ENVIRONMENTAL AND ECONOMIC RESEARCH AND DEVELOPMENT PROGRAM

Sustainability of Switchgrass for Biofuel in Southwestern Wisconsin

Executive Summary
July 2012

PREPARED BY:

MARK J. RENZ[1], ASSISTANT PROFESSOR;
RANDALL D. JACKSON[1], ASSOCIATE PROFESSOR;
MATHEW D. RUARK[2], ASSISTANT PROFESSOR;
UNIVERSITY OF WISCONSIN-MADISON,
[1]AGRONOMY DEPARTMENT,
[2]SOIL SCIENCE DEPARTMENT

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This report was funded through the Environmental and Economic Research and Development Program of Wisconsin's Focus on Energy.

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List of Acronyms

°C - degrees Celsius
ac - acre
ANOVA - analysis of variance
btu - British thermal unit
C - carbon
CH_4 – methane
Cl^- - chloride ion
cm - centimeters
cm s^{-1} - centimeters/second
CO_2 - carbon dioxide
CRP - conservation reserve program
D-IMAZ+GLY - Diverse species planting with pre-emergent applications of glyphosate and imazapic
DM - dry matter
g - grams
g ae ha^{-1} - grams acid equivalent/hectare
GHG - greenhouse gas
Gj - gigajoule
GLY - Pre-emergent applications of glyphosate
GLY+OATS - Oats (*Avena sativa*) planted as a companion crop + pre-emergent applications of glyphosate
GLY+2,4-D - Pre-emergent applications of glyphosate + post-emergent applications of 2,4-D
ha - hectare
ISO - International Organization for Standardization
kg ha^{-1} - kilogram/hectare
km h^{-1} - kilometer/hour
L. - Linnaeus
lb - pounds
m - meters
m^2 - meters squared
$m^{-2}h^{-1}$ or $m^{-2}hr^{-1}$ - per meter squared per hour
Mg - megagram
Mj - megajoule
mm - millimeters
Michx. - André Michaux
N - nitrogen
npp - net primary production
N_2O - nitrous oxide
p - p-value
PLS - pure live seed
S-IMAZ+GLY - Switchgrass only planting with pre-emergent applications of glyphosate and imazapic
SPAL - Soil and Plant Analysis Lab
Spp. - species

Executive Summary

The purpose of this project was to provide information that contributes to the development of economically and environmentally sound energy production in Wisconsin. The production of energy from perennial biomass crops holds potential to supplement fossil fuel use and thereby reduce fossil fuel emissions. Perennial biomass crops also have the potential to decrease soil erosion, improve soil quality, increase carbon (C) sequestration, and also provide other benefits such as wildlife habitat. Switchgrass and mixtures of native prairie plants (warm season grasses and forbs) have been identified as potential herbaceous bioenergy crop candidates. We evaluated the sustainability of these energy crops when planted on marginal agricultural land in Wisconsin. Specifically we estimated productivity of select agronomic practices (weed management and fertility) and estimated how potential carbon sequestration, soil erosion, greenhouse gas fluxes, and global warming potential were affected by these practices. Below is a summary of the results from this project within each of these categories.

The specific project objectives were to:

1. Assess soil C sequestration and global warming potential of establishing switchgrass stands.
2. Evaluate the potential for soil loss among various establishment methods.
3. Measure optimum N fertilizer application rates for productivity and how they impact biomass quality and thermal energy.

METHODOLOGY

- This study was located on six working farms in Grant County, Wisconsin.
- Five experimental treatments at each farm were established in May 2008.
    - Treatments included
        - 3 switchgrass monocultures.
        - switchgrass planted with a companion crop of oats (*Avena sativa*).
        - a diverse mixture that included 5 native grasses and 4 native forbs.
    - Weed management treatments for switchgrass included
        - pre-emergent applications of glyphosate.
        - pre-emergent applications of glyphosate + post-emergent applications of 2,4-D.
        - pre-emergent applications of glyphosate and imazapic.
        - oats (*Avena sativa*) planted as a companion crop + pre-emergent applications of glyphosate.
    - Additionally the effect of nitrogen fertilizer rate and harvest timing (early fall, late fall, spring) on switchgrass was productivity and fuel quality were evaluated at each site across establishment treatments.
- In May 2009, each experimental field was further divided into four plots to evaluate effects of second-year weed management strategies. These second-year treatments included
    - low-intensity prescribed burn.
    - glyphosate.
    - imazapic + glyphosate.
    - untreated control.

ESTABLISHMENT AND PRODUCTIVITY:

- A range of weed management methods were effective at establishing a productive switchgrass stand on marginal lands in Wisconsin.
- Additional management after the establishment year did not improve productivity of either switchgrass or diverse stands.

- While fields produced minimal amounts of biomass in the establishment year (< 1 ton/acre(ac)), treatments yielded between 2 and 4 tons/ac annually, two and three years after establishment.
- The diverse prairie treatment yielded between 2 and 3 tons/ac annually, two and three years after establishment. Yield was less than the most productive switchgrass treatment in 2009, but similar to all switchgrass treatments in 2010.
- Annually adding up to 100 lb/ac of nitrogen (N) fertilizer after the establishment year increased productivity of switchgrass stands by 0.5-1.5 tons/ac each year.
- Fuel quality was improved by delaying harvest until spring, but this delayed harvest decreased yield by between 1 and 2 tons/ac.

CARBON SEQUESTRATION:

- Below-ground carbon sequestered in plant material and microbes respiring carbon dioxide (CO_2) were similar between switchgrass monocultures and diverse stands.
- Burning monocultures of switchgrass increased sequestered carbon in above ground tissue compared to diverse stands, but unburned switchgrass monoculture had similar amounts of carbon sequestered.

GREENHOUSE GAS FLUXES:

- No differences in CO_2 or methane (CH_4) fluxes were found in 2009 or 2010 with respect to establishment treatments or fertilizer application.
- Nitrous oxide (N_2O) fluxes were increased with fertilizer applications in 2009 and 2010.

GLOBAL WARMING POTENTIAL:

- Burning switchgrass monocultures during establishment may support greater soil C accumulation, but simply planting and harvesting this perennial grass should achieve desired goals of minimizing global warming potential for a harvested perennial grass system.
- Even lower global warming potential would likely be realized from switchgrass stands that left more residual material present or were even left unharvested as grass cover would keep soils cool thereby reducing soil respiration.

SOIL EROSION:

- Estimated soil loss calculations did not differ between establishment practices in 2008 or 2009.
- Values of soil loss ranged between 11.0 and 18.6 tons/ac in 2008 and 2.2 and 7.6 tons/ac in 2009, and were closely related to slope of the field.
- A noticeable decline in soil loss occurred from 2008 to 2009, demonstrating the benefit of planting a perennial crop.
- Field or plot level measures of switchgrass planted as a primary crop are required to validate model outputs on soil erosion.

Results suggest that switchgrass and diverse prairies can be established on marginal soils in Wisconsin and become productive in the second or third production year. Fuel quality will increase as fields are harvested late in fall to early spring. While this increased quality will be desired by industry, producers will require increased premium prices for this product as delaying harvest can result in a substantial loss in productivity. Although differences among management and plant community treatments in carbon sequestration and greenhouse gas fluxes were measured, these differences were relatively small. For example, spring burning switchgrass monocultures during establishment may support greater soil C accumulation, but simply planting and harvesting this perennial grass should achieve desired goals of minimizing global warming potential for a harvested perennial grass system.