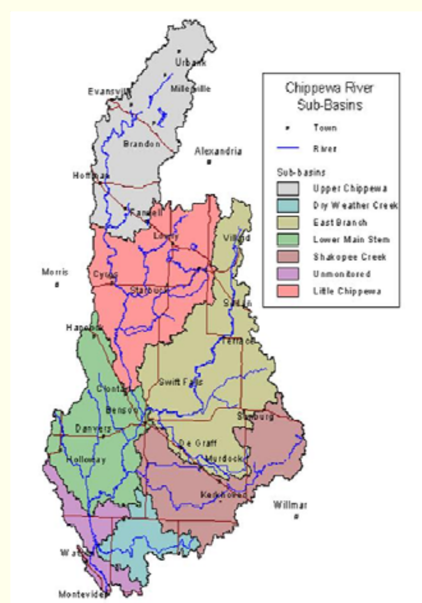


Figure 2. Chippewa River watershed, MN.

This LTAR was developed with the goal of integrating information across a range of locations and partners to address complex research questions through the development of an interactive multidisciplinary and multi-scale network. Some of the research questions to be addressed by the participating Labs include:

- What water quality improvements can be gained from new conservation practices for tile-drained landscapes?
- How are watershed hydrology and water quality responding to changes in climate and agricultural practices?
- How are the fluxes of carbon, water, and nitrogen affected by changes in conservation practices and linked to water quality?
- From a systems analysis standpoint, what are the key indicators for defining resilience and stability of an agro-ecosystem? What are the critical factors controlling resilience and stability?
- How does landscape structure (topography, vegetation, land use) affect the up scaling of soil and aquatic processes to a regional level?
- How can we use LTAR data to estimate ecosystem services?
- How do cropping systems that include perennials, longer rotations and integrated systems of crops with livestock on the land affect soil fertility and in turn water infiltration, water storage in the soil profile or loss to tiles and runoff?

Abdullah Jaradat and George Boody's presentation on the Chippewa River Watershed, 2011 Field Day

The Land Stewardship Project is one of the Soils Lab collaborators on the LTAR through our joint project on the Chippewa River Watershed (CRW) project. The CRW, with a population of about 41,000 people, drains 5387 km^2 of mixed natural and managed landscapes. The primary land-use in the CRW is agriculture as corn, soybeans, sugar beets, wheat, dry edible beans and grass-based livestock. Annual crops currently predominate on 81 to 94% of the land in southern sub-watersheds. The northern sub-watersheds are still predominantly agricultural (60 to 68%), but have more grass, forest and water and integrated crop and livestock operations. The watershed is included in the new Minnesota Prairie Plan to expand grass-based working farms around core natural prairie areas.

The Chippewa Project is intended to make voluntary, practical connections between land-use change at the field/farm level and watershed goals for multiple ecosystem services. The monitoring phase of the project will cover ecologically sensitive fields, areas in grass or wetlands to be maintained, economically marginal lands for row crops or other areas are being identified through GIS, visual inspection and discussions with farmers. Research efforts include the use of long-term datasets at the Soils Lab and West Central Research and Outreach Center for model calibration. Models are being used by the Soils Lab to test four scenarios for land use change including perennial livestock products, perennial biomass, best management practices in row crops and conservation lands developed by the project team. Economic analyses will identify costs and returns from markets for perennial crops as compared to row crop commodities, conservation program incentives and possible ecosystem services payments, as well as risk management tradeoffs. Partners intend to monitor and compare attained impacts to goals, rates of implementation and predicted ecosystem impacts for water quality and flow, habitat and community impacts over the next decades.

Additional highlights include hosting Hafiz Muhammad Rashad Javeed, a doctoral candidate from the Department of Agronomy, University of Agriculture in Faisalabad, Pakistan. He received a six-month scholarship from the Higher Education Commission of Pakistan Islamabad to visit and work with Soils Lab staff. Mr. Javeed worked in collaboration with Dr. Jaradat and Jon Starr with the farm systems Decision Support System for Agrotechnology Transfer (DSSAT) modeling program. This program, adapted for the Pakistani growing season, simulates growth and production using variable environmental conditions and differing management practices, a special emphasis was placed on tillage and fertility.

In collaboration with Jana Rinke, Hafiz received instruction in the general practices of laboratory techniques and processes with an emphasis on quantitative analysis. To relate these processes, he performed a soybean/plant density greenhouse study determining chemical composition, biomass partitioning, and statistical applications.

Heidi Swanson is a freshman enrolled at the University of Minnesota, Morris in Environmental Science. She is volunteering her services to gain experience at a "working laboratory" with an emphasis on techniques, protocols, and associated instrumentation for determining chemical composition in soils and plants. Her special interest lies in sustainable food systems developed for the short growing season of the upper Midwest.

Ecosystem services in the Chippewa River Watershed: How they will be impacted by climate change?

Abddullah Jaradat, George Boody and Jon Starr

Due to current land-use systems, the Chippewa River Watershed (Fig. 1) faces a number of environmental challenges, including degradation of water quality, threats to biodiversity, and increased flooding, soil erosion and nutrient loss to both surface and underground water. In addition to these environmental challenges, the effect of spatio-temporal climate variability in the watershed is likely to be intensified by climate change, which is predicted to disrupt many ecosystem functions, altering their capacity to provide goods and services and rendering them more susceptible to degradation. The question facing farmers and researchers alike is how to optimize a diversified agro-ecosystem, maximize production and profits, and minimize negative environmental effect of future agro-ecosystems? We carried out a simulation study with the following objectives (1) predict the long-term effect of diverse crop rotations on agro-ecosystem services and the relationship between soil types, crop rotations, and their response to historical and future climate change, (2) model the effect of targeted land-use changes on managed agro-ecosystems, and (3) develop predictive and validation models of future ecosystem services under a climate change scenario if current management practices of high external inputs and conventional tillage are continued.

Opportunities to improve the ecological functioning of managed and natural ecosystems in the Chippewa River Watershed include reduced soil erosion, runoff, and the concomitant loss of nutrients, natural habitats, and biodiversity, all of which contribute to environmental pollution within and outside the watershed. We hypothesized that (1) meditating water flow at the landscape level will help sustain managed and natural ecosystems through increased biodiversity, larger habitat-carrying capacity and better water quality, and (2) increasing perennial land-use will improve environmental health through reduced runoff and soil erosion, increased biodiversity, and sustained carbon sequestration. We calibrated, validated, and used a modular modeling framework to simulate the impact of 100-year historical weather variables in combination with current and alternative crop rotations on ecosystem services of the predominant farming system in 12 locations representing different soil types and landscape positions across the watershed. Simulation modeling and multivariate analyses indicated that differences between locations accounted for 89.0, 30.7, 82.1, and 78.4% of total variation in sequestered carbon, inorganic nitrogen leaching, runoff, and soil erosion, respectively (Fig. 2).

Differences between crop rotations and their interaction with soil types accounted for major portions of the remaining total variation. Total replacement of row crops by a perennial on sensitive lands are projected to reduce inorganic nitrogen leaching, runoff and soil erosion by 40, 24, and 48%, respectively. However, a perennial crop is expected to reduce inorganic nitrogen leaching, runoff and soil erosion by 12, 16, and 32%, respectively, as compared to the current corn-soybean rotation, when its frequency is increased up to 60% in a corn-soybean crop rotation that included a small grain crop across the watershed.

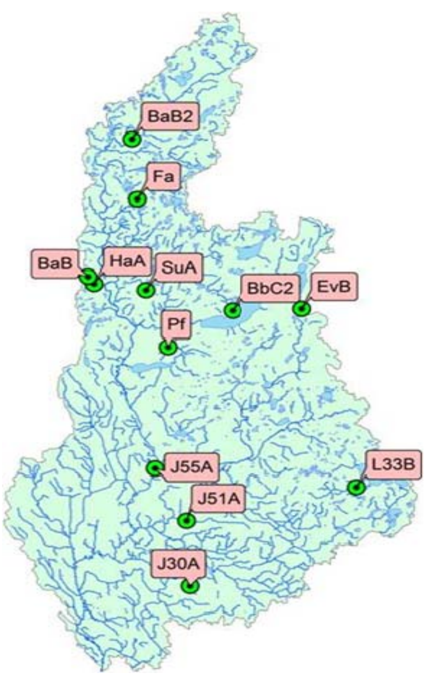


Fig. 1. Location and soil classification of 12 soil series used in the simulation study within the Chippewa River Watershed.

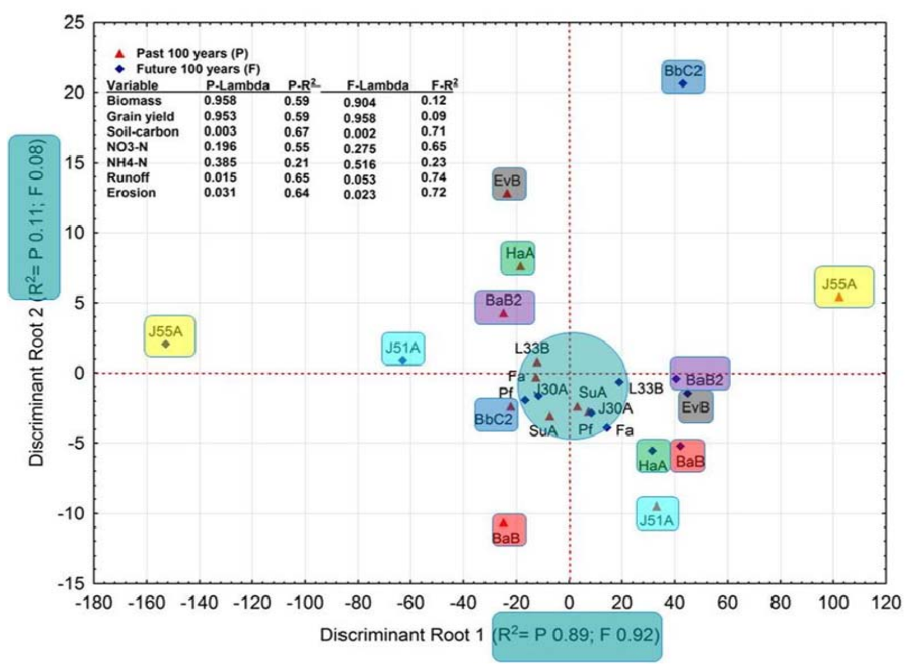


Figure 2. Scatter plot of 12 soil types on the first and second discriminant roots, and test statistics (inset; P- and F- lambda and R^2) and the standardized coefficients of seven ecosystem services (Biomass, grain yield, soil carbon, nitrate nitrogen, ammonium nitrogen, runoff and soil erosion) as impacted by past (P- [triangles]) and future (F-[diamonds]) climate change in the Chippewa River Watershed, Minnesota.

Native American Maize – Source of Sustenance and to Restore Indigenous Food Systems

Abdullah Jaradat and Jana Rinke

Maize, the Native American word for corn, literally means "that which sustains life." After wheat and rice, it is the most important cereal grain in the world, providing nutrients for humans and animals. Last March, a large gathering of indigenous farmers gathered at the 9th Annual Great Lakes Indigenous Farming to share knowledge, stories and seed of their crops, especially native maize landraces. Food insecurity and the need to restore indigenous food and agro-ecosystems were among the many issues highlighted by speakers and echoed by attendees during the meeting.

Participants from different tribes and regions across North America indicated that most landraces of maize have been lost, along with the indigenous knowledge of how to grow, improve and store their seed for future generations. These landraces are the results of thousands of years of cultivation aided by natural and human selection and resulted in the evolution of immense diversity of native maize. Participants strongly emphasized the nutritional value, the many uses, and specific adaptation of the diverse maize landraces their tribes used to grow and especially those which are still in use today. However, the participants were determined, against all challenges and in spite of the loss of large portion of maize diversity, to maintain available diversity and search for and conserve more “hidden” diversity all over North America.
Native Americans believe that the restoration of local food systems can rapidly undo much of the dietary problems faced by their people. In addition, it is considered integral to the restoration of biologically resilient ecosystems and the development of sustainable economies. The White Earth Land Recovery Project, who hosted the meeting, is working with a number of tribal members and local farmers to grow a few native maize landraces adapted to northern Minnesota. Officials of the project agreed to provide ARS with seed of nine maize landraces to be included in a larger study to evaluate the nutritional quality (macro- and micro-nutrients, protein, oil, carbohydrates) and relate that to the color and seed physical properties of the seed.

We, at the ARS Research Lab in Morris, Minnesota, carried out a preliminary evaluation of the donated seed samples during the spring season of 2011. This evaluation included seed physical and color characteristics. The variation in seed dimensions was not as large as the variation in their color patterns and composition which ranged from white to purple dark. Certain kernel colors are indicative of the presence and level of certain vitamins and amino acids. We planted these seed samples at The Swan Lake Research Farm near Morris, Minnesota, to study plant growth and development during the growing season (Figure 1). After harvest this fall, we will re-examine the same landraces for more plant, ear, cob, and seed characteristics in an effort to find out how they relate to crop yield and nutritional quality and which of these characteristics distinguishes landraces from each other and contributes to their unique qualities.

Figure 1. A Native American maize landrace grown at the Swan Lake Research Farm near Morris, MN.

Results of the initial study carried out on native maize seed suggested that the nine native maize landraces, as a group, differed from three open-pollinated varieties I grow in my home garden and from three other open-pollinated varieties (Nokomis Gold, both with opaque and translucent seed and a cross between AR16021 and B73, which are open-pollinated varieties.

The native maize landraces differed from the others by having smaller seeds, different color patterns, higher phosphorus, zinc, potassium, but lower magnesium. In spite of the low-input conditions under which these landraces have been grown for generations, protein content was relatively high and ranged from 9.5 in the landrace Hochunk to 13.5% in Seneca Blue Bear. We expect that the on-going field study will provide more seed and plant information so that we may be able to carry out more in-depth evaluation of these landraces and identify, in collaboration with The White Earth Land Recovery Project, ways and means of seed increase and saving of their genetic integrity as they represent invaluable genetic resources adapted for certain environments and local management practices and characterized by unique flavor and culinary attributes.

Appendix 1

2011 Peer-Reviewed Publications

1582. Colbach, N. and **F. Forcella.** 2011. Adapting geostatistics to analyze spatial and temporal trends in weed populations. In: Clay, S., editor. GIS Applications in Agriculture: Invasive Species. Vol. 3. New York: CRC Press, Taylor & Francis Group. 319-371.

1576. Eyherabide, J.J., M.G. Cendoya, **F. Forcella** and M. Irazazábal. 2011. Number of solaria needed to predict weed seedlings in two summer crops. Weed Technol. 25:113-118. http://hdl.handle.net/10113/50169

1571. **Forcella, F.,** T. James, and A. Rahman. 2011. Post-emergence weed control through abrasion with an approved organic fertilizer. Renewable Agriculture and Food System. 26(1):31-37. http://hdl.handle.net/10113/49261

1594. **Forcella, F., Gesch, R.W.** Papiernik, S.K.**, 2011.** Cuphea tolerates clopyralid. Weed Technol. 25:511-513.

1584. **Gesch, R.W.** and S.C. Cermak, 2011. Sowing date and tillage effects on fall-seeded camelina in the northern Corn Belt. Agron. J. 103(4):980-987. http://hdl.handle.net/10113/49907

1533. Ibekwe, A.M., **S.K. Papiernik**, C.M. Grieve, and C-H Yang. 2011. Quantification of persistence of Escherichia coli O157:H7 in contrasting soils. Intl. J. Microbiology. DOI:10.1155/2011/421379 http://hdl.handle.net/10113/47426

1579. **Jaradat, A.A**. 2011. Biodiversity of date palm. In: Encyclopedia of Life Support Systems: Land Use, Land Cover and Soil Sciences. Oxford, UK: Eolss Publishers. 31 p.

1585. **Jaradat, A. 2011**. Dynamics of mean-variance-skewness of cumulative crop yield impact temporal yield variance. Intl. J. Agron. Paper No. 426582. http://hdl.handle.net/10113/49963

1599. **Jaradat, A.A.** 2011. Energy crops to combat climate change. In: Yadav, S.S., Redden, R.J., Hatfield, J.L., Lotze-Campen, H., Hall, A.E., editors. Crop Adaptation to Climate Change. West Sussex, UK: John Wiley & Sons, Inc. p. 546-555.

1592. **Jaradat, A.A.** 2011. Ecogeography, genetic diversity, and breeding value of wild emmer wheat (Triticum dicoccoides Körn ex Asch. & Graebn.) Thell. Australian J. Crop Sci. 5(9):1072-1086.

1578. **Jaradat, A.A.** 2011. Polymorphism, population structure, and multivariate relationships among secondary traits in open-pollinated corn heterotic groups. Communications in Biometry and Crop Sci. 6(1):4-20. http://hdl.handle.net/10113/49374

1580. **Jaradat, A.A., and S.L. Weyers.** 2011. Statistical modeling of yield and variance instability in conventional and organic cropping systems. Agron. J. 103(3):673-684. http:// hdl.handle.net/10113/49953

1581. **Johnson, J.M.F.,** D.W. Archer, D.L. Karlen, **S.L. Weyers**, and W.W. Wilhelm. 2011. Soil management implications of producing biofuel feedstock. p. 371-390. In: J. Hatfield and T. Sauer (eds.) Soil management: Building a stable base for agriculture. American Society of Agronomy Series. American Society of Agronomy and Soil Science Society of America, Madison, WI.

1588. **Johnson, J. M-F**., D.W. Archer, **S.L. Weyers**, and **N.W. Barbour**. 2011. Do mitigation strategies reduce global warming potential in the northern U.S. Corn Belt? J. Environ. Quality 40:1551-1559.

1589. **Johnson, J.M-F.,** and T. Didreckson. 2011. Best management practices: Managing cropping systems for soil protection and bioenergy production [CD-ROM]. In Rasmussen, L., editor. Biomass Gasification: A Comprehensive Demonstration of a Community-Scale Biomass Energy System. Final Report to the USDA Rural Development Grant 68-3A75-5-232. Morris, Minnesota.

1586. Karlen, D.L., G.E. Varvel, **J.M-F Johnson**, J.M. Baker, S.L. Osborne, J.M. Novak, P.R. Adler, G.W. Roth and S.J. Birrell. 2011. Monitoring soil quality to assess the sustainability of harvesting corn stover. Agron. J. 103(1):288-295. http://hdl.handle.net/10113/49995

1546. Kim, K-I., **R.W. Gesch**, S.C. Cermak, W.B. Phippen, M.T. Berti, B.L. Johnson and L. Marek. 2011. Cuphea growth, yield, and oil characteristics as influenced by climate and soil environments across the upper Midwest USA. Industrial Crops Products. 33:99-107. http://hdl.handle.net/10113/49051

1587. **Weyers, S.L.,** and K.A. Spokas. 2011. Impact of biochar on earthworm populations: A review. Applied and Environmental Soil Science. DOI: 10.1155/2011/541592.

1561. Wilhelm, W.W., **J.M. Johnson,** D. Lightle, D.L. Karlen, J.M. Novak, **N.W. Barbour**, D.A. Laird, J.M. Baker, T.E. Ochsner, A.D. Halvorson, D.W. Archer, F.J. Arriaga. 2011. Vertical distribution of corn stover dry mass grown at several U.S. locations. BioEnergy Res. 4(1):11-21. http://hdl.handle.net/10113/47802

Appendix 2

Lab Employees

Amundson, Gary – Engineering Technician
Barbour, Nancy – Biologist
Boots, Dana "Joe" – Ag Science Research Technician (Plants)
Burmeister, Beth – Office Automation Assistant
Eklund, James – Computer Assistant
Eystad, Kathryn – Office Automation Assistant
Forcella, Frank – Research Agronomist
Gesch, Russell – Research Plant Physiologist
Groth, Pamela – Administrative Officer
Hanson, Jay – Physical Science Technician
Hennen, Charles – Ag Science Research Technician
Jaradat, Abdullah – Supervisory Research Agronomist,
Research Leader and Location Coordinator
Johnson, Jane – Research Soil Scientist (Plant Biochemist)
Kestner, Katie – Biological Science Aid
Klein, Nicholas – Biological Science Aid
Larson, Scott – Ag Science Research Technician (Soils)
Peterson, Dean – Ag Science Research Technician
Porcher, Elise – Biological Science Aid
Rinke, Jana – Chemist
Rohloff, Shawn – Purchasing Agent OA
Rollofson, Chad - Biological Science Lab Technician
Starr, Jon – Computer Assistant
Wagner, Steve – Electronics Engineer
Wente, Christopher – Ag Science Research Technician
Weyers, Sharon – Research Soil Scientist (Soil Biologist)
Wilts, Alan - Chemist
Winkelman, Larry – IT Specialist (Customer Support)

Appendix 3

2011 Field Day

The North Central Soil Conservation Research Laboratory (Soils Lab) celebrated its annual field day on Thursday, August 18, 2011, at the Swan Lake Research Farm. The theme was "Sustainable Landscapes: Food, Feed, Fuel, and Future" The Field Day highlighted: Ecosystems services provided by new/alternative biomass and oilseed crops being developed for biofuels and bioproducts, and proper management of conventional crops to provide food, feed, and fuel.

Appendix 4

Other Outreach

Over the past year, the Soils Lab teamed up with local schools and organizations to promote agricultural research through several outreach events.

Science Fair

Throughout the year, staff members partnered with the Morris Area Elementary and High Schools to design science fair projects and to serve as judges for the Science & Math Expo and the high school science fair.

Eyeglass Drive

As part of the National Disability Awareness Month, the Soils Lab employees partnered with the Morris and Hancock Lions Clubs and the Federal Executive Board of Minnesota to collect eyeglasses for Vision 2020: The Right to Sight.

This is a global partnership of United Nations agencies, governments, eye care organizations, health professionals and philanthropic institutions working together to eliminate preventable blindness by the year 2020.

Bonanza Education Center and SWELL

This past year, Gary Amundson gave presentations on causes and effects of compaction at the Bonanza Education Center by Clinton, MN. Five sessions were presented at the Bonanza Education Center on May 5th, to a total of 82 Students. Gary presented 5 sessions at SWELL (Scandia Woods Environmental Learning Lab, Morris, MN) on Sept. 29th to approximately 100 students. The presentation covers causes of compaction, its effect on soil structure (which affects plant growth and water infiltration) and ways to reduce the effects of compaction.

Gary Amundson giving his compaction presentation to students.

Appendix 5

Barnes-Aastad Association

The USDA-Agricultural Research Service (ARS) North Central Soil Conservation Research Laboratory ("Soils Lab") in Morris was established in the late 1950's. Dr. C.A. Van Doren, the first director, recognized the need for long-term access to land for conducting soil erosion research.

In 1959 a small group of conservation-minded farmers and business people came together to support Dr. Van Doren's vision for agricultural research in the upper Midwest. This group formed and incorporated the Barnes-Aastad Soil and Water Conservation Research Association with a mission to support agricultural research. They sold shares to raise capital to purchase land with the desired characteristics: predominantly Barnes-Aastad soil type with a 6% slope located near a source of water. The following year they purchased 80 acres bordering Swan Lake in Swan Lake Township of Stevens County. This property became known as the Swan Lake Research Farm.

The Barnes-Aastad Association leases the Swan Lake Research Farm to the ARS Soils Lab. The farm has since been expanded to 130 acres to accommodate a wide range of field studies, including land management, soil carbon cycling, crop and weed biology and sustainable cropping systems.

At their annual meeting held each April, they invite the ARS Soils Lab staff to present progress reports on their research. The Barnes-Aastad Association serves as a grass roots advisory group for the ARS Soils Lab by giving input on research needs not only from the farmers' standpoint, but also as a voice for rural society.

Each year the Barnes-Aastad Association sends a delegation of volunteers to Washington, D.C., to express their support for agricultural research. Recognizing that agricultural and environmental problems often do not have geographic boundaries, the Barnes-Aastad Association also interacts with groups supporting research at other institutions in the upper Midwest. This gives them a stronger voice when meeting with legislators. The 2012 delegation included Sue Dieter, Dean Meichsner, Dan Perkins, and Jim Wink.

Since the first informational meeting in 1959, the Barnes-Aastad Association membership increased from several people to a membership of 70. Members come from a wide range of occupations, but all have a common goal of protecting our fragile natural resources and stabilizing the economy of rural America. According to Jere Ettesvold, president of the Barnes-Aastad Association, the mission of Barnes-Aastad Association has not changed. "Research is the key to the advancement of agriculture."

Swan Lake Research Farm

This 130-acre research farm is owned by the Barnes-Aastad Soil and Water Conservation Research Association, a non-profit organization of farm managers and agri-business personnel, committed to supporting the research program of the USDA-ARS Soils Lab in Morris, MN.

Please contact Dean Meichsner if you would like to join the Barnes-Aastad Association at 6 Pomme de Terre Lane, Morris, MN 56267 or phone: (320) 589-2104.

The North Central Soil Conservation Research Laboratory
803 Iowa Avenue
Morris, MN 56267
Phone: 320-589-3411

Acknowledgements: A special thank you to all who contributed to the Research Report.