Contract No. R006-0013
"Evaluation of Perennial Herbaceous Biomass Crops in North Dakota for Production of Ethanol and other Value-Added Products and for Use in Coal Plant Co-Firing"

Submitted by ND Natural Resources Trust
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PARTICIPANTS

Sponsor	**Cost Share**
ND Natural Resources Trust	$ 52,500
Natural Resources Conservation Service CIG	$ 50,000
Great River Energy	$ 17,500
ND Farmers Union	$ 5,000
ND Game and Fish	$ 12,500
NDSU	$ 2,500
North Dakota Industrial Commission	$280,000
Total Project Cost	$420,000

Project Schedule – 2 years
Contract Date – December 3, 2009
Start Date – December 1, 2009
Completion Date – April 30, 2012

Project Deliverables:
Status Report: July 31, 2010 √
Status Report: July 31, 2011 √
Draft Final Report: March 31, 2012 √
Final Report: April 30, 2012 √

OBJECTIVE/STATEMENT OF WORK:

This project is for Phase II of a 3-phase, 10 year study to determine the best practices of producing biomass. The project will contribute to long-term data that will ultimately determine the most productive grass species, optimal harvest methods including dates and frequency, and best practices to maintain productive perennial biomass stands in ND. Additionally, this project will evaluate carbon sequestration and storage of the various perennial crops and assess chemical properties of harvested biomass to determine potential effects on Spiritwood power plant equipment. A communications plan has been included in the statement of work.

STATUS

Contract executed. A revised detailed communications plan has been approved.

September, 2010

The Annual report noted the following activities that had been completed during the year:

Biomass Crops Harvest and Analysis

In September 2009, North Dakota State University completed the harvest of biomass crops from plots established at the Streeter, Carrington, Minot, Hettinger and Williston Research Extension Centers. Biomass yield and chemical properties were determined and a report was prepared and

widely distributed. (A copy of the 2009 Biomass Crops Study Report is available in the Commission files.)

Additional Biomass Analysis

Additional analysis beyond work completed by NDSU is needed to assess the suitability of biomass crops for co-firing in Great River Energy's Spiritwood Station Combined Heat and Power Plant. Specifically, information is needed on the heat value (BTU), silica, chlorine/chloride, and alkalinity. The Trust through an RFP/bid process sought bids for the additional biomass analysis from testing laboratories. Microbeam Technologies, Inc., Grand forks, was selected to complete the analysis and prepare a report characterizing the chemical and heat value of the biomass mixtures. The report will be completed in 2010.

Communications Plan

An update was provided on the communication efforts that have been accomplished. (A copy of the communications plan update is available at the Industrial Commission Office along with copies of presentations and reports.

August, 2011

The Annual Progress Report for Calendar Year 2010 was received and an addendum was also provided with specific information on how the project objectives are being met.

Project Objectives

1. Determine if switchgrass and other grasses can be established as bioenergy crops west of the 100th meridian (boundary between the moist east with average annual precipitation > 20 inches and more arid west with average annual precipitation < 20 inches).
    - NDSU planted ten different perennial energy crop mixtures on plots at five of their Research Extension Centers including Carrington, Streeter, Minot, Williston, and Hettinger.
    - 100th meridian runs north to south in ND and crosses at Rugby, ND. The perennial energy crop plots at Carrington and Streeter are east of the 100th meridian and the plots at Minot, Williston, and Hettinger are west of the 100th meridian.

    Results to Date

    - All ten perennial energy crop mixtures have been successfully established at two of three locations west of the 100th meridian (Minot and Williston), but not at Hettinger. The switchgrass mixtures planted at Hettinger were not successful due to the combination of dry summer conditions in 2006 and winter kill. Establishment of switchgrass east of the 100th meridian can also be difficult, depending on moisture, soil quality, and weed invasion. For example, switchgrass plots were established at Streeter (east of 100th meridian), but some of these plots became invaded by brome and quack grass.

2. Determine the biomass yield and select chemical composition of perennial herbaceous crops at several NDSU Research Extension Centers. (No one has evaluated the wheatgrasses or wildrye for bioenergy crop production in the western or northern areas of North Dakota.)

   Results to Date

   - The average annual harvest yields support the conclusion that wheatgrasses are best on drier sites with the long-term average of 1.96 tons/acre for CRP mix (wheatgrass + legumes) at Hettinger. Intermediate wheatgrass yielded best at the Williston dryland site at 1.12 tons/acre and at Streeter at 2.96 tons/acre. Switchgrass and its mixtures had the highest four-year average at Carrington, Williston irrigated, and Minot. Overall, switchgrass and its mixtures had the highest yields. The highest yield observed on non-irrigated sites was Trailblazer switchgrass at 6.1 tons/ac at Carrington in 2007. Of the non- irrigated sites, plots at Carrington have consistently had the highest biomass yields, followed by Minot, Streeter, Hettinger, and Williston. Higher yields at Carrington are likely due to higher precipitation levels and better soil quality.
   - Switchgrass needs more moisture to grow than wheatgrass species.
   - Adding legumes for nitrogen appears to lessen the need for fertilizer. However, legumes are brood leaf plants and herbicides used to control weeds would be detrimental to legumes. Mowing weeds can be used in place of herbicides.
   - All plots harvested every other year yielded less over three years than the annually harvested plots, except for Sunburst switchgrass plots at Minot.
   - 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.
   - 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.

3. Determine the optimum harvest dates and frequency for maximum biomass yield and maintenance of the stands. (No one has looked at how to maintain maximum biomass yield beyond five (5) years.)

   Results to Date

   - All harvests have been completed in September due to logistical challenges associated with availability of harvest equipment. Scientists have suggested that grass stands should be allowed to completely senesce (die-back following frost) before harvesting. Delaying harvest would allow plants to absorb the maximum amount of nutrients from the vegetation and retain it in the root system, thus improving stand health and vigor over a longer period of time. If stands are harvested too early, stand yields could be affected and may require greater nitrogen inputs than if harvest is delayed.

4. Compare annual and biennial harvests on biomass yield and maintenance of the stands. (A biennial harvest would have environmental and wildlife benefits, save the producer one harvest cost, and provide a drought safety net.)

   Results to Date

   - All plots harvested every other year yielded less than the annually harvested plots, except Williston irrigated Basin + Altai wildrye which showed a slight 0.6 percent increase.
   - 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.
   - No pattern has emerged between locations or species on the percent decrease in yields due to biennial harvest. The biennial plots will be sampled in 2011 and perhaps some trends will start to emerge.
   - Some plots become invaded with grass and other plants not included in the mixture originally planted, therefore, total production of the plots is used to measure yield. During harvest, the percentage of the total production contributed by the species originally planted is visually estimated.
   - If the biomass produced is to be burned for energy, the 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 or other chemicals 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.

5. Evaluate carbon sequestration and storage of the various perennial crops. (These grasses should store major quantities of carbon even when harvested.)

   Results to Date

   - Baseline soil samples were collected in 2006 prior to seeding the biomass plots. The study methodology calls for soil samples to be collected again in 2011 and 2016 for comparison to baseline.

6. Assess chemical properties of biomass harvested from plots to determine potential effects on Spiritwood power plant equipment. (No information is available on chemical properties of biomass grown within a 50-mile radius of the plant which is the desired distance to obtain feedstock.)

Results

- Microbeam Technologies, Inc., Grand Forks, ND, completed a report, "Chemical and Heat Value Characterization of Perennial Herbaceous Biomass Mixtures", dated September 9, 2010. The report concluded, "Experience in co-firing biomass with North Dakota lignite is very limited. Based on the known interactions of the components present in biomass and Falkirk lignite, potential exists for fireside ash deposition and potential corrosion problems for some of the biomass materials characterized in this study. In order to begin to quantify and manage the ash-related problems, the following future directions are suggested:
    1. Laboratory scale fluid bed combustion testing:
        a) Determine the potential for bed agglomeration and ash deposition using selected combinations of biomass, lignite, and bed materials.
        b) Identify and test combinations of biomass, lignite, bed materials, and bed additives that minimized bed agglomeration and deposition.
    2. Develop coal, biomass, and bed material specification that can be used to manage agglomeration as a function of changing lignite and biomass compositions."

The Annual report summarized the following activities that had been completed during the year:

Biomass Crops Harvest and Analysis

In September 2010, North Dakota State University completed the harvest of biomass crops from plots established at the Streeter, Carrington, Minot, Hettinger and Williston Research Extension Centers. Biomass yield and chemical properties were determined and a 2010 report was prepared and widely distributed. (A copy of the 2010 Biomass Crops Study Report is available in the Commission files or through the NDSU Central Grasslands Research Extension Center website: http://www.ag.ndsu.edu/CentralGrasslandsREC/cgrec-annual-reports-1/2010-report/Biofuels_Report.pdf

Additional Biomass Analysis

Additional analysis beyond work completed by NDSU is needed to assess the suitability of biomass crops for co-firing in Great River Energy's Spiritwood Station Combined Heat and Power Plant. Specifically, information is needed on the heat value (BTU), silica, chlorine/chloride, and alkalinity. The Trust requested bids for the additional biomass analysis from three testing labs identified in the grant proposal. Microbeam Technologies, Inc., Grand Forks, was selected to complete the analysis and prepare a report characterizing the chemical and heat value of the biomass mixtures. The report, "Chemical and Heat Value Characterization of Perennial Herbaceous Biomass Mixtures" was completed September 9, 2010 and was distributed to the study partners and made available through the NDSU Central Grasslands Research Extension Center website: http://www.ag.ndsu.edu/CentralGrasslandsREC/biofuels-research-1/Chemical%20Analysis.pdf

Communications Plan

An update was provided on the communication efforts that have been accomplished. (A copy of the communications plan update is available at the Industrial Commission Office along with copies

of presentations and reports.) A number of public events and tours included presentations regarding the work being completed through this project.

September, 2011

A no-cost 4-month extension was requested and approved.

March, 2012

Draft Final Summary Report and Draft Final Technical Report have been presented to the Commission. The Significant Findings noted in the draft report state:

Establishment: Perennial energy crop mixtures can be successfully established in central and western North Dakota.

Management: Adding legumes for nitrogen appears to lessen the need for fertilizer, but herbicides used to control weeds would be detrimental to legumes. Mowing weeds can be used in place of herbicides. If biomass is burned for energy, total yield is the important metric. However, if biomass is used for ethanol a more pure stand may be needed and plant invasion control could be an added expense and management problem to the producer. In switchgrass or other warm season grass stands, glyphosate or other chemicals can be used to control cool season weedy grasses. No chemical exists that can control cool season weedy grasses in wheatgrass stands.

Yields: Switchgrass and its mixtures had the highest five-year average yields (tons/acre), as follows: Carrington (6.1); Williston irrigated (5.96), Minot (3.61), and Streeter (2.99). The highest five-year average yield (tons/acre) at Hettinger was the CRP mix (wheatgrasses + alfalfa + sweetclover) of 1.96 and at Williston was wheatgrass at 1.34. Factors affecting yields include moisture, soil quality, and weed invasion.

Harvest Frequency: Lower yields of biennial harvest varied considerably (20 to 50 percent) by location and harvest methods (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 yield.

End Use: 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.

Soils: 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.

May, 2012

The Final Executive Summary, Final Summary Report, Final Technical Report and budget report have been presented to the Commission. Copies of the reports are available on the Commission website. The Final Executive Summary states:

Goal of Project: Evaluate perennial herbaceous energy corps 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 wheat grass (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%), followed 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 when wildlife habitat and lower management costs are taken into 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 reduced compaction. Large aggregates act as microbial habitats for increased nutrient cycling.

Since this was the second phase of a three phase project, the participants are now working on the third phase of the project. The Renewable Energy Program is not part of the third phase. So, as it relates to the Renewable Energy Program, this project is complete. The North Dakota Natural Resources Trust will be making a presentation to the Renewable Energy Council in November.

November 9, 2012