Northern Great Plains Research Laboratory

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NORTHERN GREAT PLAINS
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For environmentally and economically sound agro ecosystems for the northern Great Plains.

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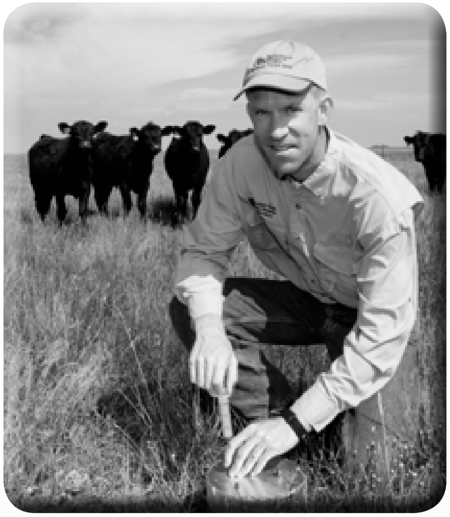
Grazed Native Pasture Traps Greenhouse Gases

Grazing lands represent one of the largest land resources in the world, yet their role as net sinks or sources of greenhouse gases (GHGs) is essentially unknown. While previous work has emphasized contributions of grazing management to affect change in soil organic carbon (SOC), there is a lack of information regarding management impacts on the flux of two potent GHGs, nitrous oxide (N_2O) and methane(CH_4) .



A team of scientists at the USDA-ARS Northern Great Plains Research Laboratory estimated net global warming potential (GWP) for three grazing management systems located in central North Dakota. The grazing management systems represented two native vegetation pastures (est. 1916) differing in stocking rate, and a seeded crested wheatgrass pasture (est. 1932) receiving supplemental nitrogen. The team measured SOC change and N_2O and CH_4 flux in the three grazing treatments, and combined their findings with estimates for CH_4 emission from cattle (via enteric fermentation) and CO_2 emissions associated with producing and applying nitrogen fertilizer. Collectively, the data allowed net global warming potential (GWP) to be estimated for each grazing treatment. Results from the study were published in the May-June issue of *Journal of Environmental Quality*.

Summing across factors, net GWP was negative for both native vegetation pastures, implying net removal of GHGs from the atmosphere. This finding underscored the value of grazed, mixed-grass prairie as a viable agroecosystem to serve as a net GHG sink in the northern Great Plains. Conversely, net GWP for the seeded forage was positive, implying net GHG emission to the atmosphere. When GWP data were expressed per unit of animal production, the native vegetation pasture with a lower stocking rate was found to be most effective at achieving net reductions in GHG emissions among the three grazing treatments. Mark Liebig, lead scientist on the project, stated "It's important to keep in mind the greenhouse gas balance we measured for the grazing treatments falls short of encompassing the full life-cycle of a steer. While our results suggest grazed native vegetation in the northern Great Plains is a net GHG sink, we need to acknowledge there are additional greenhouse gas emissions associated with cattle production outside of what we measured or estimated." The study was conducted as part of a USDA-ARS cross-location research effort called GRACEnet (Greenhouse Gas Reduction through Agricultural Carbon Enhancement Network), which seeks to provide information on global warming potential of current agricultural practices, and to develop new management practices to reduce net greenhouse gas emissions from soil.

Liebig, M.A., J.R. Gross, S.L. Kronberg, R.L. Phillips, and J.D. Hanson. 2010. Grazing management contributions to net global warming potential: A long-term evaluation in the northern Great Plains. J. Environ. Qual. 39(3):799-809.

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Summary of grazing management effects on net global warming potential (adapted from Liebig et al., 2010).

	Moderately grazed	**Heavily grazed**	**Crested wheatgrass**
Variable	------------------ **lb $CO_{2equiv.}$ ac^{-1} yr^{-1}** ------------------		
N fertilizer	0 b	0 b	228 a
Ent. Ferment.	157	432	503
SOC change	-1264	-1354	-1517
CH_4 uptake	-56	-55	-54
N_2O emission	464 b	426 b	1192 a
NET GWP	**-699 b**	**-551 b**	**352 a**

Negative numbers imply C uptake. Means in a row with unlike letters differ ($P \leq 0.05$).

Managing Nitrogen Fertilizer for Economic Returns and Greenhouse Gas Reductions in Irrigated Cropping Systems

Tillage and N fertilizer management decisions can influence greenhouse gas emissions from farming activities. While N fertilizer is important for increasing crop productivity, which can help maintain soil organic carbon (SOC) levels, N application can increase nitrous oxide (N_2O) emissions from cropland. Additionally, N fertilizer use leads to indirect greenhouse gas (GHG) emissions due to manufacturing and transportation of fertilizer to the farm. Tillage practices also influence GHG emissions, with greater tillage intensity generally associated with higher GHG emissions due to lower SOC storage and higher fuel use. There can be important interactions between N fertilizer and tillage management decisions. For irrigated corn, higher N may be needed to minimize reductions in corn yield associated with no-till (NT) corn production. Tillage and N fertilizer decisions at the farm level are driven largely by economics. While management can lead to reductions in GHG emissions, producers are understandably unlikely to adopt management practices that are not profitable. This paper looks at the economic feasibility of reducing net GHG emissions using results from an irrigated cropping systems field study conducted near Fort Collins, Colorado. Cropping systems included conventional plow tillage continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-soybean or dry bean (NT-CB).

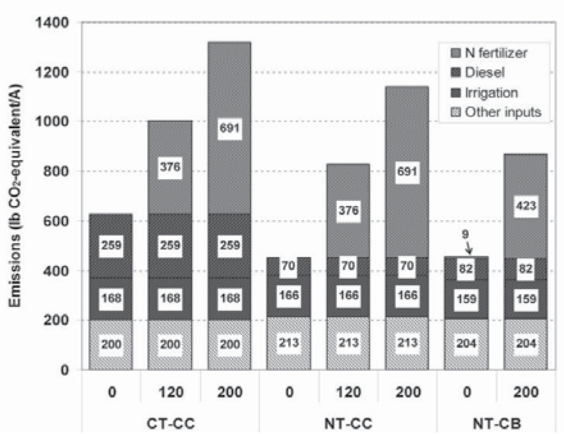

Figure 1. Average (2002-2006) greenhouse gas emissions from production activities (N fertilizer, diesel, irrigation, other inputs) for conventional-till continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-bean (NT-CB) systems at 0, 120, and 200 lb N/acre fertilizer application rates (corn year only).

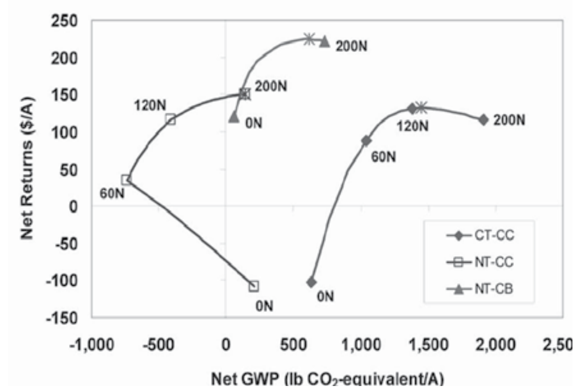

Figure 2. Relationship between average (2002-2006) net returns and average net global warming potential (GWP) for conventional-till continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-bean (NT-CB) systems. Point labels indicate N fertilizer application rates (lb N/acre).

*Denotes economic optimum within each tillage-crop rotation system.

The economic consequences of achieving GHG emission reductions were analyzed by combining enterprise budget data, constructed using the field study data, with net global warming potential (GWP) calculated as CO_2 equivalents with 1 unit methane (CH_4) = 23 units CO_2 and 1 unit N_2O = 296 units CO_2. Net GWP was calculated as the sum of CO_2 equivalents from irrigation, farm operations, N fertilizer production, soil N_2O emissions, and soil CH_4 emissions minus the annual increase in SOC. (See Archer et al., 2008, and Archer and Halvorson, 2010, for details on economic analysis and net GWP methodology). Average emissions of GHG from production activities (irrigation, farm operations, N fertilizer production) are shown in Figure 1. At the highest N fertilizer rates, emissions associated with N fertilizer manufacture and transportation account for about half the emmissions from production activities. Excluding N fertilizer emissions, average GHG emissions from production activities for the NT systems were 178 to 182 lb CO_2-equivalent per acre lower under NT than under CT, primarily due to lower diesel fuel use.

Net GWP emissions were calculated by adding emissions associated with production activities to soil GHG emissions. Combining net returns with net GWP shows some opportunities for managing GHG emissions while increasing profitability (Figure 2). Excessive application of N fertilizer reduces profitability while increasing net GWP. For a producer growing CT-CC, the economic optimum N fertilizer rate in this study was 130 lb N/acre. A producer applying 200 lb N/acre would increase GHG emissions by 460 lb CO_2-equivalent/acre while reducing profitability by $16/acre compared to the economic optimum for the CT system. Reducing N fertilizer rates within a tillage/rotation system below the economic optimum could further reduce net GWP, but these reductions would come at a cost to the producer. However, switching from CT to either of the two NT systems offers opportunities to increase profitability while further decreasing net GWP. Comparing systems at the economic optimum N rates for this study, switching from CT-CC to NT-CC increases net returns by $19/acre and reduces GWP by 1,310 lb CO_2-equivalent/acre, while switching from CT-CC to NT-CB increases net returns by $92/acre and reduces GWP by 830 lb CO_2-equivalent/acre.

While GHG emissions tend to increase with increasing N fertilizer application rates, N fertilizer is necessary to maintain crop productivity and economic viability. For irrigated corn production in northeastern Colorado, our results indicate that GHG emissions can be reduced and profitability improved by avoiding over-application of N fertilizer. Further reductions in GHG emissions and increases in profitability could be realized by switching from CT to NT production systems.

References

Archer, D.W., A.D. Halvorson, and C.A. Reule. 2008. Economics of irrigated continuous corn under conventional-till and no-till in Northern Colorado. Agron. J. 100:1166-1172.

Archer, D.W. and A.D. Halvorson. 2010. Greenhouse gas mitigation economics for irrigated cropping systems in the Northeastern Colorado.Soil Sci.Soc.Am. J. 74:446-452.

This article excerpted from:
Archer, D.W. and A.D. Halvorson. 2010. Managing nitrogen fertilizer for economic returns and greenhouse gas reductions in irrigated cropping systems. Better Crops 94:4-5.

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Friends & Neighbors Day

Mandan's USDA ag and environmental research facility opens their doors to the public on July 22nd for the annual Friends & Neighbors Day. The event is free and the public is invited. USDA Agricultural Research Service staff will provide tours of the research facility from 2 to 6 PM. The 15 acre park-like campus will also host presentations on topics of public interest. Ice cream, hot dogs, and popcorn will be served.

Informational exhibits and educational displays will be found throughout the campus. Crafts and horse-drawn wagon rides will be available for children during the afternoon. Tours of the ag and environmental research will depart promptly at 3:00 PM. Major topics on this year's tour are: bioenergy cropping systems, farming with cover crops, soil change under integrated cropping systems, and cattle and beef production with expensive fuel. A free barbecue and entertainment by Tom O'Neal will complete the evening activities.

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Northern Great Plains Research Laboratory Bioenergy Research Summary

The mission of the Northern Great Plains Research Laboratory (NGPRL) is to develop environmentally sound practices and add value to agricultural systems in the Great Plains in terms of food, feed, and biomass by conducting team-focused, systems-oriented research and technology transfer. Research on bioenergy-related topics has been conducted at NGPRL since 1999, with an emphasis on understanding production potential and natural resource impacts of switchgrass (Panicum virgatum L.). Here are some of the major cellulosic biofeedstock developments contributed by NGPRL scientists:

Cellulosic Raw Material Biofeedstock

Development Temperature and pH Effects on Germination

Summary: Optimum conditions for germination were evaluated for eight switchgrass cultivars. Results indicated germination of switchgrass occurred most successfully in substrates with a pH of 6 and at a temperature of 25°C. Optimum stand establishment in the field should be realized in soils that are warm with a pH range of 5 to 8. *Citation: Hanson, J.D., and H.A. Johnson. 2005. Germination of switchgrass under various temperature and pH regimes. Seed Tech. 27(2):203-210.*

Cultivar Evaluation

Summary: Biomass yield and phenology of eight diverse switchgrass cultivars were measured over three years at three field sites in western North Dakota. Biomass yields of Sunburst, the cultivar with the highest and most stable yield, fluctuated widely in response to available soil water (3.2 to 12.5 Mg ha-1). Consequently, producers may have difficulty providing a consistent supply of switchgrass biomass in regions subject to periodic droughts. *Citation: Berdahl, J.D., A.B. Frank, J.M. Krupinsky, P.M. Carr, J.D. Hanson, and H.A. Johnson. 2005. Biomass yield, phenology, and survival of diverse switchgrass cultivars and experimental strains in western North Dakota. Agron. J. 97:549-555.*

Crop Stand Establishment

Summary: For Switchgrass to become a primary biomass energy source stock, farmers need to learn how to produce it. Field scale trials in the Northern Great Plains states of North Dakota, Nebraska, and South Dakota, were used to determine minimal plant populations for switchgrass when grown as a biomass energy crop. Results from the three-state evaluation area indicate that an establishment year stand survivability of 40% or greater can be considered stand threshold for successful establishment. *Citation: Schmer, M.R., K.P Vogel, R. Mitchell, L.E. Moser, K.M Eskridge. 2006. Establishment stand thresholds for switchgrass grown as a bioenergy crop. Crop Sci. 46:157-161.*

Disease Identification

Summary: Potential diseases capable of affecting switchgrass production were evaluated in a multi-location collaborative research effort. Biopolaris oryzae, a common fungal pathogen on rice, was identified as the causal agent of a leaf-spot disease on switchgrass. This pathogen has the potential to reduce yields of switchgrass under intensive plantings, particularly if susceptible cultivars are seeded over a large area. *Citation: Krupinsky, J.M., J.D. Berdahl, C.L. Schoch, and A.Y. Rossman. 2004. Leaf spot on switchgrass (Panicum virgatum), symptoms of a new disease caused by Bipolaris oryzae. Can. J. Plant Path.26:371-378.*

Long-Term Herbaceous Biomass Study Collaboration

Description: NGPRL scientists are cooperating with North Dakota State University and five NDSU Research Extension Centers located in diverse growing regions of North Dakota on an extensive ten-year evaluation of perennial herbaceous biomass crops. The potential of warm- and cool-season grasses and mixes, including mixes with alfalfa and clover are being assessed. Two harvesting treatments (annual, biennial) are also being evaluated. Treatment effects on soil carbon sequestration and soil quality improvements will be measured on a five-year frequency.
Status: Baseline soil samples were collected to quantify levels of carbon storage and biological life prior to seeding in 2006 with soil sampling scheduled again in 2011.

Economics and Life Cycle Analyses

What Does It Cost Farmers To Grow Switchgrass in the Great Plains States?

Summary: Switchgrass was managed as a biomass energy crop in field trials on marginal cropland on ten farms in three Great Plains states (North Dakota, Nebraska, and South Dakota) for five years to determine net energy based on inputs and yields. Costs for individual farms, ranged from $29 to $110 per ton of biomass. The potential for reducing establishment costs and increasing yields suggests that substantial quantities of switchgrass would be produced in just a few years with prices as low as $36-$40 per ton at the farm gate. At a conversion rate of 80 gallons of ethanol per ton, the biomass feedstock cost at the farm gate would be about $0.50 per gallon.
Citation: Perrin, R., K.P. Vogel, M.R. Schmer, R. Mitchell. 2008. Farm-scale Production Cost of Switchgrass for Biomass. BioEnergy Research 1:91-97.

Life Cycle Analysis of Switchgrass Production

Summary: Switchgrass was managed as a biomass energy crop in field trials on marginal cropland on ten farms in three Great Plains states for five years to determine net energy based on inputs and yields. Switchgrass produced 540% more renewable energy than nonrenewable energy consumed. Greenhouse gas emissions from switchgrass were 94% and 76% lower than gasoline or corn ethanol, respectively. Switchgrass managed for high yield had equal or greater net energy than low input perennial polycultures and can produce 350% more liquid fuel per hectare. Improved switchgrass genetics and agronomics will enhance net values and increase total energy yields per acre.
Citation: Schmer, M.R., K.P Vogel, R. Mitchell, R.K. Perrin. 2008. Net Energy of Cellulosic Ethanol from Switchgrass. Proceedings of the National Academy of Sciences. 105: 464-469.

Soil Quality and Carbon Sequestration

A Matter of Balance: Conservation and Renewable Energy

Summary: Soils have a tremendous capacity to sequester carbon, if managed wisely, offering agriculture an exceptional opportunity to remove carbon dioxide, a greenhouse gas, from the atmosphere. Use of agricultural biomass for energy can also be part of our energy solution. Research is being conducted to determine how much, when and where biomass can be removed without soil and/or environmental degradation. A balanced, sustainable approach is critical.
Citation: Johnson, Jane M-F., Don Reicosky, Ray Allmaras, Dave Archer, and Wally Wilhelm. 2006. A matter of balance: Conservation and renewable energy. J. Soil and Water Conserv. 61(4):125A-129A.

On-Farm Research Shows Soil Carbon Accrual Over Time Under Switchgrass

Summary: Life-cycle assessments of bioenergy crops such as switchgrass requires data on soil organic carbon change and harvested carbon yields to accurately estimate net greenhouse gas emissions. Nearly all information to date has been based on either modeled assumptions or small plot research, which do not take into account spatial variability within or across sites for an agro-ecoregion. Change in soil organic carbon and harvested carbon yield for switchgrass fields was measured on ten farms in the central and northern Great Plains over a five year period. Soil carbon accrual under switchgrass across the ten farms averaged 1.1 Mg C ha-1 yr-1 for the 0 to 30 cm depth.
Citation: Liebig, M.A., M.R. Schmer, K.P. Vogel, R. Mitchell. 2008. Soil Carbon Storage by Switchgrass Grown for Bioenergy. BioEnergy Research. 1:215-222.

Switchgrass Biomass and Carbon Dynamics

Summary: Two switchgrass cultivars were evaluated for carbon sequestration and partitioning among plant components. Root biomass was found to account for over 80% of total biomass, and crown tissue contained approximately 50% of total biomass carbon. Soil organic carbon was found to increase at a rate of 1.01 kg C m-^{2} yr-1 over the 0 to 0.9 m depth. Sitchgrass plantings in the northern Great Plains have potential for storing a significant quantity of soil carbon.
Citation: Frank, A.B., J.D. Berdahl, J.D. Hanson, M.A. Liebig, and H.A. Johnson. 2004. Biomass and carbon partitioning in switchgrass. Crop Sci. 44(4):1391-1396.

Switchgrass Stores Carbon Deep in the Soil Profile

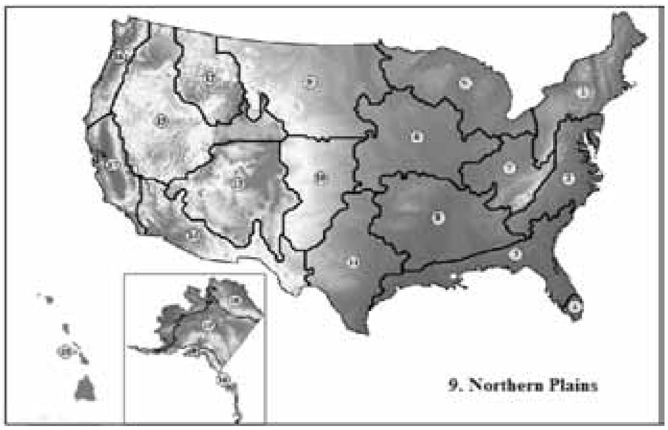
Summary: Soil carbon stocks were evaluated under established switchgrass stands and nearby cultivated cropland throughout the northern Great Plains and northern Cornbelt. Soil organic carbon was greater in switchgrass stands than cultivated cropland at soil depths of 0 to 0.05, 0.3 to 0.6, and 0.6 to 0.9 m, and especially so at the deeper soil depths where treatment differences were 7.74 and 4.35 Mg C ha-1 for the 0.3 to 0.6 and 0.6 to 0.9 m depths, respectively. Switchgrass appears to be effective at storing soil organic carbon not just near the soil surface, but also at depths below 0.3 m where carbon is less susceptible to loss.
Citation: Liebig, M.A., H.A. Johnson, J.D. Hanson, and A.B. Frank. 2005. Soil carbon under switchgrass stands and cultivated cropland. Biom. Bioe. 28(4):347-354.

Mycorrhizal Fungi Evaluations

Description: Above- and below-ground biomass and carbon:nitrogen ratios, tiller number, Haun score, and interactions with mycorrhizal fungi (i.e., glomalin production) are being evaluated for switchgrass under ambient (365 ppm) and elevated (730 ppm) CO_2 levels. The experiment was conducted in a controlled environment growth chamber using the Sunburst switchgrass cultivar. Each pot contained one of three mixes of mycorrhizal inoculum: 1. a mixture of regionally adapted mycorrhizal fungi (native inoculum), 2. a mixture of commercially produced fungi from Mycorrhizal Applications, Inc. in Oregon (commercial inoculum), or 3. a combination of both the native and commercial inoculums.Status: Preliminary results indicate the interactions between CO_2 level and mycorrhizal inoculum is not significant. The higher CO_2 level (730 ppm) did result in a significantly higher above- and below-ground biomass and carbon:nitrogen ratios. The commercial inoculum provided highest above and below ground biomass while the native and native commercial inoculums were not significantly different from each other. Based on these results, new experiments were designed to assess the impact of these inoculum sources on switchgrass under drought and defoliation stress conditions.

Continental - Scale Research Comes to Mandan

The Northern Great Plains Research Laboratory was selected as a National Ecological Observatory Network (NEON) site to represent agricultural ecosystems in the Northern Plains. There are 106 NEON sites across the United States chosen to represent 20 eco-climatic domains, including regional variations in vegetation, landforms, climate, and ecosystem performance.



NEON will be the first observatory network of its kind designed to detect and enable forecasting of ecological change at continental scales over multiple decades. This is an exciting opportunity for education and worldwide research collaborations.

The National Ecological Observatory Network (NEON) will collect data across the United States on the impacts of climate change, land use change and invasive species on natural resources and biodiversity. It is a project of the U.S. National Science Foundation, with many other U.S. agencies and NGOs cooperating.

Data will be collected from strategic locations within each domain and synthesized into information products that can be used to describe changes in the nation's ecosystem through space and time. This information will be readily available to scientists, educators, students, decision makers, and the public, enabling a wide audience (including members of underserved communities) to use NEON tools to understand and address ecological questions and issues. The NEON infrastructure is a means of enabling transformational science and promoting broad ecological literacy.

NEON will contribute to global understanding and decisions in a changing environment using scientific information about continental-scale ecology obtained through integrated observations and experiments. NEON's national observatory network will collect ecological and climatic observations across the continental United States, including Alaska, Hawaii and Puerto Rico. NEON is currently in the planning and development stages, and will enter the construction phase in late 2010. Constructing the entire NEON network will take approximately five years. NEON expects to be in full operation by 2016.

Adapted from NEON website by
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NDSU and USDA-ARS Partner to Establish Biomass Testing Lab

Igathi Cannayen and Cole Gustafson of the NDSU Department of Agricultural and Biosystems Engineering, received $450,000 from the North Dakota Renewable Energy Council and USDA-ARS to establish the first dedicated biomass testing laboratory in the state. The lab will be designed specifically to test the dimensional, thermal and physical properties of biomass. It will be located at the Northern Great Plains Research Laboratory. NDSU and NGPRL have established 10-year research trials using more than 50 different varieties of biomass at multiple locations around the state. Dr. Cannayen initially will evaluate production from these trials for both energy content and densification for shipping. Engineers are striving to develop new biomass harvesting, processing and transportation machines. Information on the physical properties of biomass will help the industry design optimal equipment.

Biomass product characteristics will be important in developing new market standards and grades, which in turn will facilitate commercialization. Information on biomass densification will aid in planning with respect to infrastructure and roads that may be needed to support the industry. The development of the lab requires time to calibrate and validate test equipment. Time is needed to conduct these steps in advance of industry demand. Additional funding is being sought to develop biomass market standards, assist agricultural producers in forming a biomass supply network, and develop a hands-on mobile biomass processing display to educate potential biomass suppliers on differing harvesting and processing methods.

The new biomass testing lab will contain four primary machines: (1) a universal testing machine to measure the force needed to compress, shear or cut biomass; (2) a machine to monitor the mass and temperature of biomass as it is heated in a controlled inert environment (these data are useful in determining the burning point of biomass and temperatures needed for operations, such as pelleting); (3) a bomb calorimeter to measure the energy content of various biomass samples; and (4) an environmental control chamber to allow biomass storage studies in a controlled environment that has a constant temperature and humidity. The lab is expected to take two years to develop before it becomes fully operational. The lab will be able to evaluate biomass samples submitted by the industry, researchers and producers.

A goal of the project is to develop a database of biomass characteristics obtained from samples coming to the lab from across the state. Information from the database will be utilized to recruit additional processors to the region.

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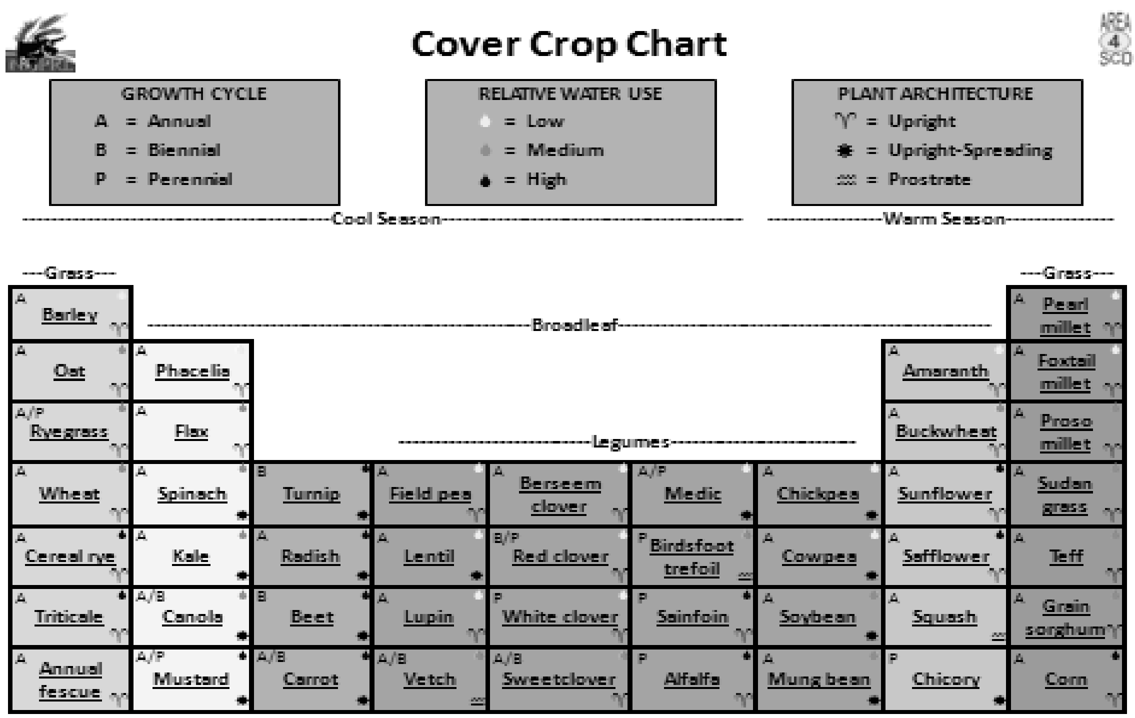
Outreach Tool for Cover Crops Released by NGPRL

Interest in cover crops by farmers and ranchers throughout the Northern Great Plains has increased the need for information on the suitability of a diverse portfolio of crops for different production and management resource goals. To help address this need, NGPRL staff developed an outreach tool called the *Cover Crop Chart*. Patterned after the periodic table of elements, the chart includes information on 46 crop species that may be planted individually or in cocktail mixtures. Specifics on growth cycle, relative water use, plant architecture, forage quality, pollination characteristics, and nutrient cycling are included for most crop species. Information in the chart was gathered from multiple sources throughout the U.S. and Canada, such as the Midwest Cover Crops Council, USDA-SARE, USDA-NRCS PLANTS Database, and the 3rd edition of Managing Cover Crops Profitably.



Accordingly, information in the chart was not based on research conducted at NGPRL. However, input from local NRCS personnel and producers from the Area IV Soil Conservation Districts was instrumental in deciding which crops and related information to include in the chart.

The chart was developed in Portable Document Format (pdf), requiring only Adobe Reader© for use on a personal computer. Using a simple 'point and click' format, users can select individual crop species by clicking on the crop name, which will direct them to additional information about the selected crop. Icons within each crop page return the user to the crop selection screen, thereby easily allowing comparisons of different crops. The chart can be downloaded for free through the NGPRL website at www.mandan.ars.usda.gov.

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Armand Bauer in North Dakota Agricultural Hall of Fame

Dr. Armand Bauer is the first Soil Scientist to be inducted into the North Dakota Agricultural Hall of Fame. Born and raised in Zeeland, North Dakota, Bauer began his education at North Dakota School of Forestry, followed by Masters and PhD degrees in Soil Science at NDSU and Colorado State University respectively. Bauer worked as a Soil Scientist for three years with USDA Soil Conservation Service (now Natural Resources Conservation Service) prior to his career at NDSU. During his tenure at NDSU, Bauer established and supervised the first soil testing laboratory at the North Dakota Agricultural Experiment Station in Fargo. Through this effort, farmers and ranchers could better understand their soil resource and the value of improving soil fertility for optimum crop production and grazing. At NDSU, he developed curriculum for many NDSU courses and taught hundreds of students improved soil and water management for dryland and irrigated agriculture. His research

focused on conserving soil and water resources in North curriculum for many NDSU courses and taught hundreds of students improved soil and water management Dakota through research on efficient irrigation practices, stubble mulch farming, and soil organic matter dynamics. Bauer was instrumental in initiating a statewide program in soil fertility and was one of the initial scientists to conduct mineland reclamation research in North Dakota. After completing 20 impactive years at NDSU, Bauer commenced important soil science research at the USDA-ARS Northern Great Plains Research Laboratory at Mandan, ND. He retired in 1991. Bauer served as the President of the North Dakota Soil and Water Conservation Society and was a Fellow of the American Society of Agronomy and Soil Science Society of America.

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