Research Report

The North Central Soil Conservation Research Laboratory

Morris, Minnesota

April 5, 2007

Lab Mission:

"Develop agricultural systems in the Midwest that are environmentally, economically and socially sustainable by providing knowledge and technologies for proper land, crop and weed management to enhance the biological, chemical and physical properties of soils and to improve environmental quality."

Preface

A.A. Jaradat
Research Leader

The "Soils" Lab continued to conduct its multidisciplinary research program in collaboration with farmers, federal research labs, and universities. With the support of the Lab's stakeholders, the Barnes-Aastad Association, new agreements were signed with farmers and new on-farm and farm-scale experiments were conducted to solve agricultural problems faced by farmers in this part of the country.

We continued to carry out research on soil and land management, global climate change, new crops and integrated cropping systems. The first two of our research projects were renewed last year and we will be working with our stakeholders to renew the last two so that we address real farming problems and come up with practical solutions to these problems.

In a continued effort to involve our stakeholders and farmers in planning our future research program, the Lab invited a farmer to participate in the national workshop of the Integrated Cropping Systems Project. In addition, the Lab organized a number of "listening" sessions where stakeholders contributed valuable ideas for the future development of our research program. It is needless to say that we, as research scientists working to solve agricultural problems, would like to listen to farmers and stakeholders, learn from their experiences, and jointly identify current and future agricultural problems. The long-term objective of this effort is to help maintain a dynamic dialogue between researchers, stakeholders, and farmers so that we, as a group, help conserve our soils as a natural resource, optimize agricultural production and protect the environment.

The 50th anniversary of the Soils Lab is approaching, and in 2008 we will be celebrating this occasion along with our stakeholders, collaborators and farmers. During 2004, we joined the nation in celebrating the 50th anniversary of the Agricultural Research Service (ARS), the USDA's main in-house scientific research agency.

As a part of ARS, this Lab contributed to the missions of USDA and ARS by finding solutions to agricultural problems that affect Americans every day, from farm to table. Most recently, however, ARS and this Lab are facing more challenges with the rise of energy costs and the need to produce more energy from agriculture.

The Soils Lab is in position to respond to these challenges; we already embarked on developing agricultural systems capable of meeting energy demands and increasing economic returns to farmers while protecting the water and soil resources. Farmers and stakeholders are demanding practical recommendations and answers to on-farm production problems. They want to know the environmental and economic impacts of planting bioenergy crops on a landscape scale; the agronomic, environmental and economic impacts of harvesting crop biomass from their land; and the impact of farm-based renewable products on the sustainability of the rural economy.

Our research team, in collaboration with partners around the country such as University of Minnesota - Morris, the Renewable Energy Assessment Program (REAP), the Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet), Technology Crops International, Landec Ag Corporation and the Energy and Environmental Research Center of the University of North Dakota are working together and with farmers to develop sustainable cropping systems that are capable of providing food, fiber, feed and fuel for the nation while protecting the environment.

This has been another year to celebrate the proud past of the Soils Lab and the Agricultural Research Service.

We look forward to serving the rural farming community and to celebrating the Lab's 50th anniversary.

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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.

Sue Dieter, Representative Collin Peterson, Dean Meichsner, Dan Perkins, Carolyn Peterson, John Mahoney and Jim Wink in Washington, DC, March 2007 .

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. The Barnes-Aastad Association believes strongly that research is the key to the advancement of agriculture.

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 2007 delegation included Sue Dieter, Dean Meichsner, Dan Perkins, Carolyn Peterson, John Mahoney and Jim Wink.

Since the first informational meeting in 1959, the Barnes-Aastad Association membership has 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. "Barnes-Aastad is committed to supporting the research program of the ARS Soils Lab in Morris."

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.

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Soils Lab Scientists

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Soil physics with particular emphasis on the mathematical modeling of soil gas transport, surface emissions and factors affecting production.

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

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Tillage-induced carbon dioxide loss and developing improved soil and residue management practices to enhance carbon sequestration and environmental quality

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Simulation modeling-based estimation of the economic and environmental effects of management practices aimed at carbon sequestration for ARS research sites across the U.S.

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C and N dynamics of plants and soils as related to C sequestration and greenhouse gas emissions across the U.S.

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Weed ecology, management, and modeling, with the goal of achieving "right-input" agriculture

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Interdisciplinary research to develop management practices for American agriculture that minimize environmental contamination while maintaining production

Russell Gesch
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Identifying and characterizing biological factors in crops and management strategies for improving tolerance to environmental stress, and development of new/ alternative crops

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Soil biology in relation to soil quality and land management issues

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Michael Lindstrom
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Soil movement by tillage and effects on long-term soil sustainability

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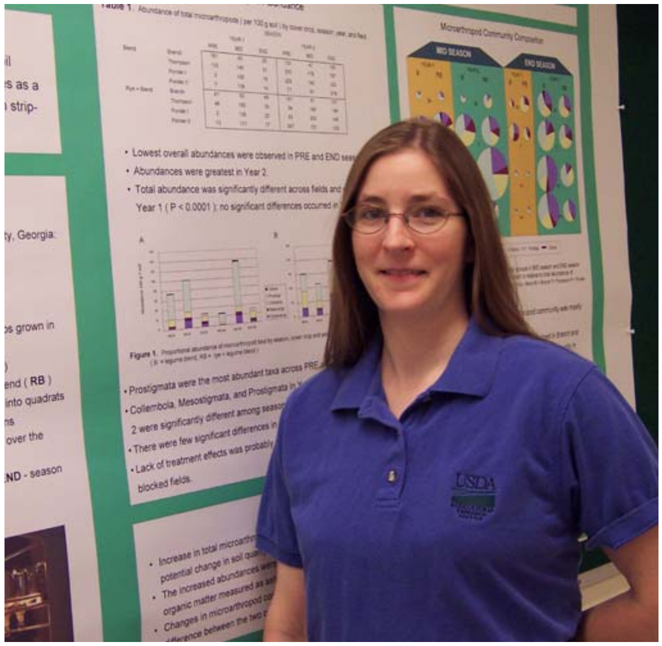
Agronomic effects of soil compaction caused by wheel traffic of farm machinery

Scientific Awards

Outstanding Reviewer Recognition



The Agronomy Journal awarded Sharon Lachnicht Weyers the Editors' Citation for Excellence in Manuscript Review, Outstanding Reviewer in 2006.

Excellence in Technology Transfer Award

Russ Gesch and Frank Forcella, as part of a group of USDA-ARS scientists researching cuphea, received an Honorable Mention for the Federal Laboratory Consortium Award for Excellence in Technology Transfer, 2006 (First Commercialization of the New Crop Cuphea).

Cropping Systems to Management to Promote Economic and Environmental Sustainability

David Archer (Lead Scientist), Abdullah Jaradat, Frank Forcella, Russ Gesch, Sharon Lachnicht Weyers, Jane Johnson, Don Reicosky and Hillarius Kludze

Problem to be addressed:
Increasing economic pressures and continued environmental concerns in agricultural production have heightened the need for more sustainable cropping systems. Research is needed to 1) identify systems that simultaneously improve the economic and social viability of farms and rural communities while protecting the environment and improving or maintaining our natural resource base, and 2) provide tools that will allow producers to utilize current science to manage their farms more sustainably.

2006 Progress Highlights
The farming systems long-term study was continued through a fifth cropping season in 2006. This study continued to be the primary focus of this research project. Research results from the first four years of the study, representing at least one full crop rotation cycle for each of the treatments, were presented by several of the team members at professional meetings and submitted for journal publication.

Similar to the experiences of many organic producers, managing weeds within the organic cropping system treatments has proved to be a challenge. However, despite increased weed pressures, several organic treatments are able to generate economic returns comparable to or exceeding returns from conventional systems. These results gained substantial public exposure for the project when they were featured in an ARS national press release. The news release was distributed by numerous web sites and publications, and also resulted in radio interviews that were aired across Minnesota and Wisconsin.

The farming systems plots continue to be intensively monitored to develop a better understanding of how the wide range of cropping system treatments being studied affect weed populations, crop stresses and growth, soil biological processes and nutrient cycling, and greenhouse gas emissions. A simulation modeling analysis of the alternative cropping systems is also being conducted to determine the potential for building organic matter, and identify the economic incentives that might be needed for farmers to adopt practices that lead to increased carbon storage in the soil.

The WeedCast decision aid and the Nitrogen Decision Aid both continue to be used in making management decisions on the farming systems plots. Improvements to WeedCast continue to be made as new information is collected, and both decision aids are freely available for download at:
http://www.ars.usda.gov/Services/docs.htm?docid=11787

The project team continues to explore ways to make the information in WeedCast more easily accessible through such things as interactive web pages linked to real-time weather station data. The Nitrogen Decision Aid has been downloaded nearly 1500 times and WeedCast about 3000 times since their initial release.

Evaluation of Net Soil Carbon Storage and Carbon Credits in Alternative Cropping Systems

Hillarius Kludze and David Archer

As part of the long-term Cropping systems research initiated in 2002 at the Swan Lake site, we analysed the net soil carbon (C) sequestration (SCS) potentials and economic performance of a range of alternative cropping systems in the production of corn, soybean, spring wheat, and alfalfa. We specifically sought to (1) determine net carbon stored in the soil when carbon emissions from consumption and processing of energy resources used to produce crops are considered, and (2) estimate incentives and ***"carbon credits"*** required to encourage producers to switch from the baseline system of growing corn and soybean in a two-year rotation to alternative systems. In this context, a "carbon credit" is a payment in dollar value of carbon that would be made to producers to encourage a switch from the baseline (business-as-usual: BAU) cropping system assumed to have less carbon storage potential to a system with a more favorable C storage potential. The BAU/baseline system is the predominant cropping system for growing corn and soybean in the Midwest.

The global nature of greenhouse-gas (GHG) emission has generated great interest in market-based approaches to address global warming. For example, a market-based approach that allows businesses to offset their GHG emissions is based on the premise that by purchasing ***carbon credits*** from producers/landowners, the latter would adopt practices that could increase SCS and/or reduce overall C emissions and earn extra income in the bargain. Many of the factors affecting the flow of C into and out of soils are affected by land-management practices. Research is therefore being directed at evaluating management practices such as reduced tillage, increased crop rotation, and altering soil inputs to increase soil organic carbon (SOC) pools without jeopardizing other environmental services or net returns. In our analysis, we compared the direct and indirect energies required to determine C credits in each cropping system by accounting for C emissions from crop production inputs. We calculated net returns to land and management using enterprise budgets derived from production practices, input use, and observed crop yields under each cropping system. Soil carbon storage/sequestration values were obtained from simulated EPIC outputs.

Overall, C gains were somehow higher in organic (ORG) and strip-tillage (ST) systems compared to their conventional (CNV) and conventional-tillage (CT) counterparts both before and after C emissions from field operations and production inputs were included in the analysis. The impact of including C emissions on net C sequestration appeared to be insignificant, indicating that accounting for CO_2 emissions from production inputs may not be necessary in issuing C credits. Observed field results as well as data from other C sequestration practices and regions are however necessary to test the reliability and consistency of our results.

Total costs for ST treatments were generally lower than for those with CT, with the exception of the four-year organic (ORG-4YR) treatments (see Table). This was largely due to reductions in machinery ownership costs. Input costs were lower for the ORG treatments than for their CNV counterparts; however, this cost reduction was offset by the cost of manure handling and loading, added diesel fuel costs and added labor costs. The baseline/BAU system had the second highest net return, but also provided the second lowest C storage potential. The system under organic treatment with conventional tillage and manure fertilization under a two-year rotation (ORG-CT-2YR-YF) was the most profitable ($289.00 ha^{-1}) and was also a better accumulator of C than the baseline system; producers would require no C credit to be encouraged to switch to this system. The C credit of $46.25/kgC/year needed to encourage a switch from the baseline system to the system with conventional tillage and chemical fertilization under a four-year rotation (CNV-ST-4YR-YR) appears relatively reasonable as this value is consistent with results in the literature. Carbon credits for all other systems were very high, and it is unlikely that C traders would be prepared to pay such amounts to producers to encourage a switch. To substantiate our results, future studies will have to use actual measured soil carbon data obtained from various farm sites and locations within the Midwest area.

Table 1. Soil Carbon and Economic analyses of alternative cropping systems

	CNV†								ORG							
	CT				ST				CT				ST			
Cropping Systems ?	**2YR**	**2YR**	**4YR**	**4YR**	**2YR**	**2YR**	**4YR**	**4YR**	**2YR**	**2YR**	**4YR**	**4YR**	**2YR**	**2YR**	**4YR**	**4YR**
	YF	**NF**	**YF**	**NF**	**YF**	**NF**	**YF**	**NF**	**YF**	**NF**	**YF**	**NF**	**YF**	**NF**	**YF**	**NF**
Total Costs ($/ha)[a]	495	413	454	402	471	393	428	379	516	441	459	409	500	423	482	438
Net return[b] **($/ha)**	216.00	145.00	154.00	100.00	105.00	144.00	145.00	95.00	**289.00**	175.00	163.00	159.00	138.00	113.00	-88.00	-38.00
Soil sequestered (kg/ha/yr[c]																
Soil C gain	**61.00**	**45.45**	**95.66**	**74.82**	**130.00**	**82.78**	**136.88**	**84.00**	**67.26**	**46.00**	**97.60**	**77.21**	**138.00**	**90.34**	**145.64**	87.00
Difference in **C** relative to 'BAU' (kg/ha/yr)		-15.55	34.66	13.82	69.00	21.78	75.88	23.00	6.26	-15.00	36.60	16.21	77.00	29.34	84.64	26.00
C incentive required[d] ($/ha)	—	71.00	62.00	116.00	111.00	72.00	71.00	121.00	-73.00	41.00	53.00	57.00	78.00	103.00	304.00	254.00
C credit required to switch ($/kg C)	—	-4.57	1.79	8.39	1.61	3.31	0.94	5.26	**-11.66**	-2.73	1.45	3.52	1.01	3.51	3.59	9.77
Net C sequestration (kg/ha/yr) [e]																
Net C Gain (Kg/ha/yr)	18	21.05	54.26	51.22	87.58	55.98	110.48	57.2	38.46	24	71.94	52.75	115.38	70.72	130.6	66.12
Difference in **C** relative to 'BAU' (kg/ha/yr)	—	3.05	36.26	33.22	69.58	37.98	92.48	39.20	20.46	6.00	53.94	34.75	97.38	52.72	112.60	48.12
C incentive required[d] ($/ha)	—	71.00	62.00	116.00	111.00	72.00	71.00	121.00	-73.00	41.00	53.00	57.00	78.00	103.00	304.00	254.00
C credit required to switch ($/kg C)		23.28	1.71	3.49	1.60	1.90	0.77	3.09	**-3.57**	6.83	0.98	1.64	0.80	1.95	2.70	5.28
C Emissions (kg/ha/yr)																
Soil C gain (kg/ha/yr)	61.00	45.45	95.66	74.82	130.00	82.78	152.88	84.00	67.26	46.00	100.00	77.21	138.00	90.34	155.64	87.00
C Emissions (kg/ha/yr)	43.00	24.40	41.40	23.60	42.42	26.80	42.40	26.80	28.8	22	28.06	24.46	22.62	19.62	25.04	20.88
Emissions as a % of SCS	70.49	53.69	43.28	31.54	32.63	32.37	27.73	31.90	42.82	47.83	28.06	31.68	16.39	21.72	16.09	24.00

† CNV: conventional system, ORG: organic system; CT: conventional tillage; ST: strip tillage; 2YR: corn-soybean rotation; 4YR: corn-soybean-wheat/alfalfa-alfalfa rotatio

YF: fertilizer or manure applied at recommended rates, NF:no added fertilizer or manure

‡ Business-As-Usual system /Baseline cropping system (CNV-CT-CS-YF)

[b] Average of annual net returns to land and management.

[c] Sequestered soil C excluding C emissions adjustment

[d] Value required to make alternative system equal to 'BAU' system

[e] Sequestered C including C emissions adjustment

Farming Systems Research CRIS

Sharon Lachnicht Weyers

Dr. David Archer, Agricultural Economist, was the project leader on the Farming Systems CRIS. He is now located at the ARS laboratory in Mandan, ND, where he will be focusing on agricultural and economic aspects of integrating crop and livestock systems. Dr. Archer led research that examined agricultural and economic risk of conventional and organic production systems, including aspects of transitioning into organic production. Dr. Archer will still be collaborating with scientists here at NCSCRL and finishing up economic analyses on the systems plots at Swan Lake. He can be reached at David.Archer@ars.usda.gov.

Every five years the Agricultural Research Service National Program Staff reviews and re-establishes research criteria that "brings coordination, communication and empowerment" to research projects carried out by ARS scientists around the country. This year, 2007, marks the end of the five year cycle for National Program 207 "Integrated Agricultural Systems" under which the Systems Plots study was initiated. We will renew our project plan for the 2008-2012 cycle under the NP 207 program now renamed as NP 216 "Agricultural System Competitiveness and Sustainability." (Information on the National Programs can be found at http://www.ars.usda.gov/research/programs.htm.)

For our new project we will be considering enhanced management approaches for the organic treatment plots at Swan Lake. This enhanced approach is required because of issues dealing with weed control and errant growth of annual alfalfa, which was used as one of the four crops in our 4-yr rotation treatment. Weeds and alfalfa are an issue in the organic treatment because we are limited to organic means of control, meaning we can't use inorganic pesticides. Because we also have a tillage treatment, those plots where we have attempted a strip-till operation have been suffering the most. Delayed planting, mowing, and in-row cultivation with a roto-tiller have been our primary means of control. This season we will attempt to use tillage, winter rye (for its alleopathic effect), and a living mulch, red clover, to control the alfalfa and weeds. Look for the results in next years' report.

To keep in the vein of the "systems" research that Dr. Archer initiated, we are developing and expanding our Swan Lake research efforts for the new cycle. We will do this by evaluating the diverse production systems found in our region through on-farm assessments.

There is a lot of diversity across the landscape in the Stevens-Pope County region. Wildlife areas, wetlands and lakes are interspersed among vast agricultural fields. There is even diversity to be seen in livestock production: milk, beef, pork and poultry systems dot the landscape with pasture, livestock barns and feed lots.

We are in the midst of establishing partnerships within the community to help us evaluate aspects of regional land management that will conserve nutrients and improve the socio-economic livelihood essential for sustainability of our agricultural systems. We will be conducting soil sampling across farms, fields, pastures, and prairie to measure nutrient availability and movement. There is likely to be limited scale assessment of insect and weed pest diversity to establish landscape factors that influence pest dynamics.

As we are in the development stage there is opportunity to get involved. We are looking for access to production systems that are conventional or organic; livestock systems that involve dairy, beef or other animals; systems that use green or livestock manures; land in CRP, CREP or other fallow; and systems which may or may not be adjacent to a wetland or other wildlife area.

If you wish to participate, want to acquire more information about this research, or be kept informed of our progress, please contact Sharon Weyers.

This is an aerial view taken west of Cyrus overlooking Long Lake, Round Lake, Lake Cyrus and Lake Charlotte. In the forefront is land in CRP and a state wildlife/wetland area.

Farming Systems: Soybean's Yield is Determined by its Architecture

Abdullah Jaradat, Derya Surek, Dave Archer and Steve Van Kempen

Reliable models are needed to describe plants with complex geometric structures, quantify the impact of management strategies on the plant's geometric distribution in space and time, and predict yield as a function of fractal dimension (i.e., geometric structure). We measured growth and development variables on single soybean [*Glycine max* (L.) Merr.] plants under five management strategies in the upper Midwestern USA. Measurements derived from digital imagery of stems and leaves were subjected to multivariate and neural network analyses to identify interrelationships among plant variables and the impact of management strategies on these variables. Plants grown under different management strategies differed significantly in their geometric structures, and were classified into their proper categories with 75 to 100% correct classification, based mainly on differences in their fractal dimension (*Do*), midday differential canopy temperature (*dT*), and canopy light interception [Log(*I/Io*)]. A multilayer perception neural network with back propagation identified plant dry weight, volume, circularity (ratio of minor to major axes) and perimeter, in decreasing order, as reliable predictors (R^2=0.76) of *Do*. The fractal dimension was the most important predictor in a generalized regression neural network, followed by plant dry weight, volume and circularity, in decreasing order, in predicting grain yield m^{-2} (R^2=0.79). A conventional system with moldboard tillage created the most ideal microenvironment for single soybean plants to develop complex geometric structures, with significantly larger *Do* (1.477) values and grain yield (11.2 g $plant^{-1}$) as compared to plants grown under organic system with strip tillage (*Do* =1.358, and grain yield = 2.32 g $plant^{-1}$). Knowledge of how plants respond to single and multiple management strategies will help agronomists develop better predictive models and will help farmers refine management practices to optimize yield.

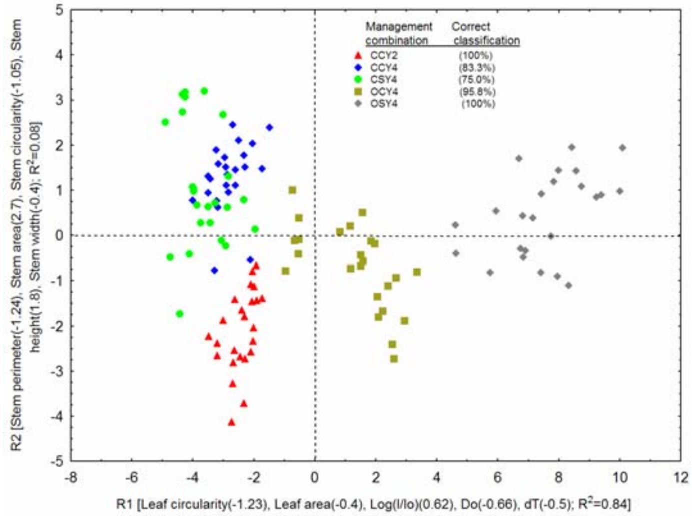


Figure 1. Canonical discriminant analysis and percent correct classification of soybean plants grown under five management strategies (CCY2= Conventional system, conventional tillage, with fertilizer and 2-year crop rotation; CCY4= Conventional system, conventional tillage, with fertilizer and 4-year crop rotation; CSY4= Conventional system, strip tillage, with fertilizer and 4-year crop rotation; OCY4= Organic system, conventional tillage, with fertilizer and 4-year crop rotation; and OSY4= Organic system, strip tillage, with fertilizer and 4-year crop rotation) and based on plant architecture.

N Mineralization in the Farming Systems

Sharon Lachnicht Weyers and Alan Wilts

Soil nitrogen comes in two forms, mineral and organic. Mineral nitrogen is the form of N that is available for plant uptake. Organic N has to be broken down by soil organisms into mineral forms before plants can use it. Conventional fertilizers, such as anhydrous ammonia, urea, and ammonium nitrate, are readily available mineral forms.

We have been measuring mineral N availability and the mineralization process of organic N breakdown (decomposition) in the Farming Systems experiment at Swan Lake, for the past two years. Measurements started mid-late June (around Day 170) after planting and all field cultivation for weed control was completed. We continued measuring mineral N during the growing season until early October (around Day 248), typically the culmination of harvest. Mineral N was measured in soil extracts in bulk soil, incubated soil (10 cm depth) and cation/anion-exchange resins that trapped solute flow (water moving through the top 10 cm of soil).

In reading the figures keep these points in mind: conventional management (CNV) indicates yearly inorganic fertilization, organic management (ORG) indicates organic fertilizer last applied in April 2006; data were collected in strip-tilled, four year rotation plots (Corn-c; Soybean-s; Wheat-w; Alfalfa-a); Similar line colors/ symbols from 2005 to 2006 indicate the same plots in the rotation-corn followed by soybean, soybean followed by wheat, etc.; dotted lines were used for 2006; Day of year indicates the continuous numbering of days: January 1, being the first day of the year, and December 31st being the 365th day of the year (366th in leap years).

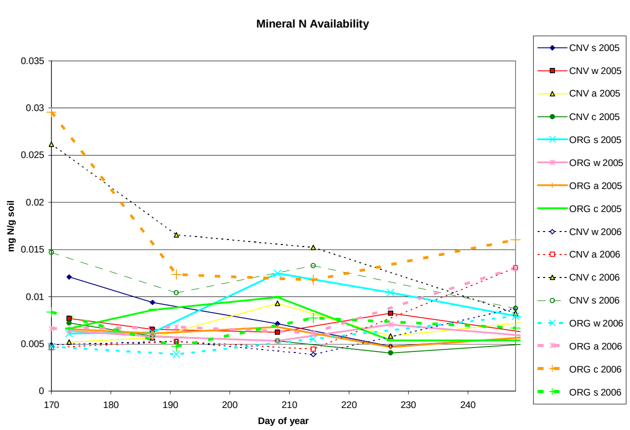


Figure 1. Standing stocks of mineral N indicate the amount of N available (mg per gram of soil) at any specific time during the growing season.

It was clear that the greatest N availability occurred early in the season, Day 170, which probably indicates the amount of N remaining after fertilization and the pulse of soil activity due to early rains that year (Figure 1). The greatest amounts were measured in 2006, when we started three days earlier than in 2005 (June 19th). Mineral N availability varies over the growing season with plant demand. Availability will typically increase at the end of the season as plant demand declines. In Figure 1, it was obvious that the greater amounts of N were available in 2006 (dotted lines), and in organic treatments specifically corn which follows in the rotation after alfalfa (a natural green manure). The peak in 2006 conventional corn was due to application of anhydrous ammonia just 6 days before sampling.

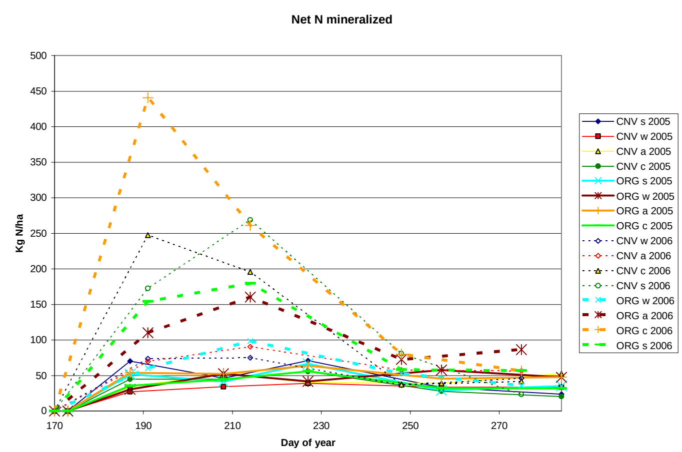


Figure 2. Net N mineralized indicates the amount of mineral N (kg per ha), excluding plant uptake, made available over a period of time through decomposition processes in the soil.

Similar to the standing stock of mineral N, the greatest amount of mineralization occurred in 2006 (dotted lines; Figure 2). In 2005, mineralization processes seem to be steady; that is the mineralization process was fairly constant. In 2006, there was a high peak in mineralization at day 191, July 10th , for organic and conventional corn (C), and on day 214, August 2nd, for organic and conventional Soybean (S), with less of a peak for alfalfa and wheat in both systems. The data for 2006 seemed unusual; however, we started off the year with early rains and then moved into drought conditions by the end of the season.

Looking at the cumulative amount of N mineralized it is quite obvious that most of the mineralization takes place in the early part of the growing season (steeper inclines; Figure 3). In 2006, mineralization slowed down by day 214; however, in 2005, rate of mineralization appeared to be more constant. The greatest amount of mineral N made available for potential plant uptake occurred under organic

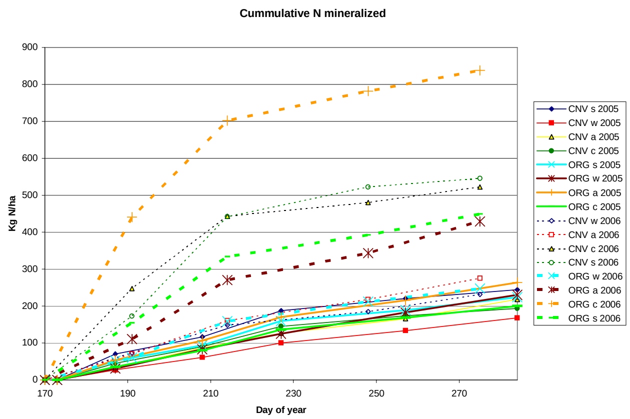


Figure 3. Cumulative amount of N mineralized gives an indication of the rate and final total amount of mineral N made available during the observation period.

management in the corn rotation, for 2006, followed by conventional soybean and corn, organic soybean, and alfalfa, conventional alfalfa, then organic wheat. In 2005, the greatest amount of N was mineralized in organic alfalfa (which was followed by Corn in 2006). Mineralized N followed in decreasing amounts from conventional soybean, organic wheat, organic soy, conventional alfalfa, organic corn, conventional corn, and conventional wheat in 2005

Although we have not resolved all the intricacies of mineralization in this experiment, it is quite clear that mineralization processes in the organic system provide a great deal of the necessary plant nutrients. It is also important to recognize that soybean and alfalfa provide sources of fixed N and green manure for the system.

Soil Carbon Cycling, Trace Gas Emission, Tillage and Crop Residue Management

Jane Johnson (Lead Scientist), Don Reicosky, Sharon Lachnicht Weyers, Abdullah Jaradat and Russ Gesch
Post-doctoral contributors: Kurt Spokas and Hilla Kludze

Problem to be addressed:

The cool, wet soils found in Northern states such as Minnesota cycle carbon more slowly than their southern counterparts. These soils may be able to store carbon that is stable over long periods, thus offering a potentially important way of offsetting the increase in atmospheric carbon dioxide (CO_2). Understanding how the biology, chemistry and physics of soil are impacted by management will lead to improved land management. It is important to identify management that is agronomically and economically successful, while protecting the environment.

Goals and objectives: The overall goal is to develop agricultural management systems that can readily adapt to climate change and to mitigate greenhouse gas accumulations. We have two general objectives, first to see how a agricultural management impacts greenhouse gas emission (N_2O, CH_4 and CO_2) and carbon storage; second, to study how global climate change may impact agricultural crops. Some of the experiments are continuations of existing work, with additional studies planned.

2006 Progress Highlights

Agricultural impacts and mitigation of greenhouse gas

As part of the USDA-Agricultural Research Service, Greenhouse gas Reduction through Agricultural Carbon Enhancement (GRACEnet) three different scenarios:

The “business as usual” scenario has conventional tillage (chisel or moldboard plow), and receives high fertilizer inputs in a corn-soybean rotation. The “maximum C sequestration” scenario is strip tilled with a mole-knife, and receives high fertilizer inputs in a corn-soybean-wheat/alfalfa-alfalfa rotation. The “optimum greenhouse gas benefits” scenario is strip tilled with a mole-knife but receives no fertilizer inputs in a corn-soybean-wheat/alfalfa-alfalfa rotation. Nitrous oxide and carbon dioxide emission were monitored using vented static chambers, since April 2004. The greatest nitrous oxide flux occurred during spring thaw events, which accounted for 33% to 55% of the flux for 2005 and 2006. Additional events corresponded primarily to nitrogen fertilizer events. Under these managements scenarios the soil tended to be neutral to slight methane sinks.

Laboratory incubations utilizing microbial inhibitors suggest that fungi play a larger role in the production of nitrous oxide than bacteria. This has potential management ramifications, in that management practices that stimulate fungal growth (i.e., increased residue) may also increase potential nitrous oxide production.

On-farm research with Doug Wulf comparing emission of carbon dioxide from corn with alternative forms of nitrogen application (manure and inorganic fertilizer) continues. Instrumentation in the field allows measurement of carbon dioxide once every 30 minutes, integrating the flux from about 40 acres 24/7 and 365 days of the year. Manure injection resulted in dramatically more CO_2 flux compared to the preceding day; the higher flux lasted at least 10 days. The increased CO_2 flux is partly due to incorporation, which disturbs the soil similar to tillage, and adds decomposable carbon.

A new on-farm project at Fehr’s dairy was initiated in collaboration with St. Paul ARS scientists to monitor water quality focusing on nitrogen and phosphorus. A companion study was also established at WCROC, which will monitor greenhouse gas emission at the plot scale.

Funding was secured on a 3-year project to improve methodologies for quantifying greenhouse gas emission from landfills in California. In conjunction with the Crops CRIS, a soil microclimate model to predict soil temperature and moisture conditions with limited climatic inputs was developed.

Global climate change may impact agricultural crops

New field, growth chamber and greenhouse experiments were established, in addition to existing long-term cropping systems plots, to identify plant phenotypic and biochemical attributes indicative of plant responses to environmental and management stresses. This information will be used to enhance the quantity and quality of plant input to maximize carbon sequestration and improve crop yields.

Greenhouse and growth chamber experiments were established to evaluate genotypic differences and genetic potential in switchgrass for photosynthetic acclimation to temperature fluctuations and avoidance of carbohydrate feedback inhibition of productivity. This research focuses on identifying genotypes and physiological traits to improve switchgrass biomass productivity in the northern Corn Belt.

Collectively there were over 10 publication assigned to this CRIS in 2006.

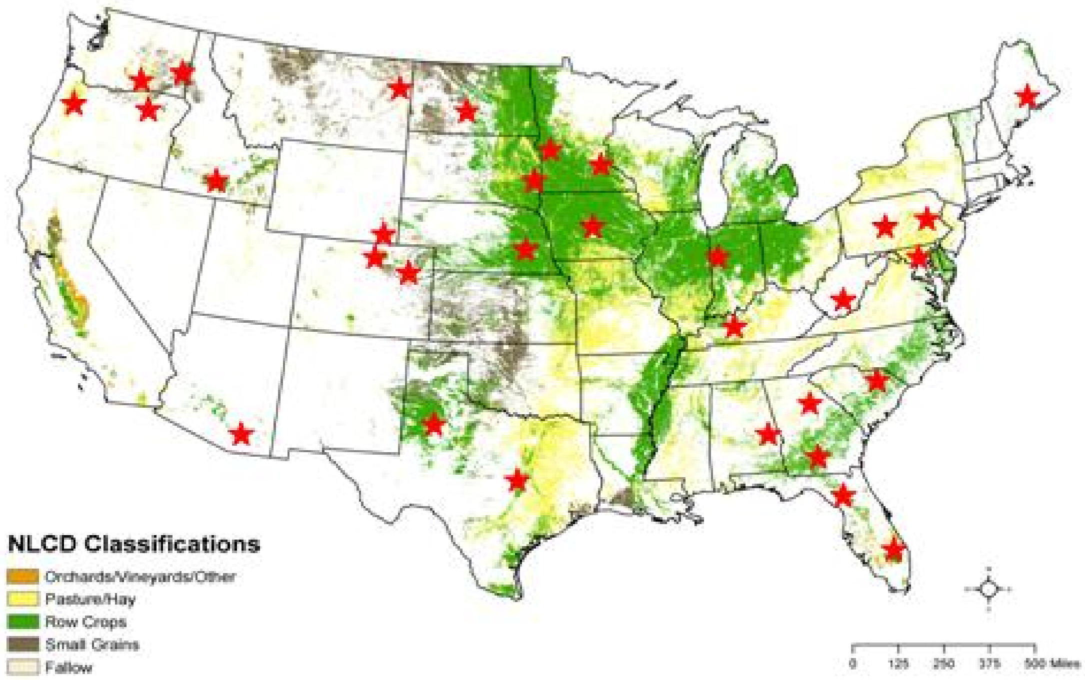
GRACEnet (Greenhouse gas Reduction through Agricultural Carbon Enhancement network) An assessment of soil carbon sequestration and greenhouse gas mitigation by agricultural management

Jane M-F Johnson

Jane Johnson is one of the four co-leaders coordinating the national GRACEnet effort. She is working with Ron Follett at Fort Collins, CO; Tim Parkin at Ames, IA; and Jeff Smith at Pullman, WA.

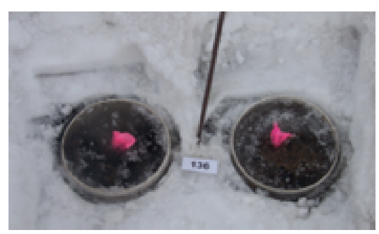
There are 30-ARS locations (red stars) across the United States participating in GRACEnet. At the Morris location Don Reicosky, Dave Archer, Hilla Kludze (post-doc) and Sharon Lachnicht Weyers are GRACEnet team-members.

The team met at Kansas City in October to review progress and review goals.



GRACEnet efforts were highlighted at the 4th USDA Greenhouse Gas Conference: Positioning Agriculture and Forestry to Meet the Challenges of Climate Change. The team published at least 24 peer-reviewed articles. Information from a recent GRACEnet review article (Liebig et al., 2005) was used in the development of a carbon credit program for the North Dakota Farmers Union in collaboration with the Chicago Climate Exchange.

The Morris team reported that the amount of trace gas (carbon dioxide, methane and nitrous oxide) emission differs among contrasting management with greatest nitrous oxide flux occurring during spring thaw in cool, wet soils. Preliminary on-farm trials suggest beneficial effects of manure on the carbon and water balances relative to inorganic fertilizers. EPIC computer model results for the field treatments show that carbon sequestration would be maximized either in an organic cropping system by using strip tillage and a corn-soybean rotation with a rye cover crop and using manure for fertility, or in a conventional system by using strip tillage and a corn-soybean-wheat/alfalfa-alfalfa crop rotation.



In addition to field work, laboratory studies were conducting, using microbial inhibitors. These experiments indicated that fungi rather than bacteria are important producers of nitrous oxide. This has important consequences in that management systems that promote fungal activity, like increased residue cover may increase the production of nitrous oxide.

Trace Gas Emission in the Farming Systems Plots

Jane M-F Johnson and Nancy Barbour

We have been measuring the emission of greenhouse gases (carbon dioxide, nitrous oxide and methane). Carbon dioxide comes from plant and soil respiration, and is released during decomposition. Nitrous oxide originates from fertilizer or legumes. There are bacteria in soil that can release methane and others that consume methane. The amount of gases that are released across a field is variable. The variability is caused by temperature, water content, nutrient availability, crop and tillage or other disturbances. Management is expected to alter flux of greenhouse gases.

Crop biomass inputs into soil are desirable to increase soil C stored thereby removing it from the atmosphere. However, the input of crop residue can increase nitrous oxide, typically more from legumes than from other crop biomass (i.e., wheat). Tillage changes the placement of residue and the rate of decomposition; therefore, tillage can change the rate of greenhouse gas flux. We are comparing the carbon storage and greenhouse gas emission from soil under different management strategies.

Three management scenarios were selected for measuring greenhouse gas emission and monitoring soil carbon storage.

"Business as usual": chisel plow (soybean) or moldboard plow (corn), high fertilizer inputs, corn-soybean rotation.
"Maximum C sequestration" strip tilled with mole-knife (only after corn and alfalfa), high fertilizer inputs, corn-soybean-wheat/alfalfa-alfalfa rotation.
"Optimum greenhouse gas benefits" strip tilled with a mole-knife (only after corn and alfalfa), no fertilizer inputs, corn-soybean-wheat/alfalfa-alfalfa rotation.

Carbon dioxide flux is higher during the growing season than in the winter (Figure 1). Higher fluxes are measured for wheat and alfalfa compared to soybean and corn because the wheat and alfalfa plants are under chamber during the measure (See photo at right). When measuring gases in corn and soybean the chamber is next to the plant or in the inter-row. Row spacing for corn and soybean is too narrow for the chamber to fit between plants (see photos at right—collars in all four crops—alfalfa, corn, wheat, and soybean).

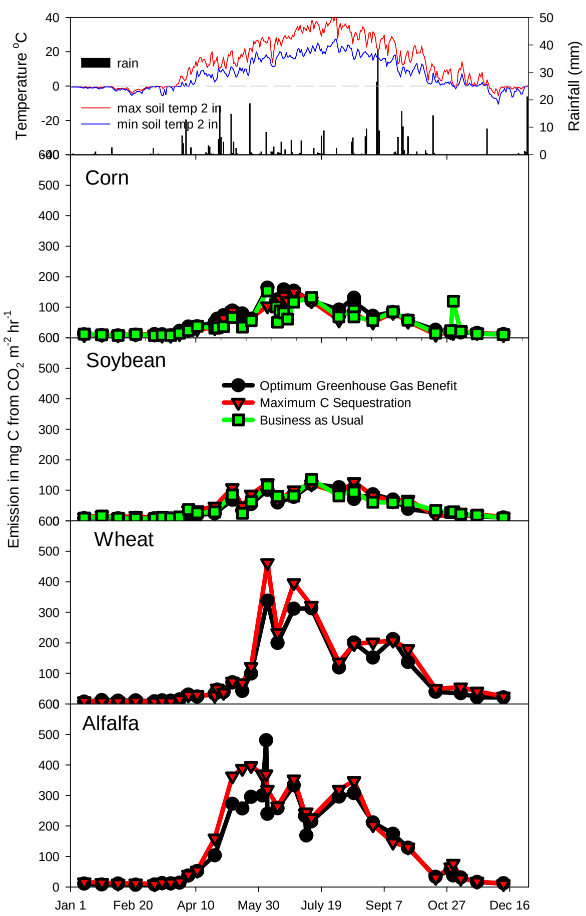


Figure 1. Carbon dioxide flux measured in 2006. Crop indicates the crop grown in 2006

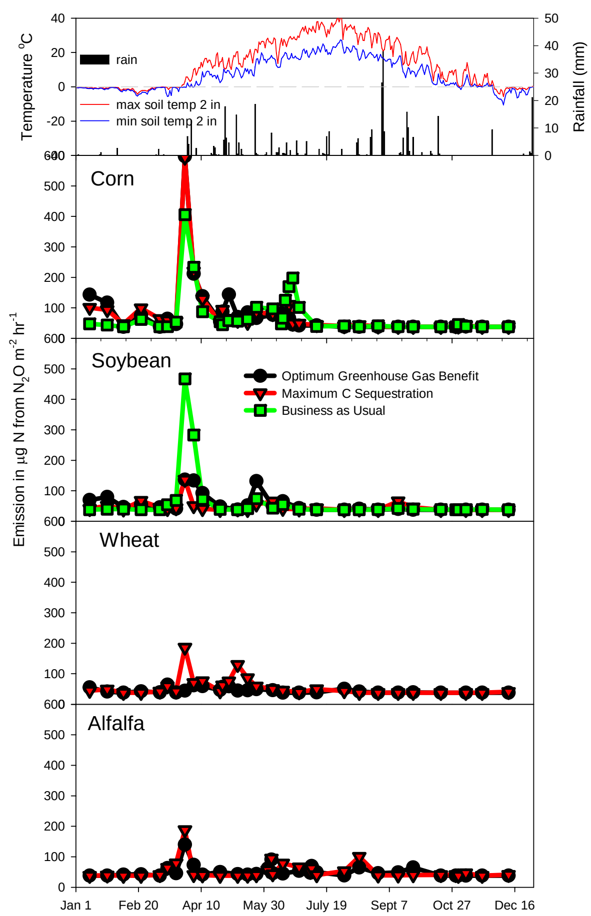


Figure 2. Nitrous oxide flux measured in 2006. Crop indicates the crop grown in 2006.

The highest nitrous oxide emission in 2006 occurred as the soil surface thawed in the early spring; this high flux was seen in all scenarios and crops (Figure 2). The largest peaks were found following alfalfa (corn in 2006) and corn (soybean in 2006). We think the cause is carry-over fertilizer from corn and nitrogen input from the alfalfa. Smaller peaks were observed in wheat and corn, which were associated with nitrogen fertilizer application. Similar results were observed in 2005, but we did not begin sampling until after the frost was out of the ground in 2004 so we missed this event (data not shown).

Global warming potential is a measure of how much a greenhouse gas contributes to global warming relative to carbon dioxide expressed on a mass or mole basis. Global warming potential allows a fair comparison among different greenhouse gases such as carbon dioxide and nitrous oxide.

Nitrous oxide has a global warming potential 296 times greater than carbon dioxide on a 100 year time scale. That is one unit of nitrous oxide is equivalent to 296 units of carbon dioxide. Methane has a global warming potential of 23 times greater than carbon dioxide on a 100-yr time scale.

When living plants are in the measurement chamber, they increase the global warming potential attributed to carbon dioxide in the optimum greenhouse gas benefit and maximum C sequestration scenario (Table 1). However, these scenarios produce enough additional root biomass to compensate for the carbon dioxide flux (data not shown). There were no measured differences in global warming potential from nitrous oxide or methane among the three scenarios. A small amount of methane was consumed in all three scenarios in 2006 and was not measured in 2004 or 2005.

Table 1. The global warming potential (GWP) from the greenhouse gases measured during each year from the three management scenarios Optimum greenhouse gas benefits (Opt. GHG benefits), maximum carbon sequestration (Max. C) and Business as usual (BAU).

Year		Opt. GHG Benefits	Max. C	BAU
2006 (Jan 11 – Dec 11)	**GWP potential from**	tons/acre		
	Carbon dioxide	2.97	3.43	1.69
	Nitrous oxide	0.24	0.24	0.26
	Methane*	-0.0017	-0.0018	-0.0018
	Total (totals/acre)	3.21	3.67	1.95
2005 (Feb 14 – Dec 20)	Carbon dioxide	2.33	2.12	1.63
	Nitrous oxide	0.18	0.15	0.15
	Total (totals/acre)	2.50	2.27	1.78
2004 (Apr 7- Nov 16)	Carbon dioxide	1.82	1.86	1.26
	Nitrous oxide	0.053	0.062	0.051
	Total (totals/acre)	1.88	1.93	1.31

*Negative value indicates reduction in Global warming potential, methane only determined in 2006.

Carbon is the "C" that starts "C"onservation

Don Reicosky

World soils serve as an important pool of active carbon (C) and play a major role in the global C cycle and contributed to changes in the concentration of greenhouse gases in the atmosphere. Society must be dedicated to investigating and protecting our global soil resources for the expanding population. The soils are the fundamental foundation of our society with soil C as one of the critical components. Agriculture has a finite amount of land suitable to support the increasing global population requiring food production systems with increasing capacity. The earth's surface area is 71% oceans and 29% land area (CIA-The World Factbook-World, 2006) with only about 14% arable land (~1,982 Mha) suitable for crop production. The scientific community has an important challenge in addressing C management of our land resources essential to ensuring food security of the expanding world population. The objective of this work is to clarify the role of C in conservation and how C management can lead to sustainable production.

Our challenge is to understand the relationship between soil C and soil organic matter (SOM) as they impact soil conservation. Soil organic matter is something we can visualize, measure, manipulate, touch; however, there are many misconceptions about SOM. Soil organic matter is the small fraction of the soil matrix, composed of anything that once lived and includes all the organic substances in or on the soil (Figure 1). It includes plant and animal remains in various states of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes. Soil organic matter refers to the sum total of all organic C-containing substances in the soil. Soil organic matter consists of a mixture of plant and animal residues in various stages of decomposition, substances synthesized microbiologically and/or chemically from the breakdown products, and the bodies of live and dead microorganisms and their decomposing remains. The main chemical element in all of these components is C, and as a result the terms SOM and C are often used synonymously.

Soil Conservation Concepts – Erosion and Water

Words can have a magical power for transferring knowledge. The proper selection of the words can arouse the strongest emotions resulting in prompt action. Conservation is one of those words that relates to environmental issues associated with moral values, social and economic justice and the well-being of all people. Conservation is a man-made concept concerned with how man relates to his land and uses its resources. Conservation is a moral concern, a personal virtue, a political issue; but anyway you say it, conservation is necessary. To some people, conservation is simply erosion control. Erosion is another word that arouses emotions because it brings visual perception of soil loss, wind blown drifts, deep gullies and muddy waters. Soil erosion causes loss of topsoil, decreased soil organic C, lower available water and nutrient holding capacity, decreased soil health and reduced yield and increased spatial variability. More management skills and equipment are required to cope with the consequences.

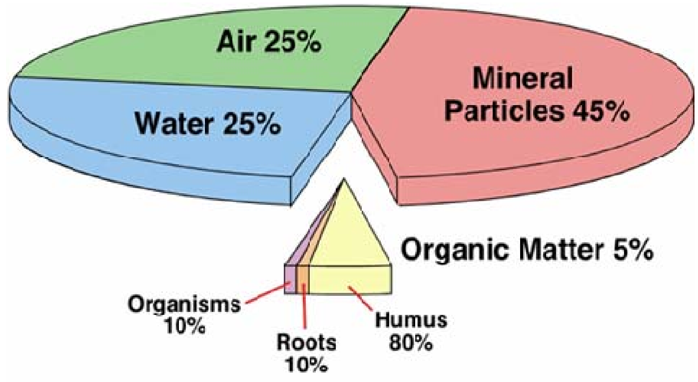


Figure 1. Most soils contain four basic components: mineral particles, water, air, and organic matter. Organic matter is about 58% C and can be further sub-divided into humus, roots, and living organisms. The values given above are for an "average" agricultural soil.

Agriculture world-wide is causing serious soil losses. These impacts are the unintended consequences of intensive agriculture that can be addressed by better C management. If the destruction of agricultural soils continues in the same way, humans might face serious problems feeding a growing population. There are different causes for this inadequate use of the soil. In many developing countries hunger is forcing poor people to cultivate areas which are not suitable for agricultural use and which only with major and costly efforts, like the construction of terraces, can be sustainably converted into agricultural land. Soil loss through erosion is only part of the problem as a consequence of the way agricultural soils are treated in mechanized agriculture. The loss of rain water that cannot infiltrate in the soils to replenish the ground water reserves might in the long-term be the more serious problem. Consequently, the way soil is cultivated must be drastically changed. Soil erosion and water loss is not only controlled by mechanical means but only by a living and stable soil structure that depends on soil C.

Conservation Practices

Agricultural ecosystems are regularly disturbed systems. The physical disturbance of the above- and below-ground species by tillage, as well as grain and biomass removal, fertilizer nutrient input and the addition of pesticides and herbicides all contribute to the ecosystem disturbance. Fields are managed to maximize production of plant biomass and grain yields that are regularly harvested.

The crop biomass removed from the system annually constitutes a removal or a mining of C and nutrients from the agro-ecosystem. After repeated annual cycles of removing grain and biomass from the system, the soil becomes poor in nutrients and organic matter (OM). The continued long-term removal of grain and crop biomass represents a net exporting of C from the crop system primarily used for animal or human nutrition. Much of this C loss comes from the soil. We must not continue to "mine" our production systems. Thus to maintain sustainability of the soil resource, we must think about soil C management and make efforts to maximize C input and minimize C loss.

Soil conservation practices not only reduce soil erosion but also increase the OM content of soils. Principal conservation strategies, which sequester C, include converting marginal lands to compatible land use systems, restoring degraded soils, and adopting best management practices. For example, removing agriculturally marginal land from annual crop production and adopting an ecologically compatible land use, such as livestock grazing and/or wildlife habitat, can lead to increases in total biomass production and an increase in C content in the soil. Best management practices (BMPs) that have been proven to sequester soil C are crop residue management, conservation tillage practices like direct seeding systems, no till, conservation tillage, mulching, strip cropping, diverse crop rotations, cover crops, grassed waterways, elimination of summer fallow; perennial forage crops for hay or pasture; application of organic materials and manures; soil fertility optimization through improved fertilizer placement and site-specific management. In addition to promoting C sequestration, BMPs can also improve crop yields by reducing soil erosion and degradation while improving water quality by reducing silt and agricultural runoff into nearby waterways. Agricultural activities related to C sequestration considered conservation practices include conserving fuel, managing nutrients and irrigation efficiently, using aerobic systems such as composting, producing dedicated biofuel crops, incorporating new crops, installing vegetative conservation buffers and restoring and protecting wetlands.

Soil Organic Matter and Carbon Properties

There are many different names, classes or types of OM in the soil system. Two broad C classifications are organic and inorganic. The inorganic C includes the free calcium carbonates and other inorganic sources. Soil organic matter (SOM) generally refers to natural C-containing organic materials living or dead, but excluding charcoal. Soil organic matter includes living organisms such as bacteria, fungi, nematodes, protozoa, earthworms, arthropods, and living roots. Organic C (OC) is the C content that is commonly used to characterize the amount of OM in soils (OM = 1.724 * % OC). Phytomass is another name for the above-ground biomass of plant origin, usually living, but may also include dead plants. Litter comprises the dead plant and animal debris on the soil surface. Dead plant material, OM, detritus, and surface residue all refer to plant, animal, or other organic substances that have recently been added to the soil and have only begun to show signs of decay.

Active fraction OM can be used as food by microorganisms and changes more quickly than total OM in response to management changes. Labile OM is also easily decomposed. Root exudates include soluble sugars, amino acids and other compounds secreted by roots. Microbial biomass is the living population of soil microorganisms. Macroorganic matter is organic fragments from any source which are > 250µm. Particulate organic matter or Light fraction OM have precise size and weight definitions and are thought to represent the active fraction of OM which is more difficult to define. Lignin is a hard-to-degrade compound that is part of the fibers of older plants degraded by fungi. Recalcitrant OM includes humus or lignin-containing material that few soil organisms can decompose. Humus is organic material remaining in soils after removal of macroorganic matter. Humic acids, fulvic acids, and humin are dark-colored amorphous materials considered generally insoluble under natural conditions that can be extracted from the soil by a variety of strong reagents.

Our soil systems contain many different forms of C. Organic C is the most important to us because it is the key chemical for energy and building blocks of all OM produced in the biological C cycle and is linked to all measures of soil quality. These C forms given in figure 2 range from crop residue and rhizo-deposition to wood chips and biodegradable garbage and everything in between. The OM must be amenable to attack by microbes and fungi and ultimately decompose into unrecognizable organic material accompanied by CO_2 emissions from microbial respiration. The common link of all these materials is their basic composition that includes a significant portion of the material that points to C.

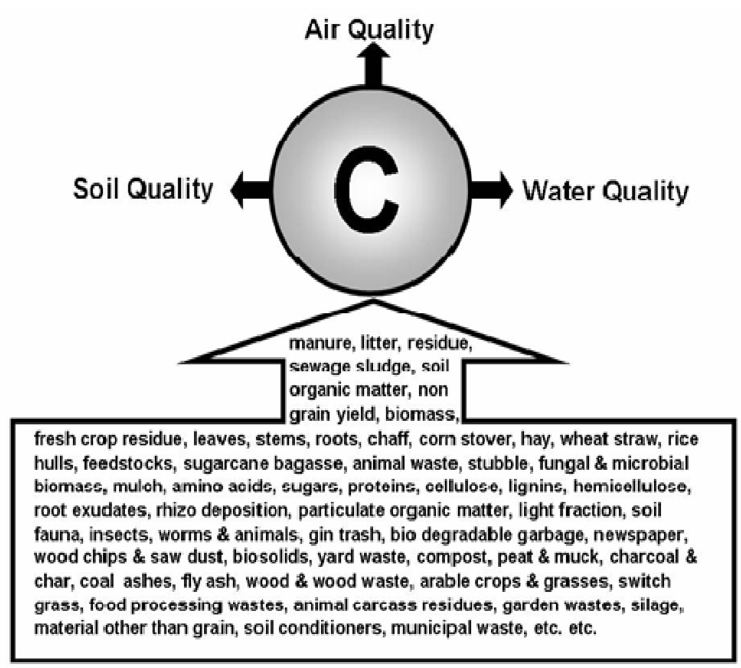


Figure 2. Various types and forms of organic matter that all point to soil C and associated environmental quality components.

Carbon in Conservation: The Biological C Cycle

Agriculture manages a large portion of the landscape to capture C through the process of photosynthesis that provides food, fiber and biofuels. Carbon dioxide (CO_2) uptake through photosynthesis converts solar energy to a useful form of C, or forms of energy that is the start of the grand biological C cycle. The C cycle is driven by solar radiation that allows photosynthesis and evapotranspiration of water required for biomass generation. The sun drives the atmosphere into patterns of everyday wind and weather and is the ultimate source of all energy on earth. Crop residue and plant roots and their exudates are the primary source of C in our agricultural ecosystems. Approximately 50% of the C in crop residues is recycled back to the atmosphere within the next year as part of the biological C cycle.

The C cycle is central to the Earth's system, being tightly coupled with climate, the water cycle, nutrient cycles and the production of biomass by photosynthesis on land and in the oceans. A proper understanding of the global C cycle is critical for understanding the environmental history of our planet and its human inhabitants, and for predicting and guiding their joint future. Carbon can be found in many different forms and locations. The "biological C" cycle is of the utmost importance in conservation agriculture and is differentiated from the "fossil C" cycle. The process of fossil C sequestration requires the capture and storage of C content of fossil fuels prior to its release to the atmosphere. Biological C sequestration also requires removal of C from the atmosphere by plants. Fossil fuels (fossil C) are very old geologically, as much as two hundred million years. One example of biological C cycling is the agricultural production of biomass for fuel with the potential to reduce net CO_2 emissions to the atmosphere. Enhanced C management in conservation agriculture may make it possible to take CO_2 released from the fossil C cycle and transfer it to the biological C cycle to enhance food, fiber and bio-fuel production as well as enhancing environmental quality. Carbon is the "graphite" that lubricates and the "fuel of the soil" that energizes our ecosystems. The C lubricates all processes and properties so that the ecosystem runs smoothly. By properly managing the C cycle in our agricultural ecosystems, we can have less erosion, less pollution, clean water, fresh air, healthy soil, natural fertility, higher productivity and beautiful landscapes.

Summary

True soil conservation is C management. The time has come for a shift in our conservation concepts and programs to get away from the stale approach of managing for only erosion control and move to managing for soil C. True soil conservation must expand beyond the traditional understanding of soil erosion. We need to move to the next level of conservation by shifting our focus to managing for both erosion control and soil C for soil quality. As we clearly understand the role of C in true conservation, we must be better managers of soil C. While soil erosion continues to be a major problem, we must expand our thinking to address related soil quality issues, which translates to soil C. Carbon management is required to address a complex list of issues including soil, water quality, biofuel, and climate change. The soil is the fundamental foundation of our economy and our existence. The current concern about possible global change and management options elevates the importance of C management and conservation. There is a question whether C management should focus on C sequestration or on C cycling. More research is needed to address this issue and it is likely that some practical compromise will be required. As in many "natural processes," we must balance sequestration and cycling for enhanced physical, chemical and biological properties and processes. Today, we must place more emphasis on all natural resources and additional emphasis on C as a key component in maintaining ecosystem stability. Yes, true "C"onservation starts with "C" management.

Bioenergy Crops as Alternatives for the Northern Corn Belt

Russ Gesch

Identifying and developing new and alternative crops that are both economically and environmentally sustainable are integral to much of the current research being conducted at the "Soils Lab." Currently, the U.S. is striving to reduce its dependence on petroleum for energy needs, and plant-derived sources of energy will play a vital role in achieving this goal, at least in the near-term. New technologies are developing to efficiently utilize whole-plant biomass for energy production. Certain alternative crop species such as switchgrass may prove to be more economically and environmentally sustainable for bioenergy than conventional food crops (e.g., corn and soybean). Switchgrass is a warm season perennial noted for producing a large amount of biomass, while requiring less agricultural inputs than high-value food crops. Therefore, the efficiency of converting switchgrass biomass to useable bioenergy (i.e., energy input vs. output) may be greater than more intensively managed crops requiring greater inputs. Also, because of its extensive root system and ground cover that it provides, it offers benefits to soil and water quality and greenhouse gas reductions. Although switchgrass is native the Great Plains, including Minnesota, it tends to yield greatest in more southerly climates than the northern Corn Belt. Partly this is due to our shorter growing season and cooler temperatures. However, through exploiting the genetic diversity available among switchgrass ecotypes (i.e., from different regions of the U.S.) it may be possible to select for higher biomass yielding plant-types for northerly climates.

Photosynthesis is the means by which plants fix and convert solar radiation and carbon dioxide into chemical energy used for plant growth. A plant's ability to adjust, or acclimate, its photosynthetic capacity to changing environmental conditions (e.g., temperature, moisture, and light) in order to optimize carbon is directly related to its growth and hence biomass accumulation. An ideal switchgrass cultivar for the northern Corn Belt region would be one that acclimates well to large temperature changes during a relatively short growing season. To explore the genetic diversity of switchgrass to photosynthetically acclimate to changing temperature, four cultivars were studied that differ in their geographic origins. The cultivars chosen were Alamo, developed in Texas; kanlow, developed in Kansas; cave-in-rock, developed in Illinois; and sunburst, developed in South Dakota.

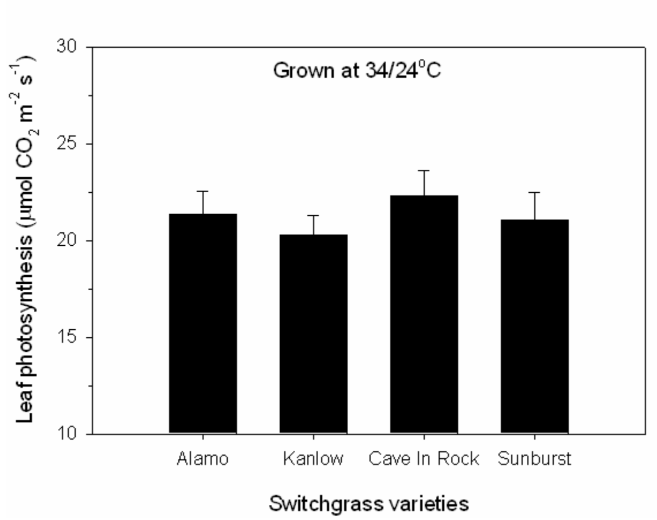


Figure 1. Photosynthesis of different switchgrass varieties grown under day/night temperatures of 34/24 ° C (90/75 ° F). Measurements were taken at 34 ° C. Alamo is from TX, kanlow from KS, cave-in-rock from IL, and sunburst from SD.

Figure 1 shows leaf photosynthesis for plants grown under a day/night temperature treatment of 32/24°C (close to optimum temperatures for switchgrass growth). Interestingly, the different ecotypes generally showed similar photosynthetic rates, although they differed greatly in their morphology (i.e., plant form; data not shown). However, differences did develop among varieties with respect to their ability to photosynthetically acclimate to a decrease in day/night temperature.

This relationship is presented in Figure 2 where Alamo (originating in TX) and sunburst (originating in South Dakota) are shown because of their contrasting response. For Figure 2, photosynthesis was measured at a common leaf temperature of 28°C (82°F) with increasing light intensity. The red line for each variety represents measurements for plants grown at 32/24°C (90/75°F) and the blue line is for the same plants, but after switching them to a temperature treatment of 22/14°C (72/57°F) for 13 days. Interestingly, Alamo, the variety with the most southerly origin, showed the greatest ability to increase (acclimate) its photosynthetic capacity when switched from warm to cool day/night temperatures (i.e., blue line with respect to the red one), while sunburst showed a decrease. The other two varieties showed very little change (not shown). Large temperature fluctuations, especially early and late in the growing season, are a common occurrence in the northern Corn Belt. Therefore, perhaps breeding for greater ability to photosynthetically acclimate to changing temperature in northern switchgrass varieties may help to bolster biomass yields.

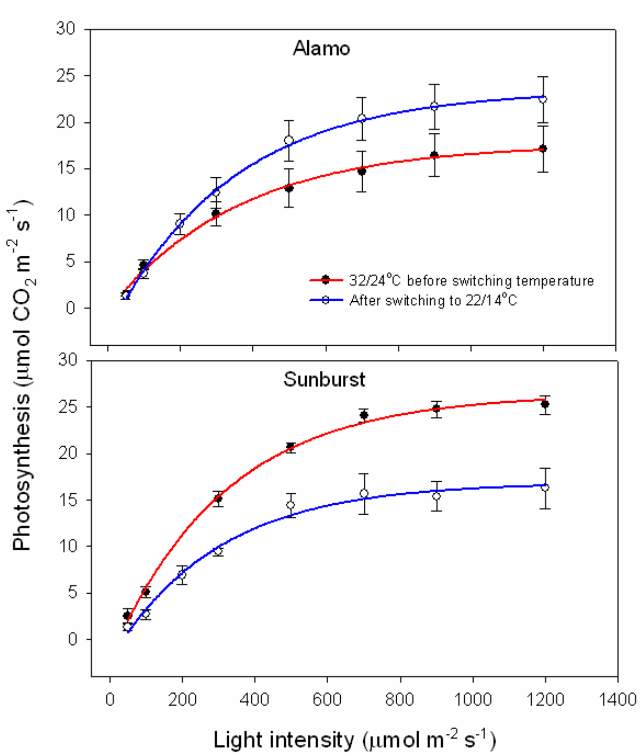


Figure 2. Photosynthesis of switchgrass as a function of light intensity. Alamo is from Texas and sunburst is from South Dakota. The plants were grown at 32/24 ° C (90/75 F) and measured (red line) and then switched to a temperature of 22/14 ° C (72/57 F) for 13 days before measuring photosynthesis again (blue line). The measurements were all made at the same leaf temperature of 28 ° C (82 F) to make comparisons of acclimation.

Laboratory experiments will be conducted on leaf samples collected from the growth chamber studies o more thoroughly understand the physiological reason(s) why certain varieties of switchgrass may adapt better to large fluctuations in temperature.

Soil and Crop Management Systems to Sustain Agricultural Production and Environmental Quality in the Northern Great Plains

Sharon Papiernik (Lead Scientist), Sharon Lachnicht Weyers, Jane Johnson, Donald Reicosky, and David Archer

Problem to be addressed:

The northern U.S. Corn Belt has some of the most productive soils in the world. Yet, agricultural production in this region is often limited by the loss of topsoil, degraded soil quality, and inefficient use of soil nutrients. The overall goal of this project is to develop soil and crop management systems that integrate biological, chemical, and physical principles to sustain agricultural production and environmental quality in the northern Great Plains. The primary objectives are to determine:

(a) the effects of management practices on carbon and nutrient cycling and soil biological communities, and

(b) the impacts of landscape restoration (soil movement from areas of soil accumulation to areas of topsoil depletion) on soil properties, soil productivity, and environmental quality in severely eroded hilly landscapes.

2006 Progress Highlights:

Agricultural management can affect physical, chemical and biological properties and processes affecting crop production and environmental quality. These include soil structure, soil erodibility, nutrient availability, water infiltration and availability, and pesticide mobility and degradation. This project is a series of linked studies that address the development of conservation tillage, residue management systems, and alternate soil management and cropping systems to improve and sustain soil productivity, environmental quality, and farm profitability throughout the northern Great Plains.

Jane Johnson and Don Reicosky are members of the USDA-ARS special Renewable Energy Assessment Project (REAP). Jane has begun field experiments to evaluate the soil and economic impacts of integrating corn stover harvest (for biofuel) into corn-soybean rotations. Her work will help determine the amount of residue that can be removed while maintaining soil organic carbon and providing sufficient soil cover to prevent unacceptable erosion losses. This work is critical for the further development of biofuel technologies that do not decrease long-term soil productivity.

Don Reicosky is wrapping up a long-term experiment examining the effect of the timing and intensity of tillage, crop rotation, and planting date on carbon storage, crop growth, and economic yield. The amount and distribution of carbon in the soil are being measured more than 10 years after treatment establishment. Don's experiments will provide crucial information about the rate and duration of carbon storage under different management practices. This information is needed for improved management recommendations that enhance soil carbon sequestration and reduce soil carbon losses from agricultural systems.

Sharon Lachnicht Weyers is examining the effect of organic and conventional land management practices on the structure of the soil biological community. She is beginning new experiments to examine the effect of nitrogen management practices on nitrogen availability and the dynamics of soil biological communities. Soil biota are integral, but poorly understood, components of soil quality affecting soil productivity and environmental quality. Sharon's research will improve understanding of the complex interactions of the soil biota and their role in the nitrogen mineralization process.

Sharon Papiernik has begun a five-year on-farm experiment to evaluate the impact of landscape restoration (soil movement from areas of soil accumulation to areas of topsoil depletion) on soil properties affecting soil productivity and environmental quality in eroded landscapes. The first-year yield response is reported here. In these experiments, Sharon is also evaluating changes in pesticide fate and weed control that occur across restored and unrestored landscapes. Several Soils Lab scientists are involved in this study, including Dave Archer (economic costs and benefits of landscape restoration), Don Reicosky (effect of landscape restoration on carbon flux), and Sharon Lachnicht Weyers (impact of soil movement on soil biological indicators). These experiments will determine the variability in soil properties in this eroded landscape, how that variability affects crop yields, and the degree to which landscape restoration can improve soil productivity and profitability.

It is the Soils Lab's loss that Dave Archer has transferred to the USDA-ARS unit in Mandan, ND. However, Dave has promised to continue his involvement in some of these experiments, particularly the corn stover/biofuel and landscape restoration projects.

We are fortunate to have excellent collaborative arrangements with scientists at other USDA-ARS stations, universities, and extension centers throughout North America. The cooperation of local farmers, including Jim Wink and Karl Retzlaff, is critical to the success of these projects. These collaborations increase the impact of our work and allow us to expand our research beyond the plot scale to provide real-world results.

Fate of Balance Pro® Herbicide in Soils

Sharon Papiernik, Scott Yates (USDA-ARS, Riverside, CA), William Koskinen (USDA-ARS, St. Paul, MN) and Gary Amundson

The herbicide isoxaflutole (Balance Pro®) is effective in controlling a variety of grass and broadleaf weeds. In the United States, isoxaflutole is labeled for use on corn in eighteen states. Due to water quality concerns, isoxaflutole is not currently registered in some major corn-producing states, including Minnesota, Michigan, and Wisconsin. Isoxaflutole and its breakdown product DKN have been found in groundwater and surface water in the United States. We completed a two-year experiment to investigate the leaching and degradation of this herbicide under field conditions in a moist, cool environment typical of the northern Corn Belt. These results provide information on expected herbicide concentrations in soil and shallow groundwater under these conditions. They will help develop management practices that reduce the threat of water contamination by isoxaflutole and DKN.

These experiments were carried out at the Swan Lake Research Farm in plots with three different soil types. Balance Pro was applied pre-emergence to cuphea, a potential new oilseed crop. A tracer that does not interact with the soil (sodium bromide) was used to describe water movement. Soil cores were collected, divided into depth increments, and analyzed for herbicide and bromide. These samples gave the amount of herbicide and bromide remaining in the soil at each depth. A simulation model was used to provide information about herbicide transport and degradation.

Results showed that the time required for half of the herbicide to disappear ranged from 7 to 17 days. In both years, herbicide dissipation was fastest in the loam soil and slowest in the clay loam soil. Very little herbicide was found at depths greater than 16 inches. Leaching below 3 feet was virtually undetectable. Simulation modeling also showed that leaching below 3 feet was insignificant. The bromide that was no longer present in the soil was taken up by the plant, with plant uptake accounting for 80% or more of the applied bromide. Plant uptake of the herbicide accounted for about 40% of the applied amount, with the remainder being degraded in the soil during the 100-day experiments.

This work showed that under these conditions, there was essentially no leaching of Balance Pro herbicide to shallow groundwater. Moderate rainfall was measured during these experiments, totaling 11 inches in Year 1 and 15 inches in Year 2. Herbicide dissipation studies are often conducted in bare soil. These results show that plant uptake may be a major pathway of herbicide dissipation in soil and should be accounted for in these studies.

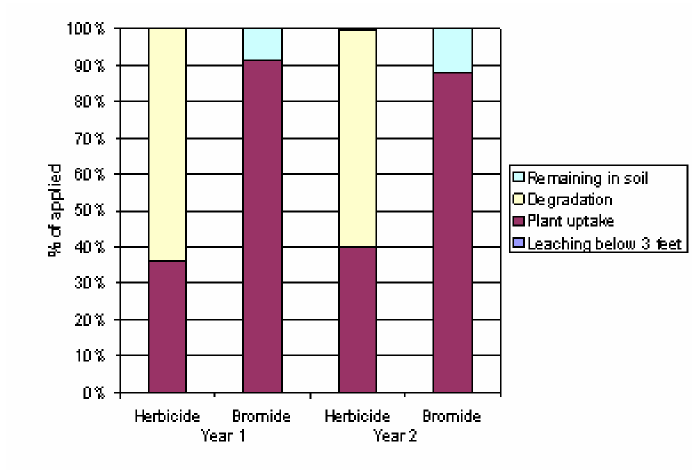


Figure 1. Routes of herbicide and tracer dissipation as described by simulation modeling coupled with field data. Results are for loam soil during two 100-day experiments.

Reversing Soil Erosion

Sharon Papiernik, Gary Amundson and Dave Archer

Intensive tillage moves large amounts of soil, removing topsoil from convex slope positions and depositing soil in concave positions. The effects of tillage erosion may be seen in hilly areas throughout west central Minnesota, where soil on hilltops is often light in color due to the removal of topsoil, and depressions have deep topsoil. Our past research measured the effect of field position and soil erosion rates on crop yield in four years. Wheat yields (3 years) in areas of topsoil removal by erosion were less than half that measured in depressions, where tillage and water erosion deposit soil. Those experiments showed that the field-scale variation in crop yield in hilly landscapes may be the result of topsoil removal through repeated intensive tillage. Soil properties, such as organic matter content, nutrient content, nd pH, were also related to soil erosion rates. Comparing surface soil properties in the cultivated field (areas of both soil removal and soil deposition by erosion) and a nearby uncultivated hillslope showed that long-term tillage and cropping resulted in the loss of soil organic matter throughout the cultivated field. Approximately 100 years of intensive tillage has removed at least 20 cm of topsoil from the shoulder slope positions at this site.

The results of these previous experiments suggested that landscape restoration may be one approach to reduce yield losses in eroded fields. Landscape restoration is the movement of soil back uphill from where it accumulated. Landscape restoration is an attempt to reverse soil erosion. In late 2005, we started a 5-year project to evaluate the productivity and profitability of this practice. This on-farm research is being completed in cooperation with Karl and Linda Retzlaff. The experimental site is an eroded ridge that we separated into six plots extending from the top to the bottom of the hill. Three of those plots were restored by removing soil from the area of accumulation (toeslope+footslope) and adding it to areas of soil removal by erosion summit+shoulder+upper backslope). In each of the three restored plots, about six inches of soil were removed from the lower slope and about six inches of soil were added to the upper slope. No soil was moved in the three remaining plots. This experimental setup allows us to compare the effects of landscape restoration at all landscape positions (from the top to the bottom of the hill). Unrestored plots are used to account for year-to-year variability. The entire site is part of a larger field and is farmed with no consideration for plot boundaries.

This soil movement cost approximately $800 per acre restored (area of soil addition). This included $130 for labor, $120 for fuel (57 gallons per acre), $90 for equipment lubrication and repairs, $250 for depreciation, and $220 in overhead.

Soil samples collected before soil movement for restoration showed that the site was uniform across the slope. However, the soil properties were very different at the top of the slope (where the tilled layer is composed of exposed subsoil) compared to the bottom of the slope (where high-organic-matter soils are more than 40 inches deep). Soil samples were collected again after soil movement for restoration to measure physical, chemical, and biological properties of the soil. These samples are now being analyzed in the laboratory.

In 2006, glyphosate-resistant soybean was grown as the first crop after restoration. We measured soybean emergence and stand, weed emergence and counts, soil moisture and temperature, and soybean development and yield. Results showed that at the top of the slope, soybeans emerged earlier in the restored plots than in the unrestored plots because of higher soil moisture and temperature—surface soil in restored plots have higher organic matter content and darker color. Final soybean stands were the same in restored and unrestored plots at all landscape positions. Weed counts showed that weed seeds were moved with the soil during landscape restoration. Weed counts were low in areas of soil removal. Areas where soil was added had a higher number of weed species (higher diversity) than unrestored plots.

Chemical weed control was effective across the site and weed pressures were very low for most of the growing season.

We measured soybean height, biomass, and yield. Soybean plants were larger and higher-yielding in restored plots at the top of the slope (where soil was added) and smaller at the bottom of the slope (where soil was removed). Severe stunting occurred near the depression in areas of soil removal, with soybean yields less than 20 bushels per acre. In contrast, the highest yields in these plots (greater than 45 bushels per acre) were measured near the depression in unrestored plots, since this area was least affected by late-summer drought conditions.

The yield decrease in areas of soil removal was at least as large as the yield increase in areas of soil addition. Overall yields (from the top to the bottom of the slope) were the same or lower in restored plots compared to unrestored plots. In this small area of the field, soil movement for landscape restoration gave no overall increase in yield. While we have not yet determined the cause of the decreased yield in areas of soil removal, we expect biological processes to be important. These experiments will continue for the next four years, and we will evaluate how quickly the soil recovers from this scalping operation. In most years, the bottom of the slope is low-yielding due to poor drainage. Therefore, overall yield in this part of the field may be more strongly affected by yield increases at the top of the slope than by yield losses in areas of soil removal.

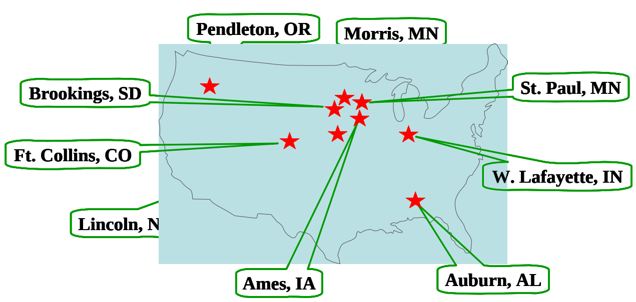
Renewable Energy Assessment Project (REAP)

Jane M-F Johnson

There are pros and con to using crop biomass (corn stover) for energy. Biomass is domestic; it is renewable. It reduces the release of greenhouse gases from using fossil natural gas or coal. It brings an additional commodity to the farm. The risks include increased erosion, removing valuable topsoil, more run-off of nutrients or pesticides, and loss of soil carbon (soil organic matter). These processes have negative environmental costs and lead to loss of productivity.

The USDA-Agricultural Research Service is using a team-approach. To assure that biomass bioenergy is based on sustainable soil and crop management practices. The **R**enewable **E**nergy **A**ssessment **P**roject (**REAP**) includes scientists at the North Central Soil Conservation Research Laboratory, Morris MN (Soils Lab). Most REAP members are in the Corn Belt but some also are working on switchgrass, computer-modeling and biomass quality.

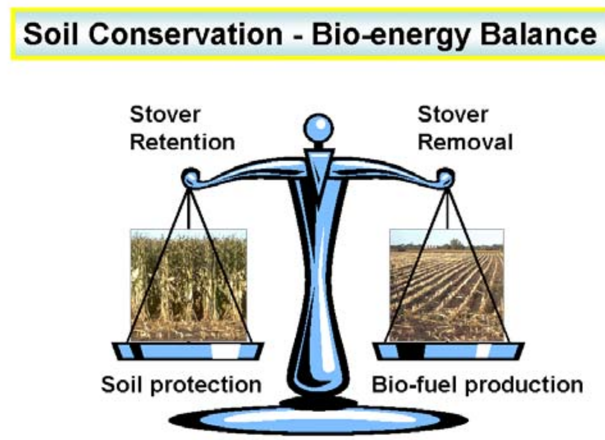
USDA-ARS REAP Team Location



REAP Goals:

1. Determine the amount of crop biomass needed to protect the soil resource from erosion and maintain soil organic matter.
2. Compare economic implications based on the value of stover as a bioenergy versus soil carbon source.
3. Provide the US-Department of Energy, farmers and other cooperators with harvest rate recommendations and guidelines.

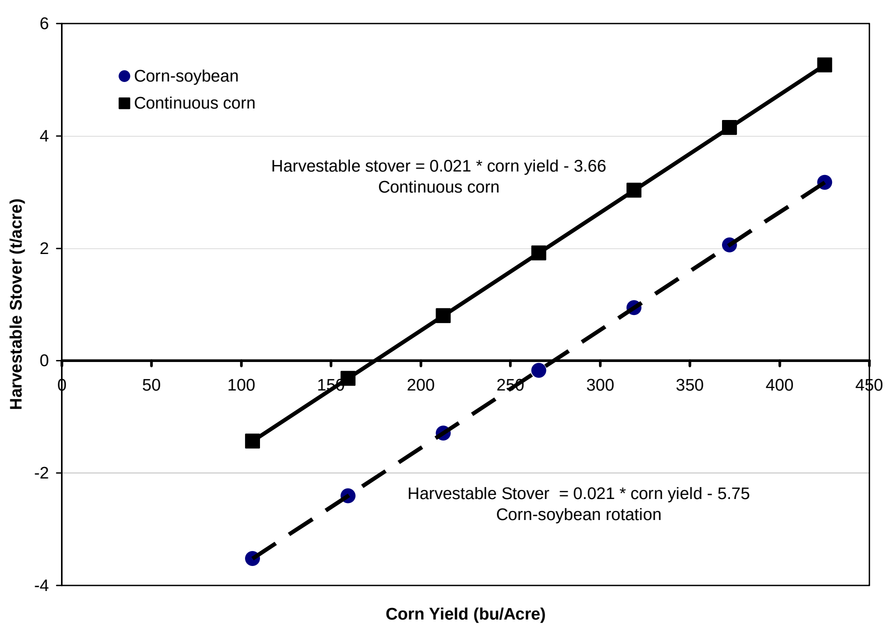
Early estimates on the amount of crop biomass (corn stover) that needs to remain on the land for maintaining soil organic carbon, appears to be greater than the amount needed for erosion protection. It is recommended that **all** biomass remain on highly erodible land and conservation or no tillage be utilized. Harvestable corn stover was estimated from corn yield assuming conservation tillage or no tillage was used.



A challenging balancing act!

The amount harvested during the corn phase of a corn-soybean rotation is reduced compared to continuous corn, due to the smaller amount of biomass produced by soybean. From the graph, 2 tons/acre corn stover could be harvested each year from continuous corn, if the grain yield was about 270 bu/acre. These estimates were published in the Journal of Soil and Water Conservation, July/August 2006. The team is refining and testing these recommendations for use across soil types and climates.

Agricultural biomass for energy including ethanol can be **part** of the solution, together with other renewable energies (e.g., solar, wind) AND changing our high energy use habits. Sound research is needed to determine how much, when and where biomass can be removed without soil and/or environmental degradation. A balanced approach is critical to solving these related problems of global warming, limited fossil fuels and maintaining soil productivity.



Biofuel Residue Removal

Jane M-F Johnson and Nancy Barbour

Corn stover or residue is being considered as a source of renewable biomass fuel. While some people may consider residue to be trash, it is critical for maintaining or increasing soil organic carbon and protecting the soil from erosion. The amount of corn stover needed to maintain soil organic matter and limit erosion will vary by tillage.

A study was initiated in 2005 to evaluate the effect of removing corn residue in a corn/soybean rotation. The study site included an area that had been managed without tillage since 1995. Adjacent to the no-till site is an area that received annual moldboard plowing; however, beginning 2005 this area will be chisel plowed instead. A new area was placed into no-tillage management in the fall of 2005, following wheat harvest. Each of the three tillage treatments will have four rates of corn stover harvest (0%, 50%, 75% and 100%). The removal rates will be implemented by harvesting stover in 0 of 8, 4 of 8, 6 of 8 and 8 of 8 rows after combining using a Carter forage harvester.

In 2005 the soils was sampled extensively and is being analyzed for total carbon and nitrogen, inorganic and organic carbon, nitrate, ammonia, phosphorus, potassium, pH, bulk density, particle size and particulate organic matter. Baseline soil properties will be determined at the beginning of the experiment (2005) in samples to 3 feet. After five years, soil will be collected in the same manner to determine net changes in total C, organic C, and particulate organic matter. Agronomic and economic crop yield will be monitored annually.

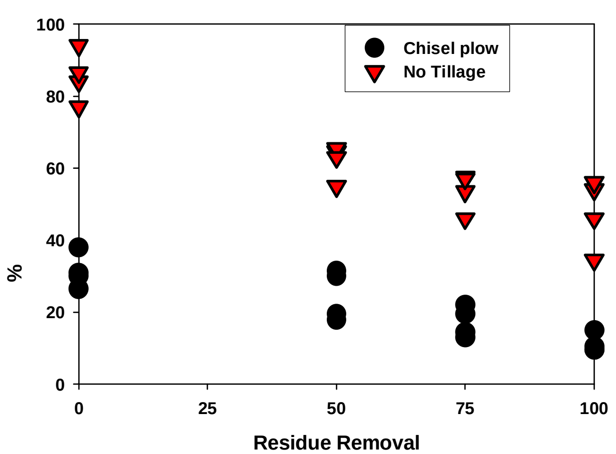


Figure 1. The % soil cover determined in the spring. Stover was harvested after grain harvest, followed by autumn tillage. Each point represents one plot.

Residue cover was measured in the spring of 2006 (Figure 1). As expected, spring residue was inversely related to percent residue removal in the fall. By spring, after chisel plowing there was less than 30% soil coverage in most plots. A minimum of 30% coverage is recommended to limit erosion. No tillage as expected provided significantly more coverage in the spring, even if all stover was removed. All no tillage plots had at least 30% coverage for minimizing erosion.

Based on a review of literature, it takes 3.52 tons/acre of stover during the corn phase of the rotation to prevent loss of soil organic matter. This estimate is based on no tillage and chisel plow, as there was not difference observed in the amount of biomass needed to maintain soil organic carbon between the two tillage treatments. The stover yield measured on these plots in 2006, did not provide sufficient biomass to support stover harvest without risking loss of soil carbon (Table 1). In fact, it is likely a net carbon loss occurred even when returning all stover to the field.

Table 1. Corn and soybean 2006 yield

	Corn yield Bu/acre	Corn Stover Dry ton/acre	Soybean Bu/acre
Chisel	161.42 ± 10.12	3.20 ± 0.42	39.79 ± 6.23
Notill05	154.00 ± 9.66	3.16 ± 0.51	46.46 ± 5.05
Notill95	123.62 ± 7.75	2.43 ± 0.5	37.78 ± 11.25

Corn stover trapped snow (see photos). These photos were taken in February prior to the two heavy snow events. In a dry year, this increased moisture could be beneficial, but not in a wet spring.

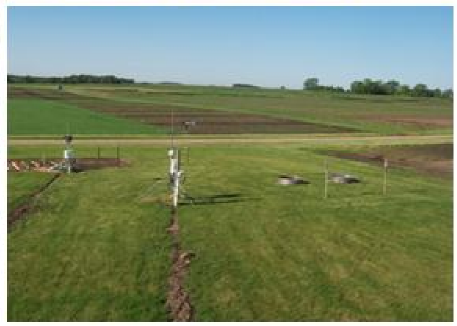
This study is scheduled to continue at least five years.

No stover removed.

Six of eight rows harvested—75%Corn

Crops Research

Frank Forcella (Lead Scientist), Russ Gesch, Dave Archer, Sharon Papiernik, Kurt Spokas and Abdullah Jaradat



New Crops Research

The NCSCRL in Morris over the past six to seven years has been working closely with industry, university, and other USDA-ARS collaborators to successfully develop cuphea, a new oilseed crop, for production in the northern U.S. In 2005 cuphea was commercially produced on about 100 acres in MN, and the seed oil was bought by a specialty oils company (FloraTech) in AZ to manufacture and test several lines of personal care products. The products manufactured from cuphea oil were of very high quality due to unique physical/chemical characteristics of the oil. Therefore, the AZ-based company continues to have a strong interest in purchasing cuphea oil, and has need for several thousand acres. Last summer (2006) cuphea was grown on about 600 to 700 acres on farms in MN, eastern ND, and SD with primary emphasis put on scaling up foundation seed for larger-scale production in 2007. Unfortunately, a combination of drought and high temperatures last summer in the areas where cuphea was grown resulted in disastrous yields. In 2007, Technology Crops International, our industry collaborator who is managing commercial production of cuphea will be seeking other areas of the U.S., particularly the cooler, wetter northeastern region, to diversify production and decrease the risk of large-scale crop failure.

We remain confident that cuphea has good potential to be a major crop in the future, but much research remains to be done concerning crop improvement. An important question concerning cuphea is whether it affects other crops, negatively or positively, when in rotation. In 2006 we completed three years of a rotation study with cuphea, with the first year (2004) being an establishment year. The study was designed to test the effects of cuphea in a two-year rotation scheme with wheat, corn, and soybean, the major agronomic crops for the upper Midwest. All possible combinations of the crops were investigated for comparison. Although not all of the data have been analyzed, results thus far show that cuphea did not have a negative or positive affect on the crops studied, or vice-versa. Furthermore, cuphea did not have a significant negative affect on the emergence and stand establishment of the other three crops. A summary of seed yields for each of the crops as a function of the two-year rotation scheme are shown in Figure 1.

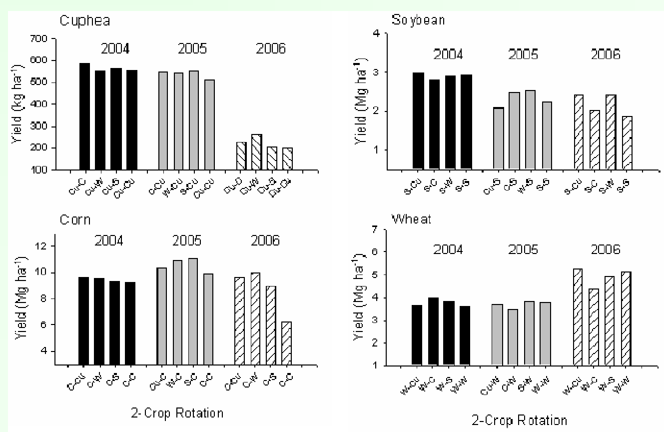


*Figure 1. Seed yields during 2004-2006 for the cuphea crop rotation study. All two-year crop rotation combinations with cuphea (Cu), soybean (S), corn (C), and wheat (W) were investigated. The study was initiated 2004 (establishment year). For corn, soybean, and wheat the * denotes where cuphea was rotated.*

Weed Research

Frank Forcella

The weed research group at the Soils Lab was involved with a number of projects during 2006. We hosted two visiting scientists and two Ph.D. students. The first was Dr. Jose Gonzalez-Andujar. Jose is from Cordoba, Spain, and is the head of the Weed Research group at CSIC (Consejo Superior de Investigaciones Científicas). CSIC is the national research agency of Spain. Jose is a biometrician by training and has an interest in our local work on developing computer software that allows users to predict the timing and extent of weed emergence. He was able to secure a grant from the Spanish government to finance his trip to the Minnesota. The primary weed of interest to Jose and his fellow researchers at CSIC is wild oat. We facilitated Jose's research by sharing our modeling concepts as well as wild oat results from Minnesota and North Dakota.

The local wild oat information was derived, in part, from the recent work by Dr. Krishona Martinson. Krishona was awarded the Ph.D. in agronomy (Weed Science) from the University of Minnesota in 2006. The Weed Research team was represented on her thesis committee. Krishona's research topic was wild oat biology and control. The weed researchers at the Soils Lab aided Krishona in developing a predictive wild oat emergence model for the Red River Valley of Minnesota and North Dakota. This model is being added to the WeedCast software at the Soils Lab so that anyone with access to the Internet can use it.

The second visiting scientist was Dr. Milton McGiffen. Milt is a professor of horticulture at the Botany and Plant Sciences Department at the University of California-Riverside. He worked on a project involving our weed team as well as Steve Poppe at the West Central Research and Outreach Center (Univ. of Minnesota) through a grant we obtained from the North American Strawberry Growers Association. The project was the development of a seedling emergence model for a weed that is becoming increasingly important in strawberry and other horticultural crops. The weed, common groundsel, does not look too threatening, but it interferes with numerous activities of growers and pickers, and there are very few herbicides that can control it. Solving this groundsel problem in strawberry and other high-value crops is a high priority activity in horticulture.

Our final visitor was Brian Schutte, who will be receiving in 2007 the Ph.D. from the Department of Horticulture and Crop Science at Ohio State University. Brian's thesis topic was the biology and control of giant ragweed. This weed is, indeed, big and mean-looking; but more importantly, it also causes allergenic rhinitis and some of its populations in Ohio and neighboring states have evolved resistance to the herbicide, Roundup. For Brian and the weed research team at the Soils Lab, this species is especially interesting because some of its populations also have evolved a delayed seedling emergence syndrome. Delayed emergence is important because it allows weeds to escape many normal weed control operations. Our goal with Brian was to develop models that would predict delayed emergence of giant ragweed. This was done and is part of Brian's thesis. Furthermore, Brian now has a website at OSU that allows farmers and others in Ohio and adjacent states to forecast the extent and duration of giant ragweed emergence. Luckily, the delayed emergence syndrome is not yet apparent in Minnesota populations of giant ragweed, so the current emergence model in our WeedCast software is still relevant for local populations.

In addition to facilitating the research of our visitors, we also have a number of our own projects. Our primary goal has been to develop computer software that allows farmers, crop consultants, extension educators, classroom instructors, and the crop protection industry to improve their understanding and predictive abilities in regard to weed behavior. By so doing, better and more environmentally-friendly weed control should result.

The processes involved with the overall software include development of models and "component software." In other words, we develop small but useful software tools that subsequently are incorporated into larger software applications. Sometimes these small components have value to other people that we originally did not expect or intend. A good example is our recent CRADA (cooperative research and development agreement) with Percival Scientific Co. The weed-oriented computer software developed at the Soils Lab requires accurate and detailed estimates of microclimate variables (air and soil temperatures, soil moisture, humidity, sunlight quality, and so forth) for any location on earth. Prediction of these same variables also is desired by other scientists who perform basic and applied research in incubators and growth chambers on a surprisingly wide variety of topics – even on cosmetics and beauty aids. Percival Scientific Co., which is headquartered in Perry, Iowa, is one the world's largest manufacturers of incubators and growth chambers. As a novel addition to their line of products (the "next generation" of incubators), they wanted computer software to interface with their incubators' controllers to simulate microclimate conditions anywhere on the planet. Fortunately, the software we developed at the Soils Lab does just this. We will be working closely with Percival during the next year to integrate our software with their incubators. Our interaction with Percival represents a direct application of USDA-ARS research results to helping American businesses.

An example of component software that might have greater appeal to the agricultural community is our SeedChaser model. This easy-to-use software ostensibly simulates the movement and distribution of weed seeds in soil after each of up to 20 passes of any of a wide mix of agricultural implements (chisels, cultivators, disks, drills, harrows, planters, plows, etc.). We needed to know the distributions and movements of weed seeds in soil so we could better simulate the timing and extent of seedling emergence from soil. However, the SeedChaser model is not only useful for estimating where the weed seeds are, it also simulates the distribution and movement of any entity added to soil. For instance, users may want to know the soil depth distributions of grasshopper eggs, nematode cysts, pesticide granules, or fertilizer pellets after passage of any of several common agricultural implements. The SeedChaser software simulations can be used for all of these purposes.

Weed team members were invited to participate in a wide variety of international, national, regional and state activities in 2006. Costs associated with nearly all of these invitations were financed by the hosts. Furthermore, weed team members published (or had accepted for publication) over a dozen articles in high-quality peer-reviewed scientific journals in 2006.

Grant monies received by the Soils Lab in 2006 due to activities by weed research team members exceeded $150,000. Furthermore, during 2006 weed team members were responsible for soliciting more than $250,000 in new funds for projects beginning in 2007.

The weed research team was comprised of the following full-time employees in 2006: Andy Kuhn, Dave Archer, Dean Peterson, Frank Forcella, Kurt Spokas, and Seth Miller. Sadly for us, Andy and Dave have moved from Morris to pursue other career opportunities, while Seth has assumed other duties at the Soils Lab. We will miss each of them. Nevertheless, the remaining team members and new recruits look forward to another new, active, and rewarding year of weed research.

Cuphea: Flowers, Capsules and Seeds

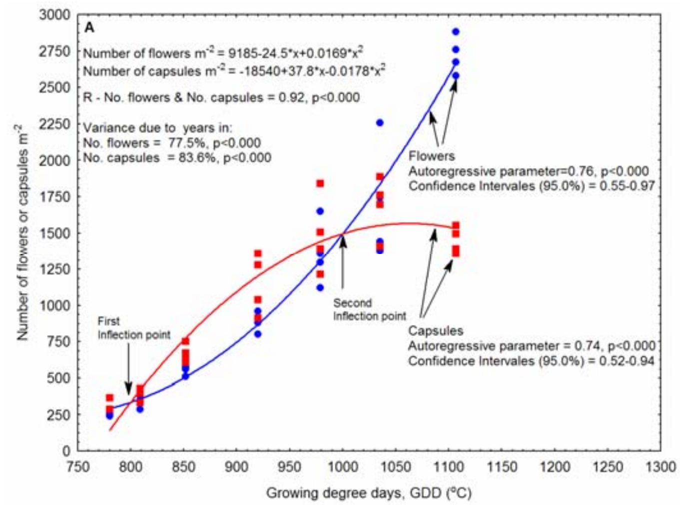
Abdullah Jaradat and Jana Rinke

Cuphea seed size and weight are inherently non-uniform because of the presence of multi-ovules within a non-uniform capsule and due to the indeterminate growth habit of the plant. Seed size is an important component of life history in cuphea as even a small variation may influence seedling emergence, seedling growth and survival, and seedling competition and yield. We studied the flowering and capsule set, quantified the level of variation in seed characteristics and the inter-relationships among seed and capsule physical dimensions, and their impact on single seed weight as the main determinant of seed yield in the potential oilseed crop, cuphea PSR23. Number of open flowers and formed capsules were time-dependent (Fig. 1a), biomass-dependent (Fig. 1b), and highly auto-correlated. Large variations were observed in seed weight, and seed and capsule physical characteristics.

Flowering and capsule set in the indeterminate cuphea proved to be a dynamic process – spread out in time at individual nodes, mainly on the main stem, and on individual plants. We documented temporal patterns of flowering and capsule set as a function of thermal time; however, much less is known about the regulation of these patterns and their involvement in determining number of fertile capsules, number of seed per capsule, average seed weight, and yield.

The significance and potential value of the long flowering period of PSR23 is negated by the fact that flowers are produced late in the flowering period due to the indeterminate growth habit of the plant. Flower initiation progressed linearly up the branches as a function of thermal time; however, the number of flowers per plant may increase without a subsequent increase in the number of capsules when thermal time exceeded 1,000 GDD (Fig. 1a). Capsule abortion simply may increase if more flowers are produced without an increase in the potential productivity of the environment. We observed that the fruit set within an inflorescence decreased in later flowers near the top. This could be attributed to non-uniform pollination, resource competition, or excess flowers per plant and excess ovules per flower.

Seed weight, as the most important yield component, can be optimized in cuphea by selecting plants with large capsule perimeter, capsule major and minor axes, capsule area, and small capsule tissue/seed weight ratio, and few (~ 9.0) seeds per capsule. This information would help plant breeders exploit genotypic variability in seed and capsule characteristics and agronomists identify optimum trait combinations to produce high yields of this potential oilseed crop.



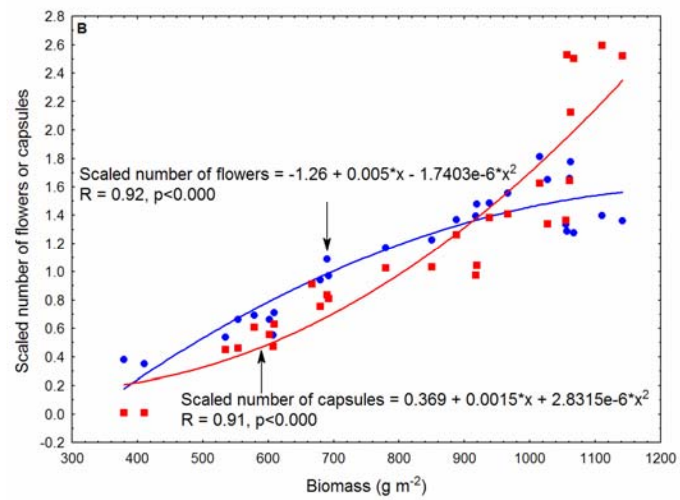


Fig. 1. Dynamics of number of flowers and number of capsules of the cuphea germplasm line PSR23 in response to growing degree days (a), and scaled number of flowers and number of capsules as functions of plant biomass (b) monitored over two growing seasons (2004 and 2005).

Appendix 1

2006 Publications

1348. Al-Maskri, A.Y., M. Shahid and **A.A. Jaradat.** 2006. Multivariate phenotypic structures in Batini barley landrace from Oman. Journal of Food, Agriculture, and the Environment. 4(2):208-212.

1330. **Archer, D.W.**, T.D. Crocker and J.F. Shogren. 2006. Choosing children's environmental risk. Environ. & Resource Econ. 33:347-369.

1338. **Archer, D.W.** and **H. Kludze**. 2006. Transition to organic cropping systems under risk. In: Proc. American Agricultural Economics Assoc. Annual Meeting, July 23-26, 2006, Long Beach, CA. 24 p.

1318. Bisikwa, J., R.L. Becker, N.R. Jordan, D.D. Biesboer, S.A. Katovich, and **F. Forcella.** 2006. Effect of method and time of buckthorn management on seedling establishment and resprouting ability of established buckthorn saplings [abstract] [CD-ROM]. 46th Annual Meeting of the Weed Science Society of America. WSSA Annual Meeting. Feb. 13-16, 2006, New York, NY. Weed Science Society of America 46:52.

1317. Bisikwa, J., R.L. Becker, N.R. Jordan, D.D. Biesboer, S.A. Katovich, and **F. Forcella.** 2006. Effect of surface litter on seedling emergence and establishment of European buckthorn (Rhamnus cathartica) [abstract] [CD-ROM]. 46th Annual Meeting of the Weed Science Society of America. WSSA Annual Meeting. Feb. 13-16, 2006, New York, NY.Weed Science Society of America 46:35.

1351. Callaham, Jr., M.A., G. González, C.M. Hale, L. Heneghan, **S.L. Lachnicht**, X. Zou. 2006. Policy and management response to earthworm invasions in North America. Biol Invasions 8:1317-1329.

1312. Chao, Wun S., Marcelo D. Serpe, James V. Anderson, **Russ W. Gesch**, David P. Horvath. 2006. Sugars, hormones, and environment affect the dormancy status in underground adventitious buds of leafy spurge (Euphorbia esula). Weed Science. 54:59-68.

1335. Clay, S.A., K.R. Banken, **F. Forcella,** M. Ellsbury, D. E. Clay and **A.E. Olness.** 2006. Influence of yellow foxtail on corn growth and yield. Commun. Soil Sci. Plant Anal. 37:1421-1435.

1328. Clay, S.A., B. Kreutner, D.E. Clay, C. Reese, J. Kleinjan and **F. Forcella**. 2006. Spatial distribution, temporal stability, and yield loss estimates for annual grasses and common ragweed (Ambrosia artimissiifolia) in a corn/soybean production field over nine years. Weed Sci. 54:380-390.

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Appendix 2

Lab Employees:

Jaradat, Abdullah – Supervisory Research Agronomist, Research Leader and Location Coordinator

Forcella, Frank – Research Agronomist

- **Peterson, Dean** – Ag Science Research Technician
- **Spokas, Kurt** – Research Soil Scientist

Gesch, Russell – Research Plant Physiologist

- **Boots, Dana “Joe”** – Ag Science Research Technician (Plants)

Johnson, Jane – Research Soil Scientist (Plant Biochemist)

- **Barbour, Nancy** – Biologist
- **Jansen, Rochelle** – Biological Science Aid
- **Warner, Katie** – Biological Science Aid

Kludze, Hillarius - Research Soil Scientist

Lachnicht Weyers, Sharon – Research Soil Scientist (Soil Biologist)

- **Wilts, Alan** - Chemist

Papiernik, Sharon – Research Soil Scientist

- **Amundson, Gary** – Engineering Technician

Reicosky, Donald – Research Soil Scientist

- **Miller, Seth** – Biological Science Lab Technician
- **Wente, Christopher** – Ag Science Research Technician

Eklund, James – Computer Assistant

Eystad, Kathryn – Program Support Assistant

Groneberg, Sandra – Program Support Assistant OA

- **Burmeister, Beth** – Office Automation Assistant

Groth, Pamela – Location Administrative Officer

- **Rohloff, Shawn** – Purchasing Agent OA

Hanson, Jay – Physical Science Technician

Hennen, Charles – Ag Science Research Technician

Knick, Brooke - Biological Science Lab Technician

Larson, Scott – Ag Science Research Technician (Soils)

Rinke, Jana – Chemist

Rollofson, Chad - Biological Science Lab Technician

VanKempen, Steve – Ag Science Research Technician (Soils)

Wagner, Steve – Electronics Engineer

Winkelman, Larry – IT Specialist (Customer Service)

Recognized for “Years of Service”

Joe Boots was recognized for 20 years and Sharon Papiernik for 10 years of federal service.

Civil Servant of the Year Award

Kathy Eystad received the 2006 Civil Servant of the Year award sponsored by the Federal Executive Board of Minnesota. Kathy was honored at an awards program and luncheon on May 6, 2005, at the Radisson South Hotel in Bloomington. Kathy serves as a volunteer on the local ambulance service and fire department. She spends her personal time in training so she can help her community. Recently, she answered a call during the work day from a coworker who was in physical trouble. Kathy was able to keep the coworker conscious until the paramedic and ambulance arrived. Kathy kept a cool head and allowed her training to take over so she could help. She sets a great example of service for all of us.

Appendix 3

2006 Visiting Scientists

Dr. Newton La Scala, Jr., a Brazilian researcher and university professor, spent six weeks as a visiting scientist at the Lab. Dr. La Scala used some of his data obtained in Brazil and a few of our data sets collected in Minnesota to develop and evaluate a simple model to characterize the impact of tillage on soil organic matter decomposition. His primary contribution was developing the simplified concept for the tillage effects on decomposition and using the no-till system as a reference condition to characterize temporal changes in carbon dioxide fluxes caused by many different soil, plant and climate factors. As a result of his effort, he drafted a manuscript entitled "Short-term temporal changes of soil CO2 fluxes after tillage described by a first-order decay model." This collaborative effort involved several scientists at our laboratory that involved challenging discussions on wind and aerodynamic effects on soil gas exchange.

Dr. Jose Luis Gonzalez Andujar received a grant from the Spanish government to visit the Lab the summer of 2006. Dr. Gonzalez Andujar is the Head of the Crop Protection Department at the Instituto de Agricultura Sostenible (CSIC). The CSIC is an agency of the Spanish Government, similar to ARS. Dr Gonzalez Andujar also is the current president of the Spanish Biometric Society, as well as president of the Spanish Weed Science Society. The reason for his visit was to confer and collaborate with our weed modeling group in regard to his successful grant proposal to the Spanish government "Development and validation of predictive emergence models in cereal-based agroecosystems: Elaboration of national level risk maps." The proposed research involved developing and sharing of equations, computer code, and simulations of seedling emergence of the weed, wild oat.

Short-term visitors

Brian Schutte, a Ph.D. student from Ohio State University, spent his spring break visiting the Lab. Brian worked with Kurt Spokas, Dave Archer and Frank Forcella to quickly develop a seedling emergence model for giant ragweed, a weed of rapidly increasing importance in the Midwest.

Mark Branson, David Cattanach and Andrew Nagorcha were three Nuffield Scholars from Australia who visited the Laboratory this year. The Nuffield Australia Farming Scholars awards scholarships each year to farmers in Australia. The objective is to increase practical farming knowledge and management skills and techniques generally. These scholarships give Australian citizens the opportunity to study farming practices in Europe, Asia and North America and those countries best suited to the Scholar. They also promote a closer understanding between farmers in the countries visited. Upon returning to Australia it is expected that Scholars will be able to actively spread the knowledge and understanding they have gained among their fellow farmers and others.

Craig Ross from New Zealand visited with Dr. Reicosky to go discuss basic principles of gas and change measurement and to compare different sized chambers.

Appendix 4

Summer Field Day 2006

The USDA-Agricultural Research Service Soils Lab in cooperation with the Barnes-Aastad Soil and Water Conservation Research Association hosted a field day at the Swan Lake Research Farm on Thursday, August 17 starting at 10 a.m. The West Central Cattlemen's Association served lunch. The research focus of the 2006 field day was "Electronics in Agriculture."

The tour stops included:

"Wireless weather stations and water stress "
by Kurt Spokas, Steve Wagner and Chris Wente (ARS-Morris) and Jerry Wright (U of M).

"Manure N build-up, GreenSeeker, fall N application"
by Roger Eigenberg and Bryan Woodbury (ARS-Clay Center, NE), Jack Gerhardt (Redball, Inc.) and Sharon Lachnicht (ARS-Morris).

"Manure N emissions and soil C emissions"
by Roger Eigenberg and Bryan Woodbury (ARS-Clay Center, NE), Russ Gesch and Chris Wente (ARS-Morris)

"GPS comparisons and auto-steering" by Dan Sieler (Raven Industries), Dave Ohm / John Anderson (Titan Machinery / Case-IH), Mike Stahn / Mike Langan (John Deere) and Dave Archer / Steve Wagner (ARS-Morris).

Hands-on auto-steering, GPS, GreenSeeker demonstrations and discussions with presenters followed lunch.

The *Swan Lake Research Farm is located (from the intersection of Highways 59 and 28 at Morris) 5.5 miles north on Highway 59 to County Road 74. Turn right (east) on 74 and travel 5.2 miles. Turn right at the dead end.*

Mark your calendars
for the
2007 Field Day -
AUGUST 16, 2007.

Appendix 5

Other Outreach

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

Take Your Daughters and Sons to Work Day

The Soils Lab hosted "Take Your Child To Work Day" for 8 participants. The day included a tour of the facility and stations demonstrating bugs, oil press, drop tower, bees and other crops.

Tomato Fest

NCSCRL conducted an experiment with the Morris Area Elementary School fifth graders.

Students measured tomato plants a number of times at the Lab's greenhouse facility. They learned about making observations, collecting data and analyzing data. The MAES hosted a Tomato Fest on December 15, 2006, and presented the results of their experiment to the community.

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 and Math Expo and the high school science fair.

Donations

The Soils Lab donated a 1986 Suburban to the Fond du Lac Tribal and Community College of Cloquet, MN.

Don Reicosky donated his personal collection of Agronomy Journal and Soil Science Society of America Journals from 1969-2006 to the library of Fond du Lac Tribal and Community College.

Outreach Initiative

Over the next five years, approximately 28% of the ARS workforce will be eligible to retire. The Lab is working with colleges and universities to promote careers with ARS by reaching a diverse pool of candidates. Several university and colleges invited our scientists to give guest lectures at the University of Minnesota-Morris, University of Minnesota (St. Paul campus), Penn State University, University of Manitoba and Sisseton Wahpeton Tribal College. Members of the American Indian Science and Engineering Society – UMM chapter toured the Lab in March.

National Ag Week Celebration

On March 21 and 22, the Soils Lab celebrated National Ag Day with over 600 students from Benson, Clinton-Graceville-Beardsley, Cyrus Math, Science and Technology, Hancock , Minnewaska, Morris Area, St. Mary's Catholic School and home schooling students from Chokio, Madison, Milan, Montevideo, Morris and Starbuck. The Lab hosted fast-paced, 45-minute tours showing how water, plants, soil, air and sun relate to agriculture and agricultural research. Students measured plant growth, encountered an indoor rain shower and discovered how important soil and sunlight are to plants.

Research Featured in ARS Magazine

Agricultural Research magazine highlighted the Lab's collaborative renewable energy project with the University of Minnesota Morris in the August 2006 issue.

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

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