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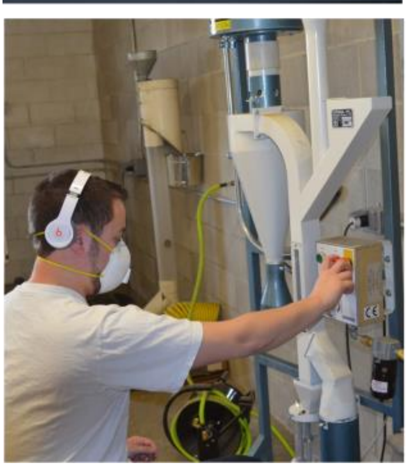
The North Central Soil Conservation Research Laboratory

Research Report

Agricultural Research



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

ARS Mission

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

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

Lab Mission

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

Preface

Abdullah Jaradat
Research Leader

March 28, 2016

I take the opportunity of the annual meeting of Barnes-Aastad Soil and Water Conservation Research Association, the Lab's stakeholders, to welcome and thank all of you for your continued support and interest in our research program. As usual, my colleagues and I will keep you informed of our progress and achievements. We welcome your initiatives, suggestions and inquiries in order to enhance the quality of our research program in service of the American people.

Research scientists and support staff at the North Central Soil Conservation Laboratory in Morris, with the relentless and unwavering support of stakeholders and the local community, and the collaboration of several federal, state and local partners, continued to carry out the mission of USDA, ARS and the Lab, and delivered solutions to agricultural and environmental problems in service of the American people. Highlights of last year's research, development and outreach are included in this report.

During the last few years, the farming community, especially in the Midwest, faced major challenges and went through major changes and transformations, and decided to embrace innovation in food and bioenergy production, coupled with environmental and natural resources conservation. The "Soils" Lab was, and still is, at the forefront of this innovation effort. The dedication to public service of scientists and support staff culminated in 2015 in meeting, if not exceeding, the goals set forth in the annual research plan. Most importantly, these accomplishments and innovations were in line with the priorities of, and contributed to achieving the strategic goals of USDA and ARS.

New developments included launching the Agency-wide "Grand Challenge" which aims to "Transform agriculture to deliver a 20% increase in quality production at 20% lower environmental impact by 2025." The Soils Lab is an active participant of this pioneering endeavor!

Scientists and their support staff developed guidelines for new management practices and strategies and demonstrated their benefits to a wide range of customers including public, non-governmental organizations, and private industry. The Annual Field Day attracted a large number of attendees who were presented with the latest developments in agricultural research carried out by the Lab scientists and their collaborators. Following the same tradition of sharing breakthroughs and innovations with our stakeholders and collaborators, the theme for the 2016 Field day will be "SOIL and WATER, we've got you covered!" My colleagues and I look forward to welcoming you to the Swan Lake Research Farm on July 21, 2016.

Soils Lab Scientists

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

Jane Johnson
Research Soil Scientist
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Research Focus: *Developing and assessing management strategies to provide sustainable food, feed and fuel while enhancing environmental quality and mitigating greenhouse gas emission*

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

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

Sharon Weyers
Research Soil Scientist
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Research Focus: *Land management impacts on soil health and nutrient availability*

Matthew Thom
Research Entomologist
Matt.Thom@ars.usda.gov

Research Focus: *Insect and pollination ecology in agricultural and natural environments; dual purpose cover crops and onsite water retention*

Matt started with the University of Minnesota in March, 2016. He is a **Post-doctoral Associate in the Department of Agronomy and Plant Genetics**, stationed at the Soils Lab.

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CLIMATE CHANGE

Advancing Sustainable and Resilient Cropping Systems for the Short Growing Seasons and Cold, Wet Soils of the Upper Midwest

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

Problem to be Addressed

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

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

Specific goals:

1. Determine crop residue needed to protect soil resources and identify management strategies that enable sustainable production of food, feed, and biofuel.
2. Develop options for managing crop systems to reduce greenhouse gas emissions and increase carbon storage.
3. Evaluate impacts of environmental changes (water, carbon dioxide, temperature) on traditional, biofuel, and alternative crops to develop a model-based risk assessment of crop production under the most likely medium-term (10-30 yr) climate change scenario for the upper Midwest.
4. Evaluate availability of nitrogen in organic production systems across different crops and soils as compared to relevant conventional practices.

2015 Progress Highlights

Long-term study on the effect of harvesting variable rates of corn stover marked its tenth anniversary, completing the fifth cycle of stover harvest in a corn/soybean rotation. The soil properties indicate the stover harvest is reducing the soil's ability to withstand erosive forces, although so far crop yield have not been significantly impacted. Integration and analysis of this large data set has begun.

Tillage can overshadow benefits of retaining residue for erosion control. Both photos without tillage, top-all residue returned and bottom-aggressive residue harvesting, which leaves the soil exposed and less resilient to erosive forces of wind or rain.

Nitrogen in organic production systems

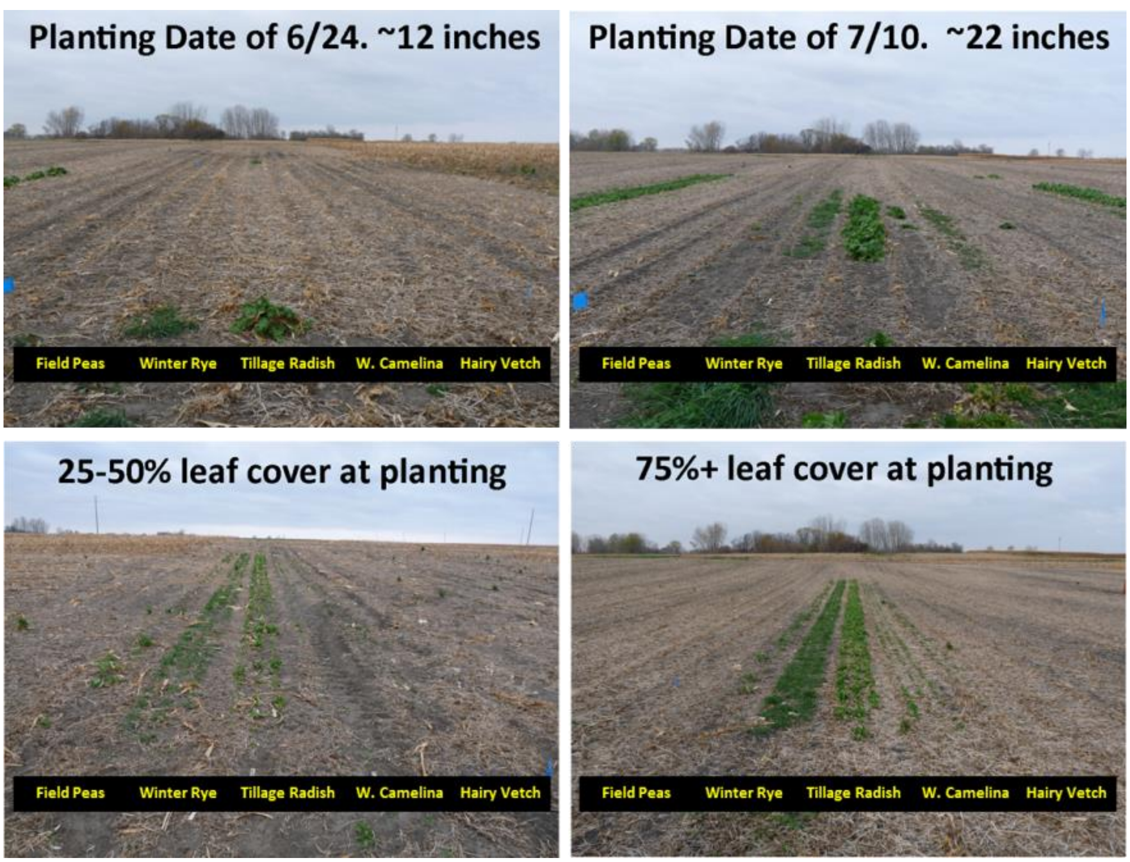
Sharon Weyers

Substantial progress has been achieved in evaluating availability of nitrogen in perennial biomass production systems using different nutrient amendments in collaboration with the University of Minnesota-Morris. Results indicated that high fertilization levels with conventional fertilizers improved green biomass production up to 30%, but resulted in the loss of plant diversity, particularly nitrogen-fixing legumes. Use of animal manures boosted productivity over the absence of fertilizers, and maintained plant diversity. Despite the lower green production, harvestable biomass taken after frost-induced senescence was slightly higher under the manure application regiment. Data from this project were presented at the biennial Soil Ecology Society Meeting in 2015

New Inter-seeder for cover crops studies

A new cover crop interseeder-applicator was purchased. (http://extension.psu.edu/plants/crops/soil-management/cover-crops/interseeder-applicator).

During 2015, preliminary trials began to assess when and how to integrate cover crops into corn and soybean rotations using this new no-till InterSeeder. This trial evaluated several winter-surviving (winter cereal rye, hairy vetch, winter camelina) and winter-terminating (field pea and tillage radish) covers. For several of the cover crops planted in the 2015 growing season, we observed very good to excellent germination under standing corn and soybean. However, the best cover crop stand was under soybean. Interseeding into corn has been successful in Pennsylvania Interseeding into soybean, in late June, early July, and early September appeared to be viable options for several of the cover crops surveyed. However, we had very limited success interseeding into corn, as excessive shading reduced cover crop vigor (stand and growth). Based on our casual observation, an east-west as compared to a north-south raw orientation of the corn crop lowered the vigor of a cover crop .



Preliminary replicated planting date trial. All photos taken October 21 after soybean harvest on September 16. Top row photos show cover crops planted June 24 when soybean were ~12 inches tall and July 10 when soybeans were ~22 inches tall. Bottom row shows cover crops planted September 4 into soybean stands with 25-50% and 75% leaf cover at planting. Cover crops from left to right are field peas, winter cereal rye, tillage0 radish, winter camelina, and hairy vetch.

Our work contributes to related ARS-wide networks:

ARS-REAP–Resilient Economic Agricultural Practices. Meeting demands for food, feed, fiber, and feedstock while supporting other agroecosystem services though enhanced soil health.

GRACEnet – Greenhouse gas Reduction through Agricultural Carbon Enhancement network. A research program to assess soil carbon sequestration and greenhouse gas mitigation by agricultural management. GRACEnet is considered the premiere agricultural GHG research project worldwide. As a result, the Global Research Alliance (GRA) adopted a similar project structure and measurement protocols approach called MAGGnet that is based on GRACEnet.

LTAR – Long-Term Agro-Ecosystem Research. As part of the Upper Mississippi Watershed.

The Soils Lab participates in ARS's upcoming "Grand Challenge"

New developments included launching the Agency-wide "Grand Challenge" which aims to "Transform agriculture to deliver a 20% increase in quality production at 20% lower environmental impact by 2025." The Soils Lab is an active participant of this pioneering endeavor!

Program planning in ARS is a continuous process; it is an ongoing effort to optimize problem-solving whereby agricultural production of high quality food and feed is balanced against environmental protection and natural resources conservation. It is a continuing "Grand Challenge!" As a first step in this process, the Agency leadership unfurled the pilot Grand Challenge:

Last July, about 50 of the Agency's scientific and program leaders convened a national workshop to develop this agricultural equivalent of the "Moon shot". The national workshop identified a number of supporting research goals to meet this challenge

- Emerging pests and diseases
- Reduce losses
- Health and nutrition
- Utilize Long-term Agro-ecosystem Research (LTAR) infrastructure to decrease environmental impacts and develop land use strategies
- Resource use efficiencies
- Increasing yield potentials

The Soils Lab was represented and actively involved in defining the Grand Challenge goals. Moving forward we will engage our fellow ARS scientists, university collaborators and stakeholders, build on our on-going agronomic and conservation research efforts, including the LTAR experiments to achieve the objectives of this Agency-wide Grand Challenge by 2025, if not before.

Technology Transfer/ Outreach items

Presentation on soils "The thin layer between us and starvation" presented to the Morris Area High School as part of a science field trip to the Glacial Lakes State Park near Starbuck, Minnesota

Two UMM -IUSE Interns – Trey Goodsell and Francis Reed were hosted by Soils Lab scientists. The program is designed to offer paid research and work experience to Native American STEM majors interested in environmental fields.

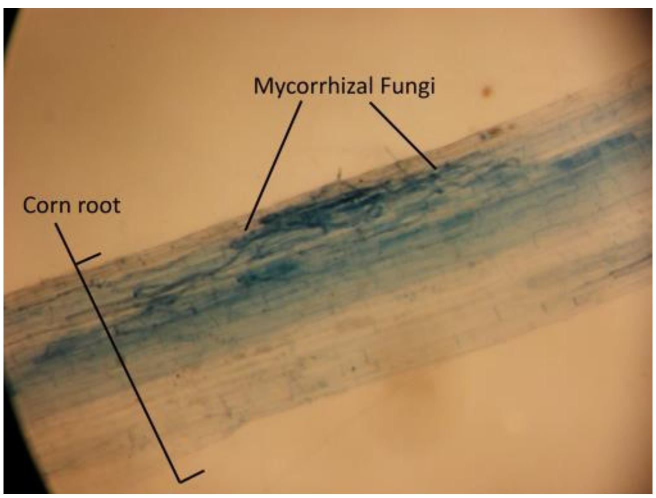
Co-hosted 10 students from Australian universities with the University of Minnesota-Morris. This tour and information exchange was part of the GO Minnesota: Innovations in Environmental Sustainability 2015, which is a summer sustainability program for international students.

Accepted an invitation to participate in and contribute to the Agro-ecology Summit, which was hosted by a progressive farmer in southwest Minnesota. The summit included discussions and field visits to evaluate and critique the application of agro-ecological concepts. These included crop production, soil and water management, integration of managed agro-ecosystems with natural or semi-natural ecosystems, and the impact on biodiversity. The event was attended by farmers and officials who work on natural resources conservation and soil and water management. Presented and led discussions on hulled wheat species (einkorn, emmer and spelt) and outlined their potential place in small farms as a cottage industry, as sources of healthy food, and their positive ecosystem and environmental services.

Farmer-friendly fungi

John Zaharick and Jane M.F. Johnson

Corn growing in a greenhouse at the USDA-ARS Lab in Morris,MN. Roots of these plants will be examined for beneficial soil fungi known as mycorrhizal fungi.



Mycorrhizal fungi inside a corn root cell. Staining allows researchers to distinguish between fungal and plant cells under a microscope.

Mycorrhizal (my-kuh-ry-zul) fungi can be a valuable aid to agriculture. Most mycorrhiza fungi form a relationship with plant roots. They grow inside root cells and extend outward into the soil, fitting into soil spaces too small for roots to access. These fungi are more efficient than most plants at obtaining nutrients (like phosphorus) and water from the ground, but they have no way of making their own food the way plants can through photosynthesis. To survive, the fungi provide nutrients and water to their host plants in exchange for carbohydrates (sugars).

The benefits of this symbiotic relationship to agriculture are numerous. When mycorrhizal fungi are present in roots, corn and soybeans require less phosphorus, soybeans withstand drought better, and corn yields more. Such crops are also more disease-resistant. Another benefit is improved soil health thanks to a protein the fungi produce that binds soil particles together. This, in turn, leads to better water infiltration and aeration, which benefit the fungi's hosts and also reduces erosion by increasing soil stability.

If these fungi are so fantastic, how do we get them into our fields? Many places sell mycorrhizal fungi inoculant as a way to promote plant growth, but if soil conditions aren't right, the fungi won't grow. Plus, the fungi that are best suited to a particular plant species and climate usually already exist in the soil, and the right conditions will cause them to prosper.

Determining what crop-management techniques influence mycorrhizal fungi requires researchers to examine soil for mycorrhizae, which isn't as straight forward as counting or weighing crops. Mycorrhizal fungi are typically too small to be seen with the naked eye, and they're not the only microorganisms that live in the soil. This necessitates having a method that can both detect the fungi and distinguish them from other soil-dwelling microbes, including bacteria. Although soil biologists have several powerful tools to do this, many of them are expensive. Fortunately, there's a simple and low-cost alternative: the biological assay.

A biological assay is a tool that uses living material for testing. For mycorrhizal fungi, soil is collected and brought into a greenhouse. Plants known to form symbiotic relationships with these fungi, such as corn, are planted in the soil. Mycorrhizal fungi there grow and inoculate the sprouting corn. The corn roots are then removed and stained with a blue dye that colors fungal but not plant cells. That way, when roots are examined under a microscope, the fungi appear bright blue and distinct from the glass-like plant cells, making it easier to identify and count the microbes.

This biological assay can be used to determine if a particular crop-management strategy increases or decreases the number of beneficial microorganisms in our soils. At the North Central Soil Conservation Research Lab, for example, scientists are using biological assays to determine the impact of corn-stover harvests or other management techniques such as choice of cover crop on these beneficial soil fungi, making the best possible use of them for improved yields and quality.

N_2O emission and soil C sequestration from herbaceous perennial biofuel feedstocks

Jane M. F. Johnson and Nancy Barbour

Switchgrass and big bluestem are potential perennial grass bioenergy feedstocks. Perennial grasses managed as bioenergy feedstock require nitrogenous inputs, which can cause nitrous oxide (N_2O) emission and; thereby, alter their effectiveness to mitigate greenhouse gas emission.

The objectives of this study were to compare N_2O flux and soil organic carbon storage between

1) Grasses with legume companion crop or with nitrogenous fertilizer,
2) Two grass harvest times (autumn, spring), and
3) Perennial systems and corn/soybean rotation, all without tillage.

Nitrous oxide flux was measured for three years. During the study period cumulative nitrous oxide emission was 14 to 40% greater in the Big Bluestem-Spring and Switchgrass-Spring treatments compared to respective Autumn harvested treatments. Big Bluestem-Clover and Switchgrass-Clover treatments had dramatically reduced annual N_2O emission compared to the respective grasses with urea fertilizer.

Emission factor (EF) is the percentage of nitrogen fertilizer lost as the potent greenhouse gas – nitrous oxide. For fertilized grasses the averaged EF was 2.5%, which was more than double that observed from corn, which averaged 1.05%. Interseeding clover with the herbaceous perennial reduced N_2O flux but also reduced yield. Harvesting in the autumn instead of delaying until spring reduced N_2O emission and yield-scaled emission.

Soil organic carbon, is directly related to soil organic matter. Storing organic carbon in the soil is a strategy to offset the excessive greenhouse gases in the atmosphere. In this study, we measured an increase in organic carbon under the perennial grasses but not in the no till corn/soybean field. The carbon stored by grass on average may have been enough to balance the additional N_2O emitted, after accounting for the fact that it takes about 300 soil organic carbon units mass for every one unit of N_2O emitted. Strategies to improve perennial grasses managed as bioenergy feedstock so they provide maximum agronomic and environmental benefits are needed.

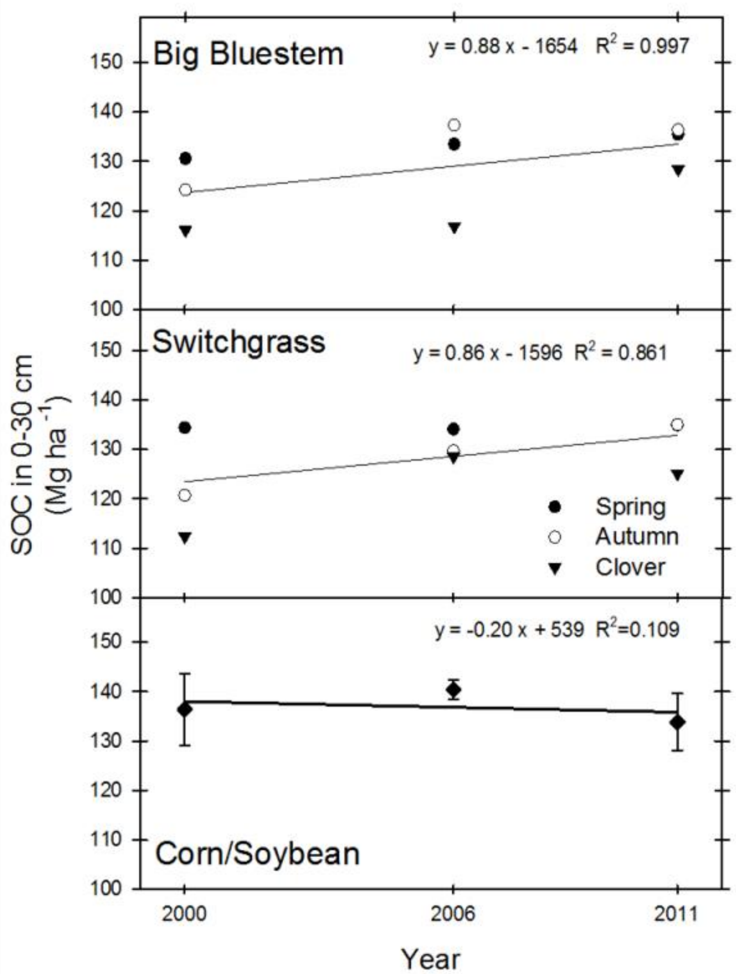


Fig. 1: Change in soil organic carbon (SOC) 0-30 cm (0-12 inches) soil profile under grass or corn/soybean. (Mg/ha * 0.47 = tons/acre)

Optimizing ecosystem services through long-term agroecosystems research

Abdullah A. Jaradat and Jon Starr

The intensive land use and agricultural production systems in the Chippewa River Watershed (CRW) in Minnesota, USA, contribute to inherent environmental problems and have major direct impact on soil conservation, and on several competing Agro-Ecosystem Services (AESs); it may have indirect impact on AESs in the Upper Mississippi River Basin (UMRB). Field-scale indicators of AESs are largely absent in the highly diverse soils of the watershed. The objective of this research was to estimate and contrast agroecosystem services for major and minor soils, and land capability classes across the watershed under past (20th century) and future (21st century) climate. This research was partially funded by The Walton Family Foundation in collaboration with The Land Stewardship Project.

The Watershed

The Chippewa River drains 5,387 km^2 of mixed natural and managed ecosystems in several counties in west-central Minnesota. Farmers produce several commodities including corn, soybean, some wheat and sugar beet, and livestock. The watershed has high-value ecological features, including seven major lakes, two State parks with prairie, forest and lake areas, wildlife and waterfowl areas, and 3,000 km of perennial and intermittent streams

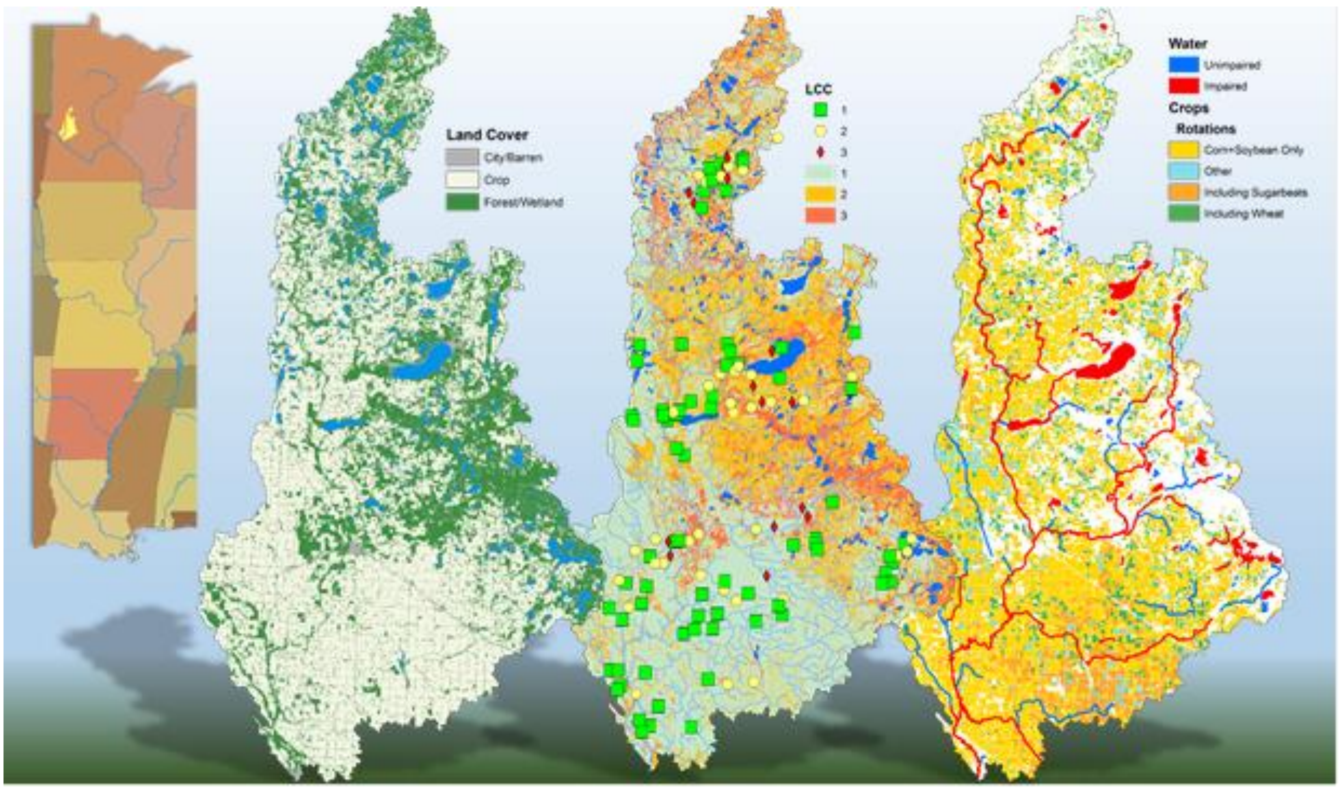


Fig. 1. Map of the Chippewa River Watershed showing crop coverage and water quality (red color indicates impaired water).

Objectives

- Develop proxy indicators to assess AESs under past 100 years (1901-2000; A0) and future (downscaled A2D scenario; 2001-2100) global climate change (GCC) scenario;

- Individual indices were developed for Biomass, Grain yield, NO3- and NH4-N, Soil Carbon, Runoff, Drainage, and Soil Erosion for 132 soil series (representing ~90% of total land area in the watershed) classified into three land capability classes (LCCs);

- The indices and a weighted index (*Iw*) were subjected to multivariate analyses procedures, including distance-weighted least squares, and variance components estimation.

- The modeling framework and the mapped AES indicators were designed to achieve multiple goals and will be used to support farmers in designing Specific Crop Rotations that are suitable for each of three LCCs and for major and vulnerable soil series in the watershed.

Simulated Data

- We calibrated a simulation model using extensive soil and crop yield data generated on soil series in the Swan Lake Research Farm for eight years.
- We performed an extensive simulation study (Table 1) using two climate change scenarios, each with 100 years of weather data, two cropping systems (conventional and organic), within each system, we simulated nine crop rotation with different crop sequences and number of crops per rotation on 132 land series we identified in the watershed. These soil series represented ~90% of the land area within the watershed.
- The number of years per crop rotation ranged from 2 to seven years. The longer crop rotations included a perennial crop (alfalfa) or hay.
- The future downscaled climate change scenario (A2D) produced realistic weather data across the watershed.
- We estimated positive ecosystem services as well as negative ecosystem dis-services for each cropping system-crop rotation-land capability class combinations.

Design of the Simulation Study

Scenario	Cropping System	Crop Rotations	Crop1	Crop2	Crop3	Crop4	Yrs
A0	CNV	CS	Corn	Soybean			2
A2D	ORG	CSbS	Corn	Sugar beet	Soybean		3
		CSbSW	Corn	Soybean	Sugar beet	Wheat	4
		1ACSW	Alfalfa	Corn	Soybean	Wheat	4
		2ACSW	2Yr-Alfalfa	Corn	Soybean	Wheat	5
		3ACSC	3Yr Alfalfa	2Yr Corn	Soybean		6
		3ACSW	3Yr Alfalfa	Corn	Soybean	Wheat	6
		3HCSW	3Yr Hay	Corn	Soybean	Wheat	6
		3ACCSW	3Yr Alfalfa	2Yr Corn	Soybean	Wheat	7

Table 1. Factors included in the simulation study to assess ecosystem services in the Chippewa River Watershed in response to climate change during the 21st century.

Results

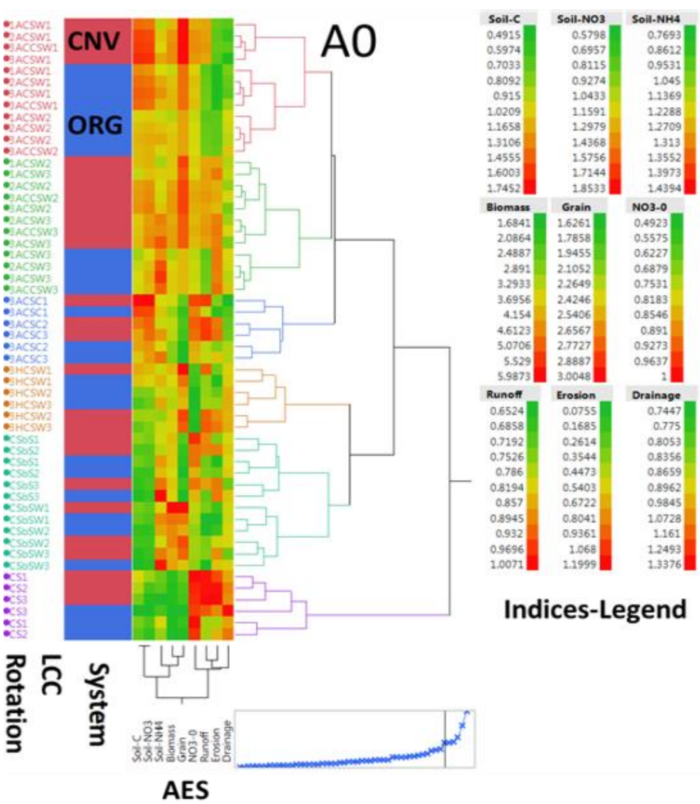


Fig. 2. Classification of agroecosystem services in the Chippewa River Watershed based on weather data of the 20th century (1901-2000) and clustered by crop rotations, land capability classes and cropping systems. Soil-carbon, Soil-NO_3, Soil-NH_4, Biomass, and Grain yield are positive agroecosystem services, the remaining are dis-services (negative).

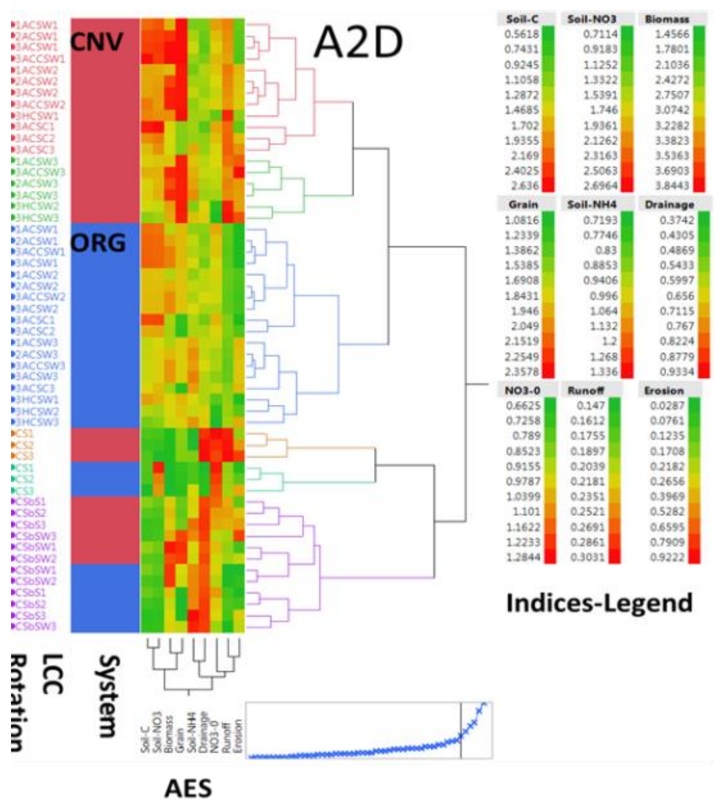


Fig. 3. Classification of agroecosystem services in the Chippewa River Watershed based on downscaled weather data during the 21st century (2001-2100) and clustered by crop rotations, land capability classes and cropping systems. Soil-carbon, Soil-NO_3, Soil-NH_4, Biomass, and Grain yield are positive agroecosystem services, the remaining are dis-services (negative).

Results continued

- The 3-dimensional maps delineated contiguous areas of increasing or decreasing AESs in response to projected GCC and its interaction with several management factors.

- The largest and most significant variance portions in *Iw* were attributed to GCC scenarios (A0 and A2D); followed by the interaction between crop rotations and LCCs within conventional and organic cropping systems.

- A gradual, but substantial increase in soil-nitrogen reserves due to increased frequency of a perennial forage legume in crop rotations resulted in positive AESs over 100-years of simulation runs; these AES were predicted with larger certainty under A2D in organically-managed LCC-1 as compared to the same soil LCC under conventional management.

- Significantly more runoff and soil erosion are predicted in conventionally-managed LCC-2 and LCC-3 under the same GCC scenario, regardless of soil heterogeneity.

Conclusions

Future global climate change scenario is expected to impact positive and negative agroecosystem services;

Interacting and nested factors (e.g., cropping systems, crop rotations, crops, etc.) explained 36.5 to 75.8% of total variation in agroecosystem services (Average 63.4% in *Iw*);

Simple-short crop rotations resulted in more negative than positive agroecosystem services;

Relationships between positive and negative agroecosystem services depends on future global climate change scenarios;

Current (A0) and Future global climate change scenario (downscaled A2D) impact agroecosystem services in conventional and organic cropping systems differently depending on the crop rotation;

Best agroecosystem services- Land capability class: 3 Yr Perennial +1 Yr Cereal + 1 Yr Grain legume + 1 Yr Cereal

Probability of providing positive agroecosystem services under A2D increases with increased length and complexity of the crop rotation;

The modeling framework and the mapped AES indicators are designed to achieve multiple goals and will be used to support farmers in designing specific crop rotations that are suitable for each of the three LCCs and for major and vulnerable soil series in the watershed. In addition, the modeling framework will address sustained delivery of multiple AESs, while enhancing soil conservation, water quality, and environmental protection aspects of farming in the CRW and the UMRB.

Future research

Plans are underway at the Soils Lab to establish a long-term common experiment and a large-scale whole system monitoring experiment as part of the Upper Mississippi River Basin (UMRB) Network; one of 18 LTAR Networks across the Nation.

These plans will eventually link LTAR activities with the objectives of the Grand Challenge; explore the effects of genotype x environment x management (GxExM) interactions on crop production and the environment; generate and contribute databases to be included in the big data initiative; and provide research-based data and information to the climate hub in the Midwest.

It is expected that the LTAR will provide data and test a broad hypothesis "… *the net primary productivity and yield, food safety and quality, and use efficiency of agricultural inputs can be increased while maintaining or improving delivery of ecosystem services*."

CROPS

Enhancing cropping systems sustainability through new crops and management strategies

Russ Gesch (Lead Scientist), Frank Forcella, Jane Johnson, and Abdullah Jaradat
Post Doctoral Research Associates: Carrie Eberle and Matthew Thom

Problem to be addressed:

Increased demand for food, loss of arable land due to urbanization, and added pressure on farm lands to produce biofuel feedstocks along with food, feed, and fiber threaten to jeopardize long-term agricultural economic and environmental sustainability. These pressures have led to production of only a few commodity crops in the Midwest, which use large amounts of agricultural inputs (e.g., pesticides and fertilizers). While input costs continue to rise, diverse and sustainable agro-ecosystems are diminishing in this region. Superimposed upon this situation are environmental stresses such as drought, heat, and short growing seasons that limit productivity, as well as economic uncertainties exemplified by highly fluctuating commodity prices.

The goal of our research is to develop new crops and timely crop and weed management strategies to increase agricultural diversity and overall cropping efficiency and add ecosystem services in northern climates. Our intent is to provide producers and other clientele with new knowledge, crops, and management tools to increase cropping efficiency and diversity in northern climates. Our outlook is long-term – agricultural systems for the future.

2015 Progress highlights:

New oilseed crops and cropping systems research

Russ Gesch

Duel cropping with winter oilseeds – Double and relay cropping are methods used to produce two crops in a single season. Although these practices have been commonly used in the south and central U.S., the growing season in the northern Corn Belt is typically too short for such systems to work effectively.

The Soils Lab, however, has developed double and relay cropping systems that use winter annual oilseeds, camelina and field pennycress, as fall-seeded cover crops that mature early enough the following spring that they can be harvested for their seeds and allow the production of a short-season primary summer crop such as soybean. A key limiting factor in double crop production is having enough soil moisture and precipitation to successfully produce both crops.

Our team recently published results that showed that double and relay cropping winter camelina with soybean on average only used about 1 to 1.5 inches more water during the growing season than a single full-season soybean crop (see Table 1), indicating that many areas within the Corn Belt region would receive enough moisture to produce both crops. We also found, as shown in Table 1, that the water use efficiency of seed production (WUE) for camelina was considerably greater than that of soybean.

	Water Use (inches)			WUE (lb. seed/acre/inch)	
Cropping Treatment	Season total	Camelina	Soybean	Camelina	Soybean
Double Crop	19.8	4.5	15.3	221	102
Relay/ glyphosate	19.1	3.9	15.2	301	136
Relay/no glyphosate	19.4	4.8	14.6	231	145
Full-season soybean	18.3	NA	18.3	NA	192

Table 1. Seasonal crop water use and water use efficiency in dual cropping systems of winter camelina followed with soybean.

Fig. 1. Relay cropping soybean with pennycress. The picture on the left is before, and picture on right is after harvesting pennycress. The soybean is allowed to mature and is harvested at a normal time in the fall. The system is the same using camelina.

Expanding the potential use of new winter oilseeds for dual cropping in the upper Midwest means incorporation in corn-soybean rotations. One of the biggest challenges of this system is establishing oilseeds as cover crops into standing corn. This is because grain corn is usually harvested too late in the fall to allow good cover crop establishment if oilseed planting is done after corn harvest. Work by our team has recently attracted extramural funding to research and develop optimum practices for planting and establishing cover crops, especially winter oilseeds, into standing corn as shown in Figure 2.

Fig. 2. Planting oilseed cover crops into standing corn with a modified highboy seeder. Picture on right shows winter camelina established in standing corn.

Winter oilseeds protect the soil – Water quality and how it is being impacted by agriculture has become an important issue in Minnesota and elsewhere. Research conducted by our team this past year, which is supported by extramural funds, has shown that winter camelina and pennycress grown as cash cover crops help to prevent soil erosion. Figure 3 shows runoff water collected from plots where cover crops, including winter camelina and pennycress, were compared to no-tillage and conventionally tilled plots in the spring after an intense rain. Less sediment (lighter colors) can be seen in the runoff from pennycress and camelina plots indicating that they held soil in place, thus preventing erosion.

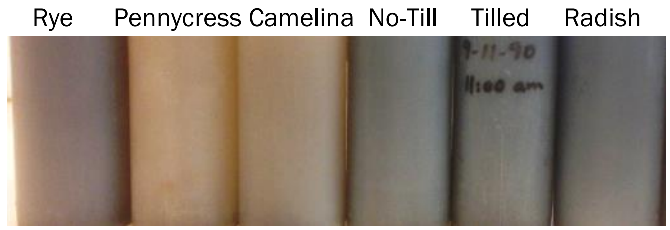


Fig. 3. Runoff from cover crop plots at the Swan Lake Research Farm after an intense rain event in mid-May 2015.

This same research study has shown that camelina and pennycress plants accumulate excess soil N left behind by the previous crop in fall and spring. The soil N sequestered by the plants is no longer susceptible to leaching into ground and surface waters where it then becomes a pollutant.

New oilseed crops in rotation bolster traditional crop yields – A primary goal of our research is to diversify cropping systems while adding new economic opportunities for farmers and improving cropping efficiency. Recent work (2013 to 2015) by our team in collaboration with one of our sister ARS labs in Brookings, SD has shown that corn grain yields are improved when following new/alternative oilseeds in rotation (Figure 4).

Similar yield improvements were found for soybean and spring wheat as compared to growing them in monoculture or following corn in rotation. Moreover, the oilseeds used in this study generally required fewer fertilizer and pesticide inputs and were also found to use less water during their growing season than either corn or soybean. Integrating these oilseeds into rotations with corn, soybean, and wheat can improve cropping efficiency and minimize negative environmental impact.

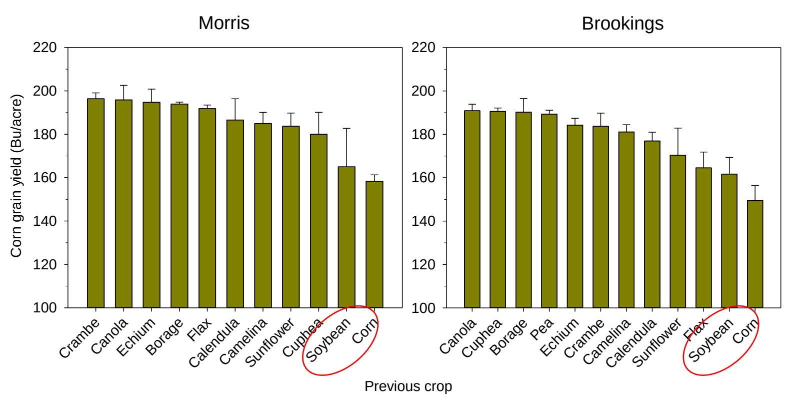


Fig. 4. Yields of corn following corn or 10 other crops at the Swan Lake Research Farm, Morris and at Brookings, S.D. Note that corn yields are consistently lower when following corn or soybean than any of the nine other oilseed crops.

Pollinator research - A lack of agricultural diversity and the loss of pollinator forage resources are major factors contributing to declines observed in beneficial insects such as pollinators. These declines include increased annual losses to managed honey bee colonies as well as reductions in the abundance and diversity of wild bee species. Research by our team has shown that specialty oilseeds can provide abundant floral resources to support pollinating insects, and provide high-value crops for farmers. Nectar of oilseed echium provides the most sugar for pollinators at about 421 lbs/acre (Figure 5 below).

Other specialty oilseeds such as canola, crambe, borage, and cuphea in addition to echium, provide enough sugar in just 2.5 acres to supply the entire annual sugar needs of at least one managed honey bee colony. Research also showed that the flowers of all oilseed crops were visited by pollinators with as many as 90 visitations per minute. Incorporating specialty oilseed crops into current crop rotations in the upper Midwest could reverse the decline in pollinators and provide forage resources that are currently lacking. This work led to a recently published (2016) peer-reviewed article in Crop Science, and a picture from the study was included on the front cover of that magazine.

Our team has also been instrumental in developing an easy to use "app" for Tablets that can be used to categorize and record insect visitations to flowering plants. The NRCS and Xerces Society (a non-profit organization that protects wildlife through conservation of pollinators and other invertebrates) plan to use a version of this app for monitoring pollinators.

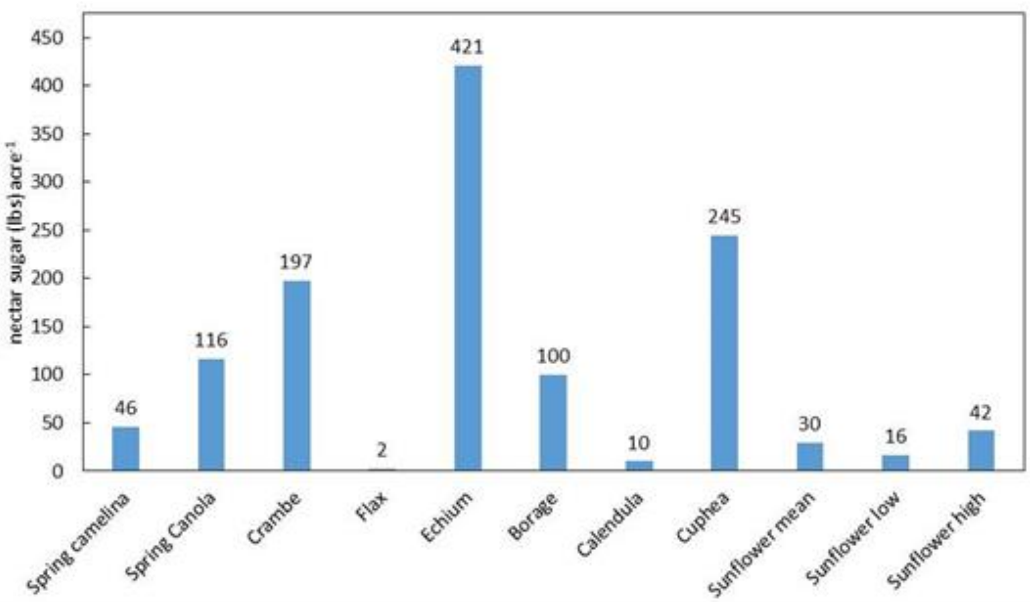


Fig. 5. Total floral sugar production of specialty oilseed crops grown at the Swan Lake Research Farm.

Weed Management Research

Frank Forcella

Weed control for new crops – Developing good weed management is critical to new crop production. Cuphea is a new oilseed crop on which the Soils Lab has worked for a number of years as a replacement for imported palm oil (for the manufacturing of detergents, etc.). The crop now is being produced commercially in North America. Cuphea is known to tolerate only a few herbicides. Of particular importance for cuphea production is identification of herbicides to selectively control broadleaf weeds. Our research team has demonstrated in both lab and field studies that cuphea tolerates bromoxynil a herbicide that controls a wide range of broadleaf weeds and that is found in common herbicide products familiar to farmers. This now adds to the choice of herbicides that growers can use for producing cuphea and has been added to a "Growers Guide" that our Lab has developed. Additionally, a new herbicide, known as bicyclopyrone, also was shown to be tolerated by cuphea, which adds to the small but growing arsenal of products that cuphea farmers need to control weeds in this novel crop.

Weed seed germination and modeling emergence – Pennycress, although considered by many as a weed, is being developed as an oilseed feedstock for biofuels. However, it does possess certain weedy characteristics that make it difficult to manage as a crop. One of these traits is seed dormancy. Our team collaborated with researchers from the University of Lleida in Spain to demonstrate that seeds produced by plants that originally germinated and began growing in the fall had a much greater degree of dormancy than seeds produced from plants that began growing in the spring. This knowledge will be shared with other scientists with whom we collaborate to develop domesticated lines of pennycress whose seeds are not dormant. We also collaborated with scientists from Spain on developing an improved simulation model for predicting the emergence of camelina. This model is novel in that it incorporates daylength along with soil temperature and moisture to predict when seedlings emerge from the soil. Camelina is another plant that is managed as a weed in some areas such as Spain, but that is also being developed as an oilseed feedstock for industrial and food applications.

New weed management techniques – The PAGMan (air Propelled Abrasive Grit Management of weeds) concept, which originated at the Soils Lab, was extended in 2015 by several developments. One is centered at the University of Illinois (in conjunction with ARS and South Dakota State University) and is devoted to using the PAGMan technique for weed control in vegetable production. The new equipment is known as "Veggie Blaster."

This concept now is being adopted for weed control in organic strawberry and other horticultural crops in California and was featured in the recent EcoFarm Conference in Asilomar (January 2016). The technique also has been adopted by weed control technicians in county parks in Maryland.

Frank Forcella with the PAGMan

Additionally, researchers at the University of Seville, Spain, are implementing the concept for weed control in olive orchards and vineyards. The Soils Lab is a collaborator on both the Illinois and Spanish projects. In all cases the grit materials being used for weed control are derived from agricultural residues: olive pits, grape seeds, corn cobs, canola meal, poultry manure, etc. Some of the grits are organically-approved nitrogen fertilizers.

Dan Humburg at South Dakota State University and the most recent Veggie Weed Blaster

Veggie Blaster – construction finished late 2015

Technology transfer - Technology developed by our team during 2015-2016 was transferred to clientele and other interested parties through several venues including professional meetings, field days, industry and grower meetings, and popular press articles as well as several peer-reviewed scientific publications and through downloading of usable software from our Web site for modeling and predicting soil microclimate and weed phenology/ecology. Some specific examples are as follows:

One of our team was invited to participate as a member of a presidentially mandated Task Force to co-author the "Pollinator Research Action Plan," which was published and released by the White House in May 2015. The Action Plan, which resulted from this mandate, contains a "roadmap" for federally-supported pollinator health research and will help to prioritize where and how federal funds are used for pollinator research.

Team members were invited by the Minnesota Corn Growers Association and the Minnesota Soybean Research and Promotion Council to attend a meeting in Mankato, MN and present our research highlights on double and relay cropping soybean with winter camelina and pennycress as cash cover crops. One of our team members was also invited to present research on double cropping strategies with winter oilseeds at a Crop Pest Management Short Course hosted by the University of Minnesota that was attended by about 1500 agriculture professionals from across the Midwest.

Team members have contributed to update guidelines and management strategies for efficient production of new/alternative oilseed crops including camelina, calendula, and cuphea. Aveda Corporation (division of Estee Lauder) is contracting with a commercial seed oil expeller, specialty chemical company, and growers in MN to scale-up cuphea production for a newly developed line of shampoo and facial cleanser.

The team hosted, by request, the annual field trip for the Minnesota Honey Producers Association. This field day and evening barbeque involved the leadership plus about 120 other members of MHPA. It was held at the USDA-ARS Swan Lake Research Farm. The event attracted the attention of Minnesota Public Radio and led to a broadcasted interview on radio as well as Twin Cities television stations.

Team member was invited to present the PAGMan weed control concept to the annual EcoFarm Conference. This conference is the largest organic conference in North America, with thousands of attendees. The conference organizer, Bob Canistano, himself an organic farmer and organic crop advisor, built his own version of a grit applicator and advocated for the concept in front of 500 organic growers during the meeting. This represented a ringing endorsement that was far more valuable than nods of affirmation by fellow scientists.

Team member was invited to the University of Seville to lecture on new methods of physical weed control to the Crop Pest Management graduate program.

Team member was invited to the ALAM conference (Latin American Association of Weed Science Societies) to present a keynote address on the practical use of simulation models in weed management.

Team members include:
Joe Boots
Michael Carlson (SDSU grad student)
Rebecca Carlson (UMN grad student)
Carrie Eberle
Jim Eklund
Mauricio Erazo-Barradas (SDSU grad student)
Frank Forcella
Russ Gesch
Cody Hoerning (UMN grad student)
Dean Peterson
Matt Ott (UMN grad student)
Matt Thom
Jason Thomas (UMN grad student)

Corn Quality: High macro– and micro-nuitrient contents

Abdullah A. Jaradat[1], Walter Goldstein[2], Jana Rinke[1], and Jon Starr[1]
1: USDA-ARS; 2: Maandaamin Institute

Introduction

It is a challenge to breed and select maize varieties with enhanced levels of protein, oil, starch, and essential amino acid contents while maintaining competitive agronomic capability. Moreover, it is more challenging to maintain high levels of nutrients, especially iron and zinc, while improving other quality traits under farm conditions. Earlier, we identified sources of variation of single and multiple quality traits, determined the level of genetic diversity present in a wide pool of maize germplasm, and quantified phenotypic variation that may be useful for developing high-quality maize varieties. The germplasm and information are also of value for genetic studies to investigate the genetic architecture of relevant quality traits. We developed a relational database and constructed a complex array of direct and indirect relationships between and within physical, biochemical, nutrient, and color traits of maize kernels that can be used for further research and for in-depth understanding of its diversity structure. In this article, we present highlights of a study of the nutrient contents and interrelationships and how they are influenced by other quality traits in the maize kernel.

Germplasm and its characteristics

The maize germplasm consisted of 1,348 accessions classified into two heterotic groups, each with opaque or translucent endosperm. There were four genotypes within the stiff stalk heterotic group and eight genotypes within the non-stiff stalk heterotic group (Table 1).

Heterotic Group	Genotypes	Endosperm entries		Total
		Opaque (O)	Translucent (T)	
Non-stiff stalk (NS)	1895-DK212-N11a	22	47	69
	CHO5015-Mo17	27	55	82
	DKXL370-N11a-N20	36	54	90
	DKXL888-N11a-N17	41	72	113
	GQ-N16-N12	9	39	48
	LH28-AR16021	37	112	149
	Mo42-N220A	25	0.0	25
	NG-Mo508-Mo506	3	3	6
	NG	115	129	244
Sub-total		**315**	**511**	**826**
Stiff stalk (SS)	AR16021-B73	113	117	230
	CHIS740-S14-S12	32	70	102
	DKXL370-S11	7	117	124
	LH119-AR16035	27	39	66
Sub-total		**179**	**343**	**522**
Total		**494**	**854**	**1348**

Table 1. Classification of 12 maize genotypes within two heterotic groups and two endosperm types, evaluated for nutrient relationships.

Laboratory Experiment

Whole maize kernels were used in developing the color space for each of the 1,348 accessions used in the study. The Red-Green-Blue readings derived from digital camera images were transformed into *L* (light-dark), a*(green-red), b* (blue-yellow)* color space estimates, then the large data set was summarized as principal components that captured the maximum variability for each accession, genotype, endosperm type, and heterotic group. A nutrient (quality) index was developed based on nutrient contents and a weighted index (Fig. 1) was developed taking into consideration iron and zinc contents, as the most limiting micro-nutrients in maize (and other grain crops).

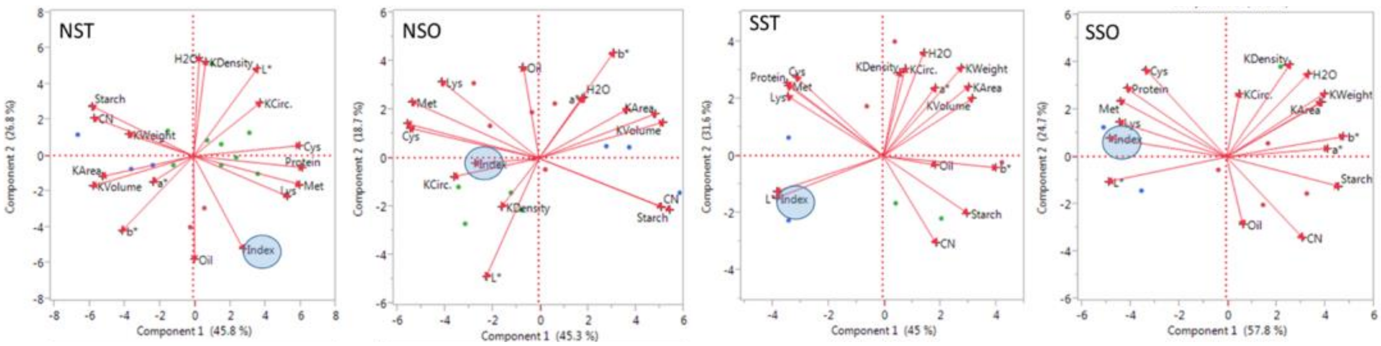


Fig. 1. Relationships between seed biochemical constituents, including color space indicators, and their influence on a nutrient index (Index) in four combinations of heterotic groups. Loadings (i.e., correlation between a seed constituent and each of two components derived from seed biochemical, physical and color space traits) indicate a positive or negative impact of these traits on the nutrient "Index." In addition, percent variation accounted for by the first two components is presented.

A three-way clustering of 12 groups based on their nutrient contents and L*, a*, and b* color space data (Fig. 2), along with a scaled index (Right) serves as a selection criterion for high content of one or multiple nutrients, and can be used as a guide to selection based on the relationship between the content (and intensity of corresponding scale index) and one or more of the color space components (i.e., L*, a*, and b*).

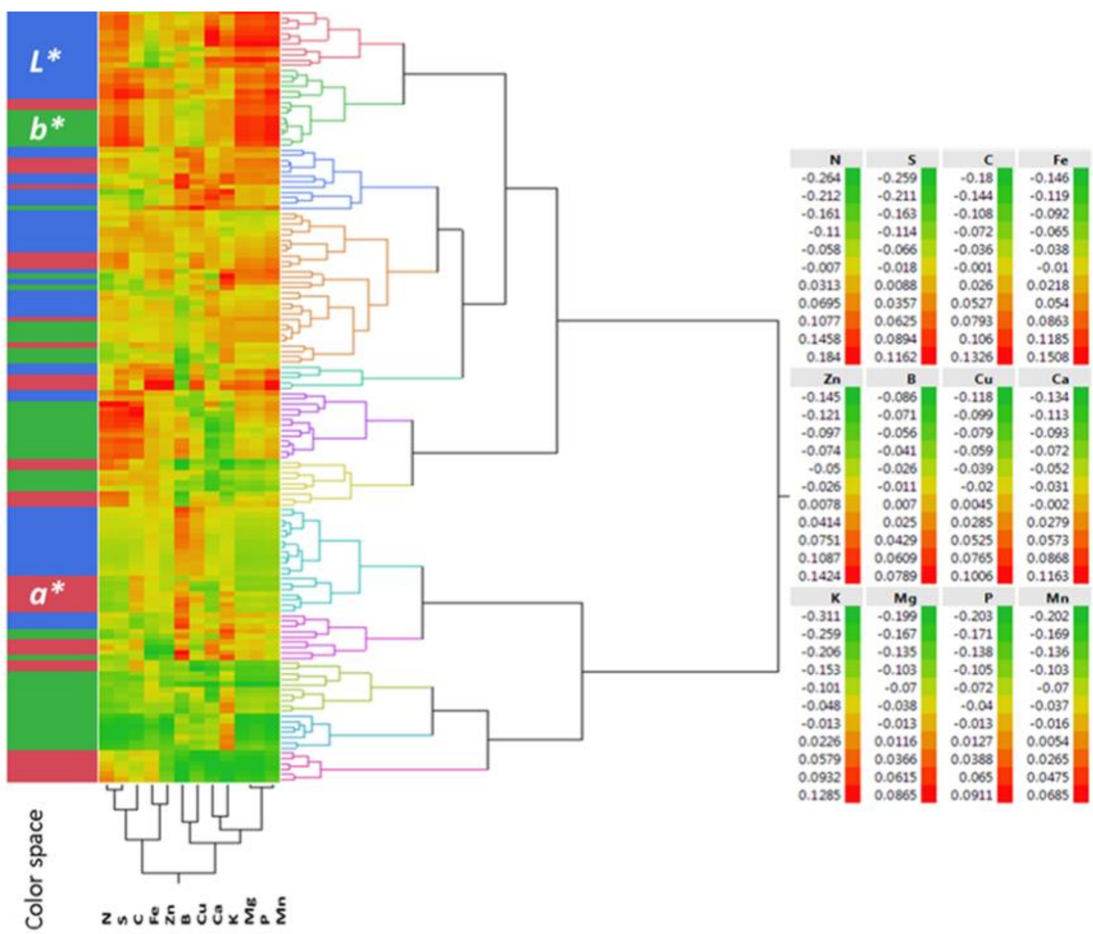


Fig. 2. Joint clustering of centered and scaled contents of 12 macro- and micro-nutrients, and kernel color space (*L*, a*,* and *b**) measured on 1,348 accessions in 12 populations of maize genotypes and classified into four heterotic group-endosperm type combinations.

Conclusions

Both macro- and micro-nutrients do not behave independently and are affected by other contents and composition of the maize kernel. A selection index based on a few visible and easily measured or observed kernel traits can be invaluable to identify, as a first step in a selection program, germplasm of potentially high nutrient contents, especially of the limiting and essential micro-nutrients.

UAV: A flying research and monitoring tool

Abdullah A. Jaradat and Jon Starr

Photo 1. A drone or Unmanned Aerial Vehicle (UAV) equipped with multiple sensors to collect data from research plots is taking off to fly a preprogrammed route at the Swan Lake Research Farm (Summer 2015).

Introduction

The "Soils Lab" acquired and is operating a versatile new tool to aid its research on the health and productivity of crops and soils: the "drone"—otherwise known as the Unmanned Aerial Vehicle (UAV). The drone is a relatively low-cost aerial camera platform that flies like a helicopter and uses global positioning system (GPS) technology to help it navigate. Following a thorough review and implementation of Federal Aviation Administration regulations governing the use of UAVs for research purposes, we began our first test flights of the drone this past summer at the Swan Lake Research Farm near Morris, MN. We also demonstrated it to the public during our 2015 Field Day. As a research tool, the drone allowed us to capture high-resolution images that can be stitched together to produce visually dynamic, data-rich maps of crop and soil conditions.

Objectives

Our research objective was to better define the role of drones as a key part of technology- and long-term data-driven approaches for research and production agriculture. At the research level, the objective was to optimize flight paths, duration and frequency to capture crop variables at specific developmental stages. At the farm level, drones are already an indispensable tool to optimizing the input-output equation in modern agriculture. Practically, a single pass of a drone over research plot or crop field can generate a wealth of data critical to optimizing water use and reducing the chemical load—safeguarding both the environment and food we consume.

Fast and precise phenotyping tool

Large scale qualitative and quantitative field phenotyping is the standard approach to characterize agronomic traits for adaptation to soil conditions, specific management practices, biotic and abiotic stresses, or for breeding and selection objectives. In order to minimize the time scale and overcome economic constraints to large-scale precision phenotyping in breeding and selection programs, new phenotyping techniques are required that are cost-effective; combine precision, timing, and speed; and provide a relational database for further statistical analyses and phenotypic selection that can be as effective as genotypic selection.

Depending on the types and number of sensors on board, the drone can provide many types of detailed views of a research plot or farm field of interest—regardless of size. These images can be processed to reveal the status of crops as well as to identify problems associated with diminished yield, from environmental factors like drought, outbreaks of pests and diseases, inadequate management practices or lack of sufficient inputs. In a research setting, the drone's images can reveal subtle differences between crop treatments that the naked eye cannot detect. Farmers can monitor their crops at regular intervals or on an as-needed basis to identify problems and remedy them more quickly or efficiently.

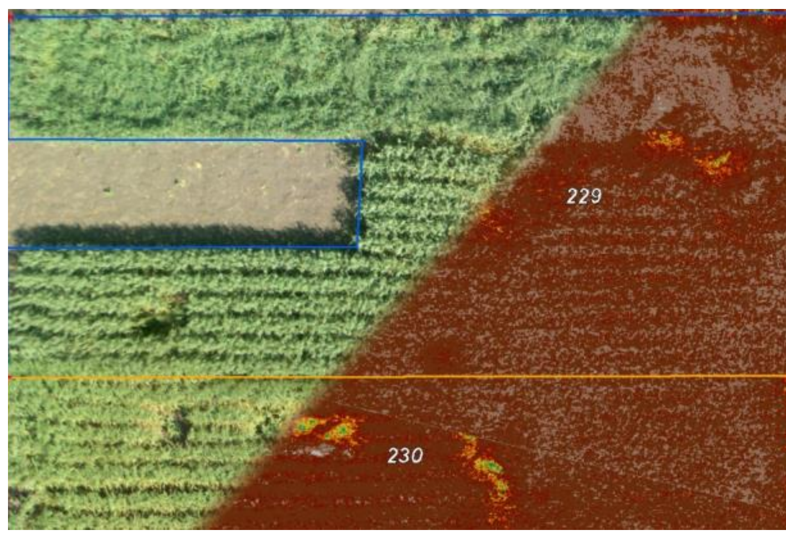


Photo 2. Researchers at the Soils Lab in Morris use the images taken by the drone to look for indicators of nutrient- or climate-stressed plants that are not visible to the naked eye (Left).

Phenotyping and monitoring field crops

The drone was effective in capturing multiple variables at the plot level through digital imagery. The Red-Green-Blue color images, when converted to L^*, a^*, and b^* color space can be very informative when taken over time. The large raw data is usually summarized in the form of principal components that can capture the maximum portion of variation in the color space.

As a demonstration of this procedure, the display in Fig. 1 (see page on right) is a summary of 18,360 data points derived from RGB/Near Infrared images. It reflects the changes in NDVI for the same crop variety over approximately two months.

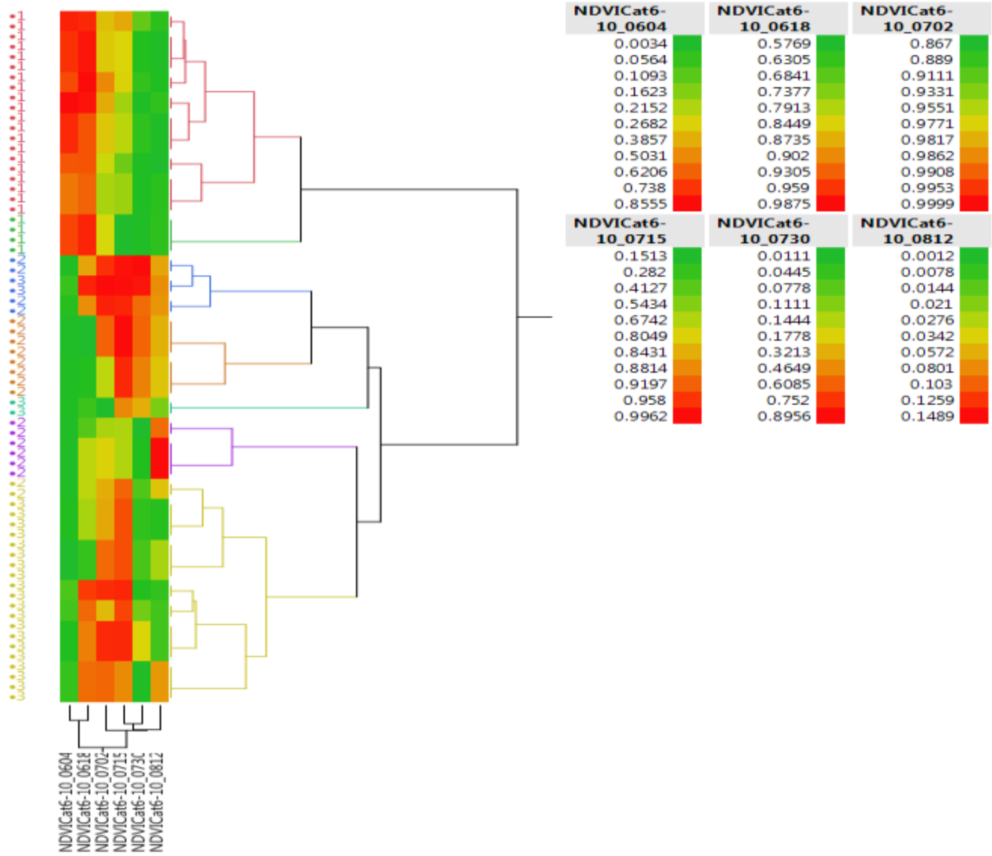


Fig. 1. The drone captured imagery from which the Normalized Difference Vegetation Index (NDVI) was calculated. The Figure illustrates the variability of a crop variety planted with three planting scenarios (1 = early, 2 = medium, i.e., one month after date 1, and 3 = medium under stress). The imagery was captured on June 4, and 18; July 2, 15, and 30; and August 12, 2015. Notice the large level of separation between the three planting treatments and the change in NDVI values over time as can be measured by the legend/scale (Right).

Conclusions

This small, relatively inexpensive, and easy-to-use research- and monitoring-tool became available to researchers and farmers alike as a result of amazing advances in a wide range of technological fields. These include everything from extremely small accelerometers, gyros, magnetometers, and pressure sensors, to tiny GPS modules, exceptionally powerful processors and various digital radios.

Appendix 1

2015 Peer-Reviewed Publications

1711. Aguilar, J., Gramig, G.G., Hendrickson, J.R., Archer, D.W., **Forcella, F.** and Liebig, M.A. 2015. Crop species diversity changes in the United States: 1978-2012. PLoS ONE 10(8):e0136580. DOI:10.1371/journal.pone.0136580.

1718. Berti, M., and **Gesch, R.W.** 2015. Cuphea production and management. In: Cruz, V.M.V., Dierig, D.A., editors. Industrial Crops, Handbook of Plant Breeding 9. New York, NY: Springer Science+Business Media. p. 291-313.

1716. Berti, M., **Gesch, R.W.**, Johnson, B., Ji, Y., Seames, W., Aponte, A. 2015. Double- and relay-cropping of energy crops in the northern Great Plains, USA. Industrial Crops and Products. 75 (B):26-34. http://handle.nal.usda.gov/10113/61654

1715. **Eberle, C.A., Thom, M.D.,** Nemec, K.T., **Forcella, F.,** Lundgren, J.G., **Gesch, R.W.**, Riedell, W.E., Papiernik, S.K., Wagner, A.K., **Peterson, D.H., Eklund, J.J.** 2015. Using pennycress, camelina, and canola cash crops to provision pollinators. Industrial Crops and Products. 75:20-25. http://handle.nal.usda.gov/10113/61664

1703. **Forcella, F.**, Eberle, C.A., **Gesch, R.W.**, **Johnson, J.M.** 2015. Oilseed cuphea tolerates bromoxynil. Industrial Crops and Products. 70:201-203. http://handle.nal.usda.gov/10113/60554

1708. **Forcella, F., Eklund, J.J., Peterson, D.H.** 2015. Rolled-crimped winter rye cover effects on hand-weeding times and fruit yield and quality of cucurbits. International Journal of Vegetable Science. 21(4): 386-396. doi: 10.1080/19315260.2014.880542. http://handle.nal.usda.gov/10113/61082

1714. **Gesch, R.W.**, Isbell, T., Oblath, E.A., Allen, B.L., Archer, D.W., Brown, J., Hatfield, J.L., Jabro, J.D., Kiniry, J.R., Long, D.S., Vigil, M.F. 2015. Comparison of several Brassica species in the north central U.S. for potential jet fuel feed-stock. Industrial Crops and Products. 75(B):2-7. http://handle.nal.usda.gov/10113/61656

1706. **Gesch, R.W.** and **Johnson, J.M-F.** 2015. Water use in camelina-soybean dual cropping systems. Agron. J. 107(3):1098-1104. http://handle.nal.usda.gov/10113/60946

1709. **Jaradat, A.A.** 2015. Beyond biodiversity: Ecosystem services of crop wild relatives. In: Redden, R., Yadav, S.S., Maxted, N., Ehsan Dulloo, M, Guarino, L. and Smith, P., editors. Crop Wild Relatives and Climate Change. New York, NY: John Wiley & Sons. p. 336-349.

1713. **Jaradat, A.A.** 2015. Genotypic response to multiple abiotic stresses: Functional relationships among nutrients. Procedia Environmental Sciences. 29:45-46. DOI: 10.1016/j.proenv.2015.07.148.

1712. **Jaradat, A.A.** 2015. Genotypic response to multiple abiotic stresses: Nutrient density and stability. Procedia Environmental Sciences. 29:28-29. DOI: 0.1016/j.proenv.2015.07.138.

1700. Kim, K. and **Gesch, R.W.** 2015. Macro and microminerals of four Cuphea genotypes grown across the upper Midwest USA. Industrial Crops and Products 66:38-43. http://handle.nal.usda.gov/10113/60132

1701. Lehman, R.M., Acosta-Martinez, V., Buyer, J.S., Cambardella, C.A., Collins, H.P., Ducey, T.F., Halvorson, J.J., Jin, V.L., **Johnson, J.M-F**, Kremer, R.J., Lundgren, J.G., Manter, D.K., Maul, J.E., Smith, J.L. and Stott, D.E. 2015. Soil biology for resilient, healthy soil. Journal of Soil and Water Conservation 70(1): 12A-18A.

1707. Mueller, S., Unnasch, S., Tyner, W., Pont, J., **Johnson, J.M.** 2015. Handling of co-products in life cycle analysis in an evolving co-product market: A case study with corn stover removal. Advances in Applied Agricultural Science. 3(5):8-21. http://handle.nal.usda.gov/10113/61089

1704. Royo-Esnal, A., Garcia, A.L., Torra, J., **Forcella, F.**, Recassens, J. 2015. Describing *Polygonum aviculare* emergence in different tillage systems. Weed Research. DOI: 10.1111/wre.12154. http://handle.nal.usda.gov/10113/60702

1722. Royo-Esnal, A., **Gesch, R., Forcella, F.**, Torra, J., Recasens, J., Necajeva, J. 2015. The role of light in the emergence of weeds: Using *Camelina microcarpa* as an example. PLoS ONE 10 (12):e0146079. doi:10.1371/journal.pone.0146079.

1702. Royo-Esnal, A., Necajeva, J., Torra, J., Recasens, J., **Gesch, R.W.** 2015. Emergence of field pennycress (Thlaspi arvense L.): Comparison of two accessions and modelling. Industrial Crops and Products. 66:161-169.

1710. Thapa, R., Chatterjee, A., **Johnson, J.M.**, Awale, R. 2015. Stabilized nitrogen fertilizers and application rate influence nitrogen losses under rainfed spring wheat. Agronomy Journal. 107(5):1885-1894. DOI:10.2134/aj15.0081. http://handle.nal.usda.gov/10113/61118

1705. **Thom, M.D.**, Daniels, J.C., Kobziar, L.N., Colburn, J.R. 2015. Can butterflies evade fire? Pupa location and heat tolerance in fire prone habitats of Florida. PLoS One. 10(5):e0126755. Doi: 10.137/journal.pone.01126755. http://handle.nal.usda.gov/10113/60943

1673. Osborne, S.L., **Johnson, J.M.F.**, Jin, V.L., Hammerbeck, A.L., Varvel, G.E., Schumacher, T.E. 2014. The impact of corn residue removal on soil aggregates and particulate organic matter. BioEnergy Research 1-9. 10.1007/s12155-014-9413-0.

1655. Schutte, B.J., Tomasek, B.J., Davis, A.S., Andersson, L., Benoit, D.L., Cirujeda, A., Dekker, J., **Forcella, F.,** Gonzalez-Andujar, J.L., Graziani, F., Murdoch, A.J., Neve, P., Rasmussen, I.A., Sera, B., Salonen, J., Tei, F., Tørresen, K.S. and Urbano, J.M. 2014. An investigation to enhance understanding of the stimulation of weed seedling emergence by soil disturbance. Weed Research 54: 1-12.

1689. Ward, S.M., Cousens, R.D., Bagavathiannan, M.V., Barney, J.N., Beckie, H.J., Busi, R., Davis, A.S., Dukes, J.S., **Forcella**, **F.**, Freckleton, R.P., Gallandt, E.R., Hall, L.M., Jasieniuk, M., Lawton-Rauh, A., Lehnhoff, E.A., Liebman, M., Maxwell, B.D., Mesgaran, M.B., Murray, J.V., Neve, P., Nuñez, M.A., Pauchard, A., Queenborough, S.A. and Weber, B.L. 2014. Agricultural weed research: A critique and two proposals. Weed Science 62: 672-678.

1679. **Weyers, S.L.** and Spokas, K.A. 2014. Crop residue decomposition in Minnesota biochar-amended plots. Solid Earth. 5:499-507.

Appendix 2

Lab Employees

Aanerud, Rebekah – Biological Science Aid
Amundson, Gary – Engineering Technician
Barbour, Nancy – Biologist
Boots, Dana "Joe" – Ag Science Research Technician (Plants)
Brockamp, Rachel – Biological Science Aid
Burmeister, Beth – Program Support Assistant OA
Eklund, James – Computer Assistant
Eystad, Kathryn – Office Automation Assistant
Forcella, Frank – Research Agronomist
Gesch, Russell – Research Plant Physiologist
Groth, Pamela – Administrative Officer
Hanson, Jay – Physical Science Technician
Hennen, Charles – Ag Science Research Technician
King, Eric – Biological Science Aid
Jaradat, Abdullah – Supervisory Research Agronomist, Research Leader and Location Coordinator
Johnson, Jane – Research Soil Scientist
Larson, Scott – Ag Science Research Technician (Soils)
Lindsey, Jennifer – Biological Science Aid
Peterson, Dean – Ag Science Research Technician
Rinke, Jana – Chemist
Rohloff, Shawn – Purchasing Agent OA
Starr, Jon – Biological Science Technician
Thom, Matthew – Research Entomologist
Wagner, Steve – Electronics Engineer
Wente, Christopher – Ag Science Research Technician
Weyers, Sharon – Research Soil Scientist (Soil Biologist)
Wilts, Alan - Chemist
Winkelman, Larry – IT Specialist (Customer Service)
Zaharick, John – Biological Science Lab Technician

Appendix 3

2015 Field Day

The North Central Soil Conservation Research Laboratory (Soils Lab) celebrated its annual field day on Thursday, July 23, 2015 at the Swan Lake Research Farm. The theme was "Partnering for Solutions." The Field Day highlighted: Dual-Purpose Cover Crops and Onsite Retention of Water and Nutrients; Establishing Winter Oilseed Crops in a Corn-Soybean Rotation; and United Nations - Food & Agriculture Organization Internal Year of Soils.

2016 Field Day

"SOIL and WATER, we've got it covered!" is the theme for the 2016 field day, to be held on **July 21st**. Presentations on current research will be given at the Swan Lake Research Farm.

Appendix 4

Other Outreach

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

Conservation Day at SWELL-Scandia Woods Environmental Learning Lab

For the past several years, sponsors of Conservation Day have invited Gary Amundson, Engineering Technician, to give a presentation on soil conservation. On October 1, 2015, Gary presented to seven groups of students. The topic was titled “Stay on The Trail” and dealt with soil compaction and ways to decrease it’s effects. The total number of students was 140.

Eyeglass Drive

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

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

Feds Feed Families Food Drive

During July-August, ARS employees participated in a non-perishable food drive. Total donations of 50 pounds were given to the local Stevens County Food Shelf.

Stevens County Fair

The Soils Lab hosted a booth at the local county fair, sponsored by the Stevens County Agricultural Society. The booth highlighted our research and offered presentations on pollinators, wheat research and also healthy soil.

Presentation to Local Girl Scout Group

Dr. Matthew Thom, Research Entomologist (Post Doc), with the North Central Soil Conservation Research Lab, spent some time on January 11, 2016 with 2nd and 3rd grade children, mostly Girl Scouts, at the Morris Public Library.

Dr. Thom shared information about insects, particularly pollinators, and the importance they play in enabling us to have delicious fruits and vegetables.

Appendix 5

Barnes-Aastad Association

Jeff Swenson, President
Greg Fynboh, Vice President
Dan Perkins, Secretary
Dean Meichsner, Treasurer

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

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

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

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

Each year the Barnes-Aastad Association sends a delegation of volunteers to Washington, D.C., to express their support for agricultural research. Recognizing that agricultural and environmental problems often do not have geographic boundaries, the Barnes-Aastad Association also interacts with groups supporting research at other institutions in the upper Midwest. This gives them a stronger voice when meeting with legislators. The 2016 delegation traveled to Washington, D.C. on February 29 - March 3rd. The delegation included Sue Dieter, Dean Meichsner and Dan Perkins.

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

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

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.

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