FINAL REPORT – EXECUTIVE SUMMARY

Project Number: R006-013
Recipient: North Dakota Natural Resources Trust
Award Amount: $280,000
Total Project Costs: $420,000

Goal of Project: Evaluate perennial herbaceous energy crops in North Dakota to assess establishment potential and management requirements; biomass yield and chemical composition; optimum harvest frequency; and soil quality and carbon storage.

Significant Findings: Cool-season grasses such as intermediate and tall wheatgrass were successfully established in central and western North Dakota. Establishment of warm season grasses such as big bluestem and switchgrass was not as successful in western North Dakota due to lower moisture conditions. During the establishment year, mowing weeds can be used for weed control. In warm season grasses, glyphosate can be used to control cool season weedy grasses. Adding legumes for nitrogen appears to lessen the need for fertilizer, but herbicides used to control weeds would be detrimental to legumes. After full establishment, management is minimal compared to annual cash crops. Biomass yield varied by species and their mixes, by site, and by year due to climatic and soil conditions. From 2007-2011, highest average yields (tons/ac) were: Sunburst switchgrass at Williston irrigation site (5.96) and Carrington (4.73); Williston dry site, haymaker intermediate wheatgrass (1.34). At Minot, Alkar tall wheatgrass and its mixtures had the highest yields from 2007 to 2008; from 2010 to 2011, Sunburst switchgrass had the highest yield; from 2007-2011 Sunburst switchgrass and Alkar tall wheatgrass combination had the highest yield (3.61 tons/acre). At Streeter, the five-year average yield was highest for Alkar tall wheatgrass and Sunburst switchgrass combination (2.99 tons/acre). Biennial harvest only accounted for 63% total biomass compared to annual harvest over all sites and years. However, biennial harvest yields varied by location, with Williston dry lands the highest (76%), following by Minot (71%), Williston irrigated lands and Streeter (66%), and the least at Carrington (56%). With colder and drier locations, biennial harvest could be an option especially the wildlife habitat and lower management costs take into the consideration. Harvest method (swather-like machine) may have impacted yields. If a mower and rake had been used, more of the litter likely would have been collected, thus increasing biennial harvest yield. Tall wheatgrass and its mixtures had superior quality to other species for ethanol production and also seemed to be better than other species for direct combustion. Potential exists for fireside ash deposition and potential corrosion problems for some of the biomass materials characterized in this study. Perennial herbaceous crops had subtle short-term effects on soil properties in central and western North Dakota. Changes in soil properties were most prevalent at the Williston site, where less fertile sandy soil and high biomass production contributed to increases in soil organic carbon, total nitrogen, and available phosphorus. Coarse-textured soils have the greatest potential to respond positively from perennial biofeedstocks in the short-term. Combined, this data indicates that perennial growth may improve soil quality. Larger aggregates increase pore space which improves air and water movement and reduces compaction. Larger aggregates act as microbial habitats for increased nutrient cycling.

Next Steps: Distribute the Final Report and continue the study through 2016.

FINAL
EVALUATION OF PERENNIAL HERBACEOUS BIOMASS CROPS IN NORTH DAKOTA

Summary Report
April 2012

Switchgrass plot following the 2011 harvest at NDSU Central Grasslands Research Extension Center, Streeter, ND. Photograph by Rick Bohn

Sponsored by the ND Natural Resources Trust, ND State University, U.S. Department of Agriculture-Agriculture Research Service, Northern Great Plains Research Lab and Natural Resources Conservation Service, Great River Energy, ND Farmers Union, ND Association of Rural Electric Cooperatives, ND Game and Fish Department, and ND Commerce Department

Report Authors:

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Compiled By: Karen Kreil, North Dakota Natural Resources Trust

Submitted in Cooperation with Project Partners:

Great River Energy
North Dakota State University
Research Extension Centers – Streeter, Carrington, Dickinson, Minot, and Hettinger
USDA, Natural Resources Conservation Service
North Dakota Farmers Union
USDA, Agriculture Research Station, Northern Great Plains Research Lab, Mandan, ND
North Dakota Commerce Department
North Dakota Game and Fish Department
Great Plains Institute
North Dakota Association of Rural Electric Cooperatives

Table of Contents

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Next Steps: Distribute the Final Report and continue the study through 2016.

Project Background

Using biomass as feedstock in bioenergy production has the potential to replace fossil fuels as well as corn grain that may be better used as human and livestock feed. The northern Great Plains provides a vast number of acres for perennial biomass production, particularly in highly erodible and non-productive areas, which would have a low impact on food production. To achieve the most success in biomass conversion, feedstocks most suited to the region in terms of biomass quantity and quality need to be identified. **This study evaluated perennial herbaceous biomass energy crops in North Dakota to assess establishment potential and management requirements; biomass yield and chemical composition; optimum harvest frequency; and soil quality and carbon storage.**

Six sets of plots were located at five sites across central and western North Dakota (Figure 1). Each set of plots contains ten species/varieties of perennial grasses planted alone and in combination in two harvest treatments (annual and biennial).

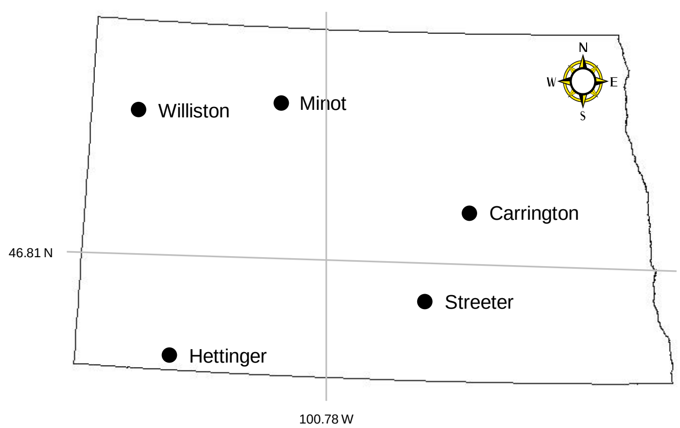


Figure 1. Location of study sites in North Dakota, in relation to 100th meridian.

Results and Discussion

Biomass Stand Establishment and Maintenance

The establishment of cool-season grasses such as intermediate wheatgrass and tall wheatgrass was appreciable for all study sites; however, the establishment of warm-season grasses such as switchgrass and big bluestem was problematic at Hettinger and Williston without irrigation. In comparison, at Williston with irrigation the warm-season grasses were soundly established under same cultural management as Williston dry land. Therefore, the establishment of the warm-season grasses in these dry areas was mainly driven and constrained by the available soil water in the growing season. Furthermore, intermediate wheatgrass and tall wheatgrass are the alternatives for the biomass production in these dry areas from the establishment perspective. At Streeter and Minot, weed control was crucial to establish warm-season grasses, otherwise more years needed to let the warm-season build themselves and outcompete with common weeds. Roundup could be used to control early growing weed species in spring before the warm-season grasses start to grow, however, the application rate and time window need to be further tested. At Carrington, the establishment of warm-season grasses was promising, with mechanical mowing in the establishment year being helpful as well as with the appropriate ecological and climatically conditions. The seeding methods (timing, rate, depth, seedbed preparation et al.) at all study sites were the exactly same, site-specific seeding strategy should be investigated if establishment of warm-season grasses is the goal.

Due to poor stand establishment of warm season grasses (switchgrass and big bluestem) in 2007, the Hettinger plots were reseeded in 2008. Although they were harvested the following two years, the decision was made to abandon these plots as the stands were still not productive enough to obtain meaningful data. Establishment and maintenance of switchgrass in central and western North Dakota can be difficult, depending on moisture, soil quality, and weed invasion. For example, switchgrass plots were established at Streeter, but some of these plots became invaded by brome and quack grass. Mowing weeds can be used in place of herbicides.

If the biomass produced is to be burned for energy, total yield is the important metric. However, if the product is to be used for ethanol then a more pure stand may be needed and the amount of species that invade the biofuel crop may decrease its value. The need for a pure crop for ethanol production could pose a problem for producers trying to raise cool season forages such as wheatgrasses. In switchgrass or other warm season grass stands, glyphosate can be used to control cool season weedy grasses. There is no chemical on the market that can control cool season weedy grasses in wheatgrass stands. Maintaining a pure crop will be an added expense to the producer.

Biomass Yields

For annual harvest, study site accounted for 63% of the total data set variance and was a main factor for biomass production. With irrigation at Williston, the production (4.29 tons/acre) was the highest, following by wettest study site Carrington (4.12 tons/acre), then Minot (2.99 tons/acre) and Streeter (2.40 tons/acre), the lowest at Williston without irrigation (1.04

tons/acre). The study site biomass production and its long-term mean annual precipitation were in the same order. However, the highest productive species or their combinations varied at each study site. Sunburst switchgrass produced the highest consistently from 2007 to 2011 at Williston irrigated land and Carrington with average production of 5.96 tons/acre and 4.73 tons/acre, respectively. At Williston non-irrigated land, haymaker intermediate wheatgrass was consistently the highest from 2007 to 2011 with an average production of 1.34 tons/acre. The results at Minot and Streeter were mixed and complex. At Minot, Alkar tall wheatgrass and its mixtures were the highest from 2007 to 2008 while in 2009, they were still the highest but all the entries were statistically same. From 2010 to 2011, Dakota switchgrass, Sunburst switchgrass, and Sunnyview big bluestem were the highest. As a result, five years average was not significantly different for all the entries, however, Sunburst switchgrass + Alkar tall wheatgrass combination (3.61 tons/acre) was the highest numerically. At Streeter, the similar trend as at Minot was found, namely, from 2007 to 2009, cool-season grasses produced higher than warm-season grasses, they were similar in 2010, while in 2011, Sunburst switchgrass produced the highest (4.34 tons/acre). Five years average of Alkar tall wheatgrass + Sunburst switchgrass combination (2.99 tons/acre) was the highest.

Higher yields at Carrington are likely due to higher precipitation levels and better soil quality compared to the other sites. Based on long-term average annual harvest yields, wheatgrasses yielded best on drier sites and switchgrass and its mixtures yielded best on wetter sites. At Streeter, the pure warm season plots were sprayed with glyphosate the third week of May 2011. This application gave good control of cool season grasses including smooth brome and quackgrass and subsequently improved yields of Sunburst switchgrass and its mixtures, but did not improve yields of Trailblazer switchgrass.

For biennial harvest, similar results were found as annual harvest, i.e. study site with higher annual harvest production was also had higher biennial harvest production; species with higher annual harvest production at each study site normally had higher biennial harvest production in that corresponding study site. However, at Williston non-irrigated land biennial harvest of Sunburst switchgrass or its combination with Mustang altai wildrye was the highest (1.00 tons/acre) while annual harvest of Haymaker intermediate wheatgrass was the highest.

Annual Versus Biennial Harvest Yields

Overall, biennial harvest biomass production could only account for 63% total biomass from two-year annual harvest. However, it accountability varied with study sites, with Williston dry land (76%) the highest, following by Minot (71%), Williston irrigated land and Streeter (66%), and the least at Carrington (56%).

The hypothesis of this study was that by harvesting biomass plots every other year the loss in total yield would be offset by the reduction in harvesting costs. For most of the plots the reduction in yearly yield due to biennial harvesting ranged between 20 to 50 percent. The dryland plots at Williston varied the most with switchgrass + wildrye plots having higher yield on the biennial harvest. Lower yields of biennial harvest varied considerably by location and harvest method may have impacted yields. A swather-like machine was used to harvest the standing crop. If a mower and rake had been used, more of the litter likely would have been collected, thus increasing yield.

Biomass and Ethanol Production
Tall wheatgrass and its mixtures had superior quality to other species for ethanol production and also seemed to be better than other species for direct combustion. Potential exists for fireside ash deposition and potential corrosion problems for some of the biomass materials characterized in this study.

In a nutshell

- **In central North Dakota, Sunburst switchgrass established and produced well, however, in western North Dakota switchgrass establishment was problematic and intermediate wheatgrass could be an alternative. Irrigation improved western North Dakota warm-season grass establishment and had a profound effect on biomass production.**
- **Weed control was crucial, especially at Streeter and Minot. Switchgrass can take up to three years to establish because the initial energy and growth occurs below ground in the root system. Tall wheatgrass establishes more quickly than switchgrass, therefore the combination of switchgrass and tall wheatgrass at Streeter and Minot could stabilize the first three years' production.**
- **The highest productive species or their combinations varied at each study site. Sunburst switchgrass produced the highest consistently from 2007 to 2011 at Williston irrigated land and Carrington with average production of 5.96 tons/acre and 4.73 tons/acre, respectively. At Williston non-irrigated land, haymaker intermediate wheatgrass was consistently the highest from 2007 to 2011 with an average production of 1.34 tons/acre. At Minot, Alkar tall wheatgrass and its mixtures were the highest from 2007 to 2008. From 2010 to 2011, Dakota switchgrass, Sunburst switchgrass, and Sunnyview big bluestem were the highest. As a result, Sunburst switchgrass + Alkar tall wheatgrass combination (3.61 tons/acre) was the highest numerically for 5-year average. At Streeter, the similar trend as at Minot was found, namely, from 2007 to 2009, cool-season grasses produced higher than warm-season grasses,**

they were similar in 2010, while in 2011, Sunburst switchgrass produced the highest (4.34 tons/acre). Five years average of Alkar tall wheatgrass + Sunburst switchgrass combination (2.99 tons/acre) was the highest.

Soil Profile Attributes

Perennial herbaceous crops were found to have subtle short-term effects on soil properties at the sites included in the study. Effects of harvest schedule and plant species on soil properties were infrequent and inconsistent across sites, and were unlikely to induce change in soil function. Inherently fertile soil conditions, high within-site variation in soil properties, and trends in biomass production among research sites likely contributed to observed results.

Changes in soil properties due to growth of perennial herbaceous crops were most prevalent at the Williston site, where the less fertile sandy soil and high biomass production contributed to increases in SOC, TN, and available P. Soil organic C increased at the Williston dryland site by 6 Mg C ha^{-1} yr^{-1}, supporting previous findings where perennial grasses managed for bioenergy production sequestered C within fragile, sandy soils.

In surface soil samples, differences in dry aggregate size distribution (DASD) and water-stable aggregation (WSA) could not be detected between treatments at any site. However, differences in three aggregate size classes (ASC; 1-2, 0.25-1, 0.053-0.25 mm) were observed within and across sites. Differences in ASC were detected during the baseline (2006) and 5-yr (2011) samplings, as well as between the two sampling periods. Results indicated growth of perennial biomass crops shifted more soil into the largest ACS (1-2 mm). Larger aggregates increase pore space and improve microbial habitat, thereby enhancing air/water movement and nutrient cycling in soil. Accordingly, perennial crops included in the study served to improve near-surface soil quality.

Broad outcomes from this short-term study indicate perennial herbaceous crops can maintain or improve soil properties, depending on inherent soil conditions and site productivity. In that regard, coarse-textured soils have the greatest potential to respond positively in the short-term from the growth of perennial herbaceous crops. Such focused production – based on soil type – would not only improve the condition of fragile soils, but would also serve to improve wildlife habitat, decrease water pollution, and reduce wind and water erosion compared to annual row crop production.

In a nutshell

- **Production of perennial herbaceous crops as biofeedstocks had subtle short-term effects on soil properties in central and western North Dakota.**
- **Changes in soil properties were most prevalent at the Williston site, where the less fertile sandy soil and high biomass**

production contributed to increases in soil organic carbon, total nitrogen, and available phosphorus.

- **Coarse-textured soils have the greatest potential to respond positively from perennial biofeedstocks in the short-term.**

Soil Surface Properties

The energy source for all animals, whether it has been food or fuel, comes from plants converting sunlight into carbon-based fuels. Because fossil fuels are a finite energy source and economic and social concerns exist in obtaining these fuels, alternative energy sources are being sought such as biofuels from perennial biomass. This project was designed to identify regionally appropriate and consistent high biomass perennials for the cold, semi-arid northern Great Plains. The environmental impacts, particularly soil parameters, of this production will be assessed. In this report, soil aggregation and glomalin production are reported. Soil aggregation is a major component of soil functions, such as water infiltration, water holding capacity, gas exchange, and nutrient cycling. The pore space provided between aggregates impacts water and gas movement whereas the aggregates themselves act as microbial habitats for nutrient cycling. Arbuscular mycorrhizal (AM) fungi provide nutrients to plants in exchange for carbon compounds by directly connecting plant roots and soil aggregates. Soil aggregates are formed and stabilized by AM fungi through the production of hyphae (i.e. fine threads) and glomalin, a sticky glycoprotein. Analysis showed that across all sites, treatments, and aggregate size classes only site and aggregate site class had significant differences between samples. For water-stable aggregation (WSA) and glomalin (measured as Bradford-reactive soil protein, BRSP) values, the Williston Dryland and Minot sites had the highest values in 2006 while in 2011 Carrington and Minot had the highest values. Within each site, only aggregate size class was significantly different. The differences between the aggregate size classes showed a shift from smaller aggregates to larger aggregates over the five years of production in this study.

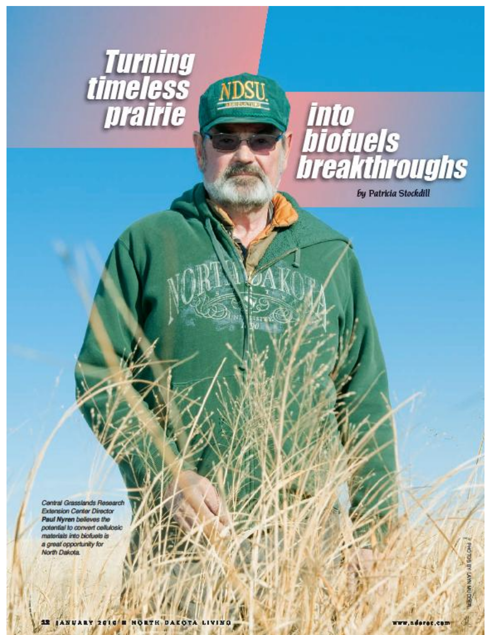
In a Nutshell:

- A significant difference could not be detected between treatments across all six sites for the dry aggregate size distribution and water-stable aggregation values. A site difference was detected for the water-stable aggregation and glomalin values.
- A difference was found between the three aggregate size classes (1-2, 0.25-1, and 0.053-0.25 mm) across all the sites and within each site. This difference was detected in both baseline samples collected in 2006 and in samples collected 2011 after 5 years of growth as well as the difference between these two sampling periods.

- The data showed that over the five years of growth more soil was distributed into the largest aggregate size class while it declined in the two smaller sizes.
- In 2006, the BRSP amounts of glomalin also differed by aggregate size class rather than treatment. However, in 2011, because the main difference in aggregation was the shift to the largest aggregate size class and no treatment difference was detected between treatments, glomalin was only extracted from the largest aggregate size class. A site difference was detected but a treatment difference was not.
- Combined this data indicates that perennial growth may improve soil quality. Larger aggregates increase pore space which improves air and water movement and reduces compaction. Larger aggregates act as microbial habitats for increased nutrient cycling.

Deliverables – Communication Plan

Communication and coordination on the study and the results generated were important aspects of the study. A communication plan was developed that outlined tasks, the responsible entity, and a timetable for completion. Communication tasks included publication of articles in partner magazines and newsletters; posting information on partner websites; distribution of information to agriculture producers through direct mailings; field tours and research reviews; presentations at agriculture and energy related workshops and conferences; and bi-annual conference call/meeting of project partners.



Turning timeless prairie into biofuels breakthroughs

by Patricia Stockdill

Central Grasslands Research Extension Center Director **Paul Nyren** believes the potential to convert cellulosic materials into biofuels is a great opportunity for North Dakota.

PHOTOS BY LANI MILDGER

12 JANUARY 2010 ■ NORTH DAKOTA LIVING www.ndarec.com

Farmers Union February 2010 • www.ndfu.org

UNION FARMER

A Cooperative Effort

When the restaurant closed a few years ago, it wasn't a sure bet that the 322 residents of Drake would again have a place to sit down and have a hot bite to eat.

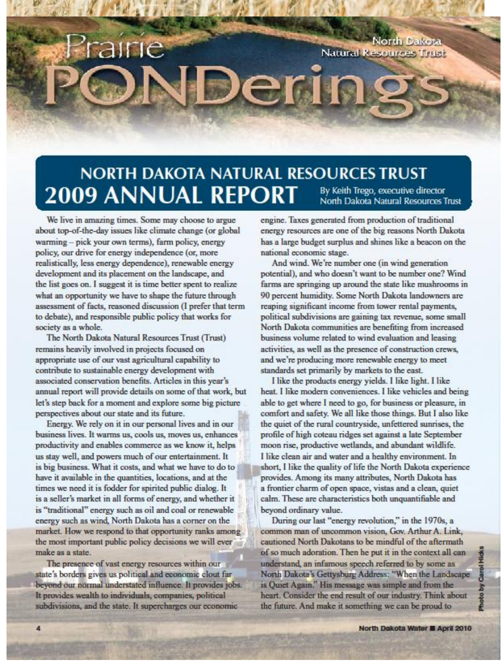
By Michael Shirek, Union Farmer

Continued on page 10

In this issue

- President's Viewpoint/ Page 2
- Optimizing cellulose ethanol production/ Page 3
- Perennial energy crops/ Page 4
- Carlson speaks about climate change/Page 5
- Family fun in Emmons County/Page 7
- Young producers get together/Page 8
- Big turnout at active producers event/Page 9

PERIODICALS – POSTAGE PAID



Prairie PONDerings

North Dakota Natural Resources Trust

NORTH DAKOTA NATURAL RESOURCES TRUST 2009 ANNUAL REPORT

By Keith Trego, executive director North Dakota Natural Resources Trust

We live in amazing times. Some may choose to argue about top-of-the-day issues like climate change (or global warming – pick your own terms), farm policy, energy policy, our drive for energy independence (or, more realistically, less energy dependence), renewable energy development and its placement on the landscape, and the list goes on. I suggest it is time better spent to realize what an opportunity we have to shape the future through assessment of facts, reasoned discussion (I prefer that term to debate), and responsible public policy that works for society as a whole.

The North Dakota Natural Resources Trust (Trust) remains heavily involved in projects focused on appropriate use of our vast agricultural capability to contribute to sustainable energy development with associated conservation benefits. Articles in this year's annual report will provide details on some of that work, but let's step back for a moment and explore some big picture perspectives about our state and its future.

Energy. We rely on it in our personal lives and in our business lives. It warms us, cools us, moves us, enhances productivity and enables commerce as we know it, helps us stay well, and powers much of our entertainment. It is big business. What it costs, and what we have to do to have it available in the quantities, locations, and at the times we need it is fodder for spirited public dialog. It is a seller's market in all forms of energy, and whether it is "traditional" energy such as oil and coal or renewable energy such as wind, North Dakota has a corner on the market. How we respond to that opportunity ranks among the most important public policy decisions we will ever make as a state.

The presence of vast energy resources within our state's borders gives us political and economic clout far beyond our normal understated influence. It provides jobs. It provides wealth to individuals, companies, political subdivisions, and the state. It supercharges our economic engine. Taxes generated from production of traditional energy resources are one of the big reasons North Dakota has a large budget surplus and shines like a beacon on the national economic stage.

And wind. We're number one (in wind generation potential), and who doesn't want to be number one? Wind farms are springing up around the state like mushrooms in 90 percent humidity. Some North Dakota landowners are reaping significant income from tower rental payments, political subdivisions are gaining tax revenue, some small North Dakota communities are benefiting from increased business volume related to wind evaluation and leasing activities, as well as the presence of construction crews, and we're producing more renewable energy to meet standards set primarily by markets to the east.

I like the products energy yields. I like light. I like heat. I like modern conveniences. I like vehicles and being able to get where I need to go, for business or pleasure, in comfort and safety. We all like those things. But I also like the quiet of the rural countryside, unfettered sunrises, the profile of high coteau ridges set against a late September moon rise, productive wetlands, and abundant wildlife. I like clean air and water and a healthy environment. In short, I like the quality of life the North Dakota experience provides. Among its many attributes, North Dakota has a frontier charm of open space, vistas and a clean, quiet calm. These are characteristics both unquantifiable and beyond ordinary value.

During our last "energy revolution," in the 1970s, a common man of uncommon vision, Gov. Arthur A. Link, cautioned North Dakotans to be mindful of the aftermath of so much adoration. Then he put it in the context all can understand, an infamous speech referred to by some as North Dakota's Gettysburg Address: "When the Landscape is Quiet Again." His message was simple and from the heart. Consider the end result of our industry. Think about the future. And make it something we can be proud to

Photo by Carol Hicks

4 North Dakota Water ■ April 2010

Participants view the perennial energy crop plots at the July 2010 “Annual Field Tour” held at the NDSU Central Grasslands Research Extension Center at Streeter, ND.

North Dakota State University
Central Grasslands Research Extension Center (CGREC)
Grass-N-Beef Research Review
at Central Grasslands Conference Room
4824 48th Ave SE, Streeter
10:00 a.m. Wednesday, January 26, 2011

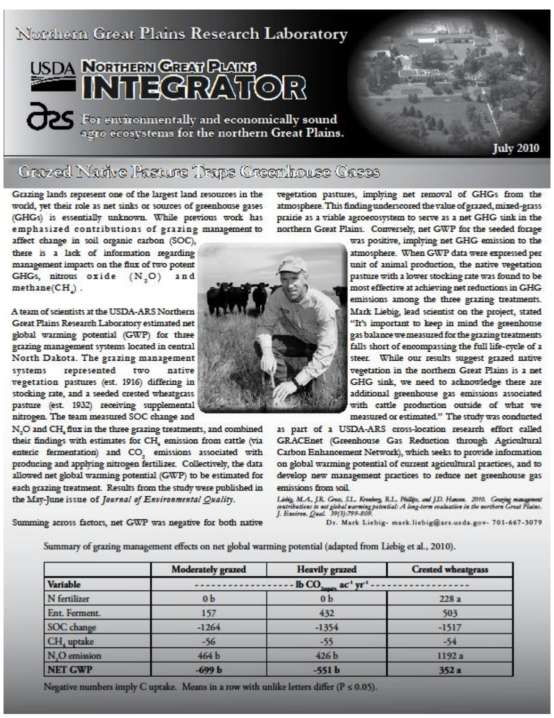
Master of Ceremonies: Amanda Gearhart, Research Specialist, NDSU School of Natural Resource Sciences

10:00 a.m	**Introduction and Welcome** Paul Nyren, Director, CGREC
10:15 a.m.	**Opening Remarks** Ken Grafton, Director, ND Ag Experiment Station
10:30 a.m.	**Utilizing Annual Cover Crops to Extend Grazing** Kevin Sedivec, Professor/Rangeland Mgt Specialist, NDSU Natural Resources MGT
11:00 a.m.	**Effects of Grazing Pressure on Efficiency of Grazing on Northern Great Plains Rangeland** A.J. Smart, Professor, Department of Animal & Range Sciences, South Dakota State University Bob D. Patton, Range Scientist, CGREC
11:30 a.m.	**Culture and Agriculture: Living and Working on the Coteau** Tom Isern, Distinguished Professor, NDSU History Dept.
Noon-1:00	**Catered Lunch**
1:00 p.m.	**China, Hay Bales and Economics** Chip Poland, Dept Chair, Agriculture and Technical Studies, Dickinson State University
1:30 p.m.	**New Animal Research Program at CGREC** Bryan Neville, Animal Scientist, CGREC
1:45 p.m.	**Grazed Native Pasture Traps Greenhouse Gases** Mark Liebig, USDA-ARS Mandan
2:00 p.m.	**Screening and Evaluation of Legume Species/Varieties for Forage Production, Soil Health and Cover Crops** Guojie Wang, Forage Agronomist, CGREC
2:15 p.m.	**Production and Sustainability of Perennial Biofuels Crops** Paul Nyren, Director, CGREC
2:30 p.m.	**Use of Patch Burning for Revitalization of Native Prairies** Amy Ganguli, Professor, NDSU School of Natural Resources
2:45 p.m.	**A Naturalist’s Guide to the Coteau** Chuck Lura, Professor of Biology, Dakota College Bottineau
3:00 p.m.	**Producer Discussion and Interaction** Jerry Doan, Chair, CGREC Advisory Board
3:30 p.m.	**Door Prizes and Adjourn**

DIRECTIONS TO CENTRAL GRASSLANDS
Four miles north of Streeter, or 11 miles south of I-94 on Highway 30, take 48th Street and drive 5 miles west to 48th Ave and ¼ mile south.

Examples of articles published in partner magazines are shown below, including North Dakota Living (ND Association of Rural Electric Cooperatives); North Dakota Water (ND Natural Resources Trust “Prairie Ponderings” space in magazine, ND Water Education Foundation); and Union Farmer (ND Farmers Union).

Powerpoint presentation given by Sandra Broekema, Great River Energy, at two conferences held in 2009.



Northern Great Plains Research Laboratory

USDA NORTHERN GREAT PLAINS INTEGRATOR

ars For environmentally and economically sound agro ecosystems for the northern Great Plains.

July 2010

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 $CO_{2 equiv.}$ 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 ($P \leq 0.05$).

The USDA-Agriculture Research Service, Northern Great Plains Research Lab newsletter, "Northern Great Plains Integrator".

COMMUNICATION PLAN – SUMMARY OF COMPLETED TASKS

TASK	ENTITY*	TIMETABLE
Presentation "Biomass Fuel: Which Comes First, the Market or the Supply". 2009 Northern Plains Bioeconomy: What Makes Sense. Fargo, ND	GRE	Sept. 22, 2009
Case Study Presentation at Forum on The Future of Coal and Biomass in a Carbon Constrained World, sponsored by Great Plains Institute. Fargo, ND	GRE, TNC	Nov. 2, 2009
Formal Report Out on Feasibility Study of a Biomass Supply for the Spiritwood Industrial Park. ND Industrial Commission/Renewable Energy Council meeting, Fargo, ND.	GRE	Dec. 7, 2009
"Biomass Co-firing" Presentation at Energy Generation Conference, Bismarck, ND	GRE	Jan. 26, 2010
Summary of Biomass Plots Study results and related Spiritwood Project activities in NDSU Extension Service bi-weekly newsletter.	NDSU	Dec. 2009, 2010, 2011
Annual Report on Biomass Plots Study. Prepared, posted on Website, and distributed to 25,000 agriculture producers/constituents throughout central ND.	NDSU	Dec. 2009, 2010, 2011
Grass and Beef Research Review for agriculture producers/constituents	NDSU	Jan. 20, 2010 Jan. 26, 2011 Jan. 25, 2012
Annual Field Tour for area agriculture producers/constituents on Biomass Plots Study results	NDSU	June 23, 2010 June 29, 2011
Friends and Neighbors Day – Presentation on study results for area agricultural producers	ARS	July 22, 2010 July 21, 2011
ND Water Magazine article	NDNRT, NDWEF	April 2010 issue

ND Living Magazine article	NDNRT, NDARE, GRE	Jan 2010 issue
Union Farmer Publication article	NDNRT, NDFU, GRE	Feb 2010 issue
Presentations by project partners at local, regional, or national biomass energy related meetings, workshops, or conferences		Throughout study
Bi-Annual conference call/meeting of project partners	NDNRT lead	January 22, 2010 July 19, 2010 January 24, 2011
Rural Developers' Round Table Talk – Featuring Spiritwood Biomass project	NDAREC, GRE, NDSU	February 9, 2010
Bioenergy Research Summary – "Integrator Newsletter"	ARS	July 2010
Presentation "Evaluation of perennial herbaceous forages for bioenergy in central and western North Dakota" at 2011 North American's Grasslands Conference, Sioux Falls, SD.	NDSU	August 15-17, 2011
Grant wrap-up session	NDNRT, NDSU, ARS	April 10, 2012

* ARS = U.S. Department of Agriculture, Agriculture Research Service, Northern Great Plains Research Laboratory, Mandan, ND
GPI=Great Plains Institute
GRE=Great River Energy
NDAREC = North Dakota Association of Rural Electric Cooperatives
NDFU = North Dakota Farmers Union
NDGFD = North Dakota Game and Fish Department
NDNRT = North Dakota Natural Resources Trust
NDSU = North Dakota State University Research Extension Center, Streeter
NDWEF = North Dakota Water Education Foundation
TNC = The Nature Conservancy