Carbon Sequestration And Greenhouse Gas Emissions Associated With Short-Rotation Woody Biomass Production In The Upper Great Lakes Region

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Project Objectives

(1) develop predictive relationships between site conditions, establishment procedures and life-cycle GHG benefits of SRWC across the Upper Great Lakes Region,

(2) incorporate these relationships into biogeochemical process models and Life-Cycle Assessments (LCAs) designed to predict regional-scale impacts of varying scenarios of SRWC deployment, and

(3) develop geospatial tools to assist in the sustainable deployment of SRWC across existing Great Lakes landscapes.

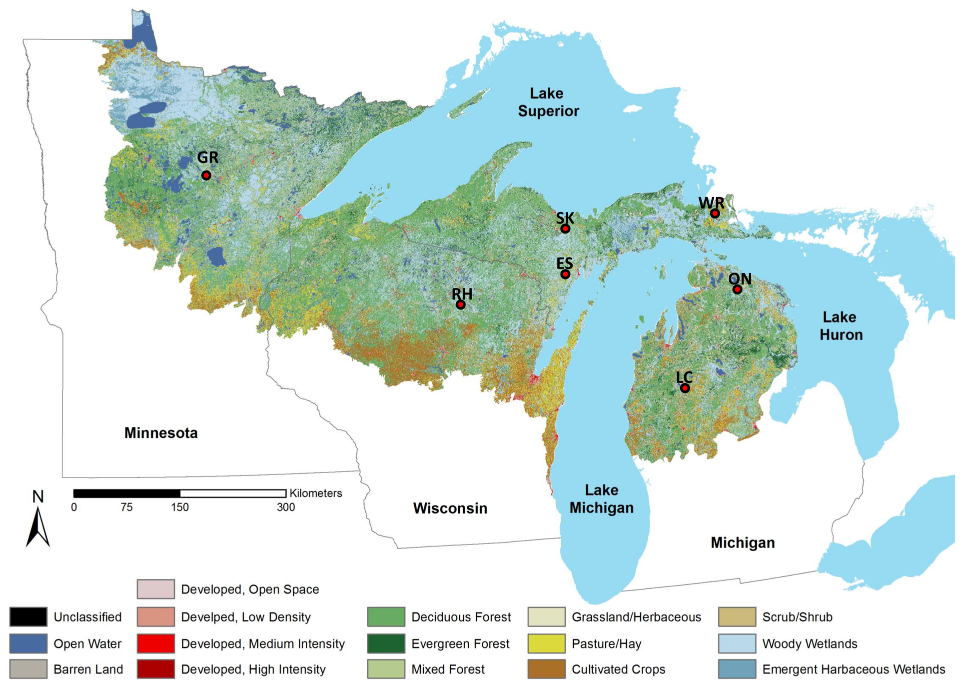

Figure 1. Upper Great Lakes landscape matrix showing locations of six existing study sites (Table 1).

Study Sites

•We are studying the impacts of open-land conversion across a wide range of site conditions (Table 1).

•All sites have plots planted to willow (*Salix*), plots planted to hybrid poplar (*Populus*) and reference plots maintained in prior herbaceous vegetation (Fig. 2)

•We are measuring aboveground biomass production, soil GHG emissions, nutrient leaching and soil C stock changes.

Table 1. Study site characteristics. Locations of all sites are shown in Fig. 1. Initial soil organic C and N concentrations are given in units of g kg^{-1} for the surface 10 cm.

Site	Esta-ished	Texture	Drainage Class	Prior Land Use	Initial Soil C	Initial Soil N
1	2009	Fine sandy loam	Moderately well	Pasture/Hay	33	2.4
2	2009	Silt loam	Somewhat poorly	Pasture	35	2.7
3	2010	Sandy loam	Well	Pasture	19	1.4
4	2010	Loam	Somewhat poorly	Grass-alfalfa hay	28	1.9
5	2010	Fine sandy loam	Well	Grass-alfalfa hay	26	1.9
6	2010	Loamy sand	Well	Grass hay	18	1.4
7	2011	Very fine sandy loam	Poorly	Grass Hay	28	1.8

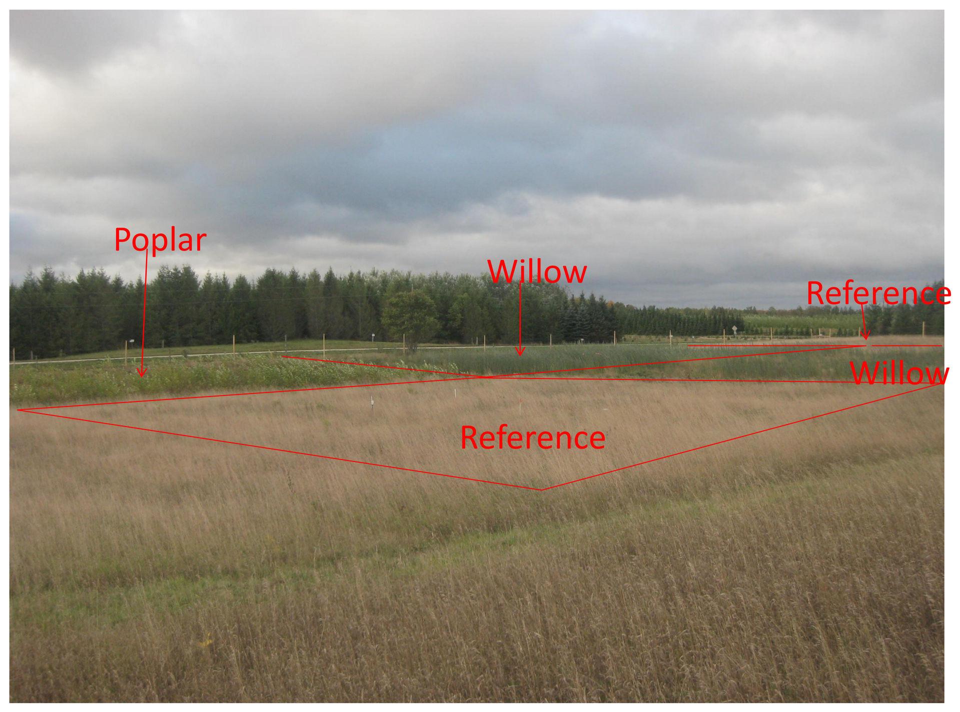

Figure 3. View of portion of site ES showing two reference plots, two willow plots and one poplar plot.

Results – N_2O Fluxes

•Conversion of herbaceous openlands to SRWC represents a major disruption to N cycle – increasing soil available NO_3^- (**Fig. 3**) and concomitant N_2O emissions at every site (**Fig. 4**).

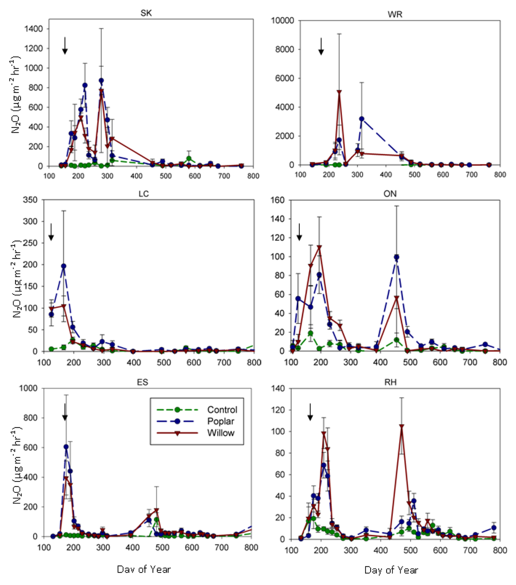

Figure 3: Soil extractable nitrate (mg kg^{-1}) over the first two years after planting at each site. Arrows represent the date of plowing.

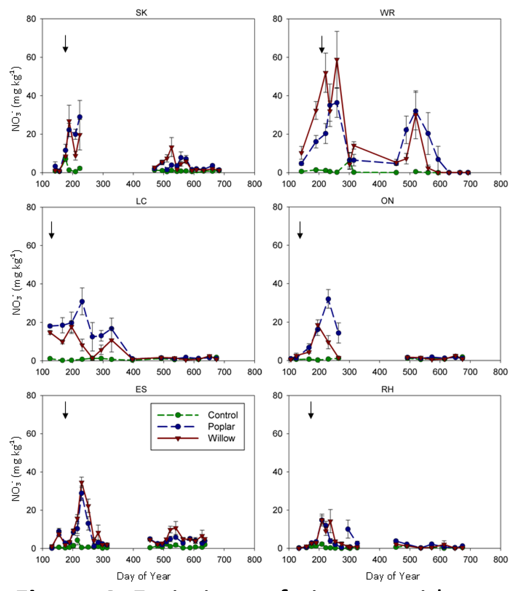

Figure 4: Emissions of nitrous oxide (µg m^{-2} hr^{-1}) over the first two years after planting at each site. Arrows represent the date of plowing. **Note the different scales between sites.**

•Conversion-induced N_2O flux was a major source of direct GHG emissions on N-rich sites – typically ignored in LCA studies (**Fig. 5**).

•There was a 30-fold range in cumulative N_2O emissions among sites, indicating that LCA models of GHG balance need to take into account underlying site conditions.

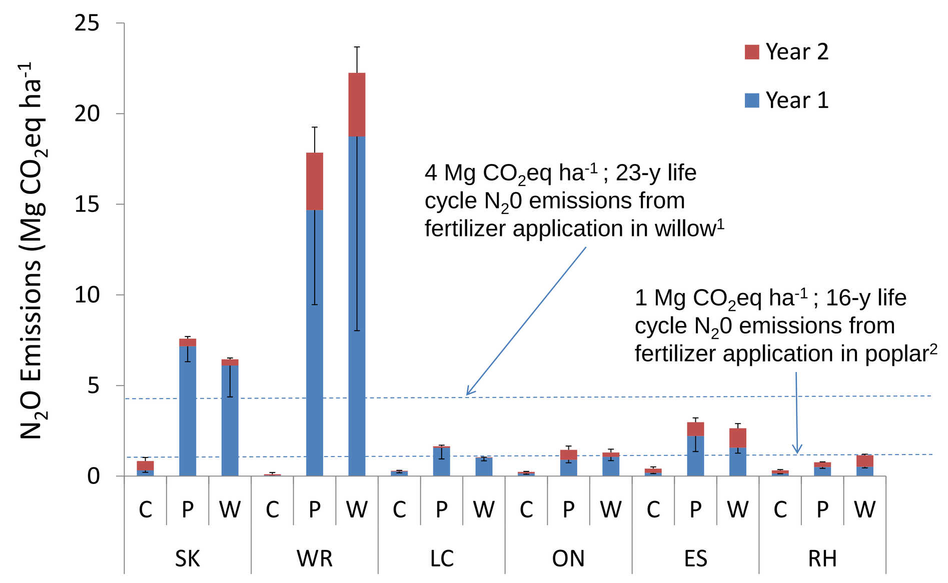

Figure 5. Cumulative two-year N_2O emissions across treatments and study sites, relative to life-cycle N_2O fluxes reported in the literature.
[1]Keoleian and Volk. 2005. Critical Reviews in Plant Science 24:385-406.
[2]Gasol et al. 2009. Biomass and Bioenergy 33(1):119–29.

•Differences among sites in cumulative N_2O fluxes were associated primarily with soil NO_3^- levels, and secondarily with temperature and soil NH_4^+ levels (**Fig. 6**).

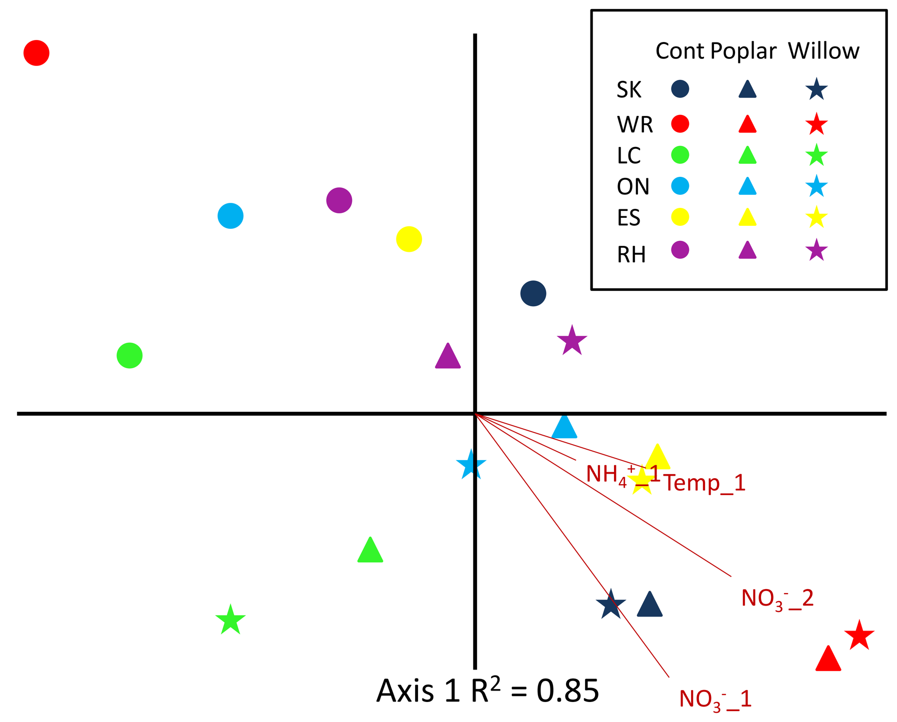

Figure 6: NMS ordination of cumulative annual estimates of N_2O flux for control, poplar, and willow treatments at each site overlain with mean annual NO_3^-, NH_4^+, soil temperature, and WFPS values.

Results – Net Global Warming Potential

- We quantified productivity and GHG debt associated with converting grasslands to SRWC at our two intensively-studied sites (ES and RH) over the first 2-years of plantation establishment.
- Early aboveground (Fig. 7) and belowground (Fig. 8) productivity of SRWC is low. Second-year willow at RH was the only SRWC treatment that matched productivity of existing grassland.

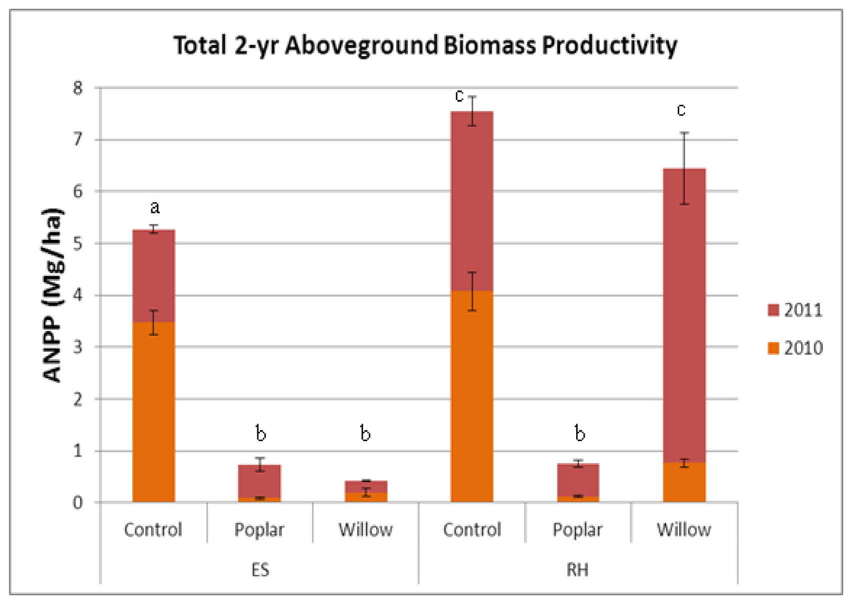

Figure 7. Aboveground biomass production in SRWC plots at ES and RH sites in comparison to undisturbed grassland controls

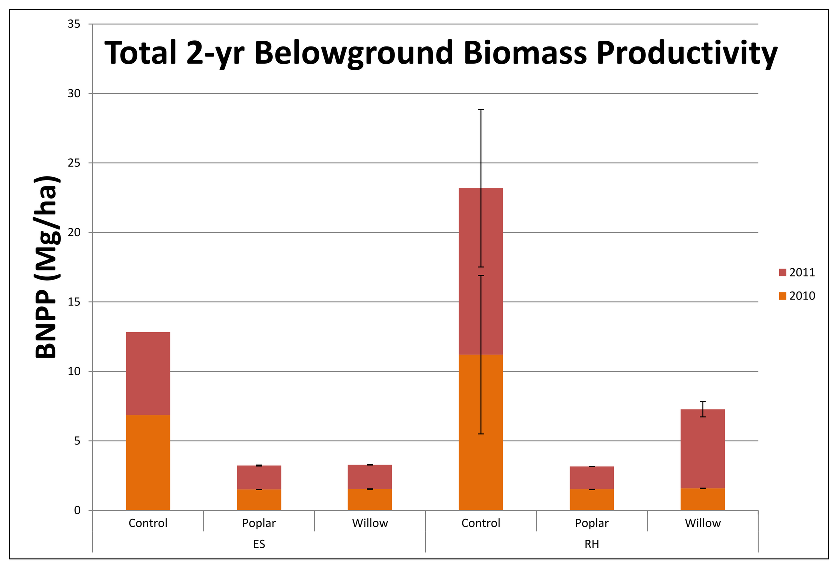

Figure 8. Belowground biomass production in SRWC plots at ES and RH sites in comparison to undisturbed grassland controls

- Conversion of grasslands to SRWC resulted in elevated soil CO_2 and N_2O emissions over the first two years. Methane emissions were extremely low and unaffected by land conversion.

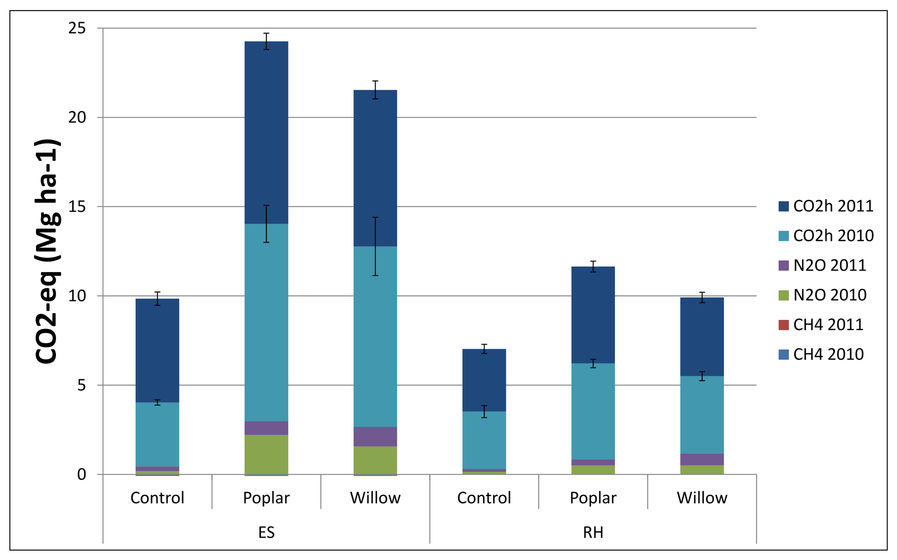

Figure 9. Cumulative soil GHG emissions from SRWC plots at ES and RH in comparison to undisturbed grassland controls.

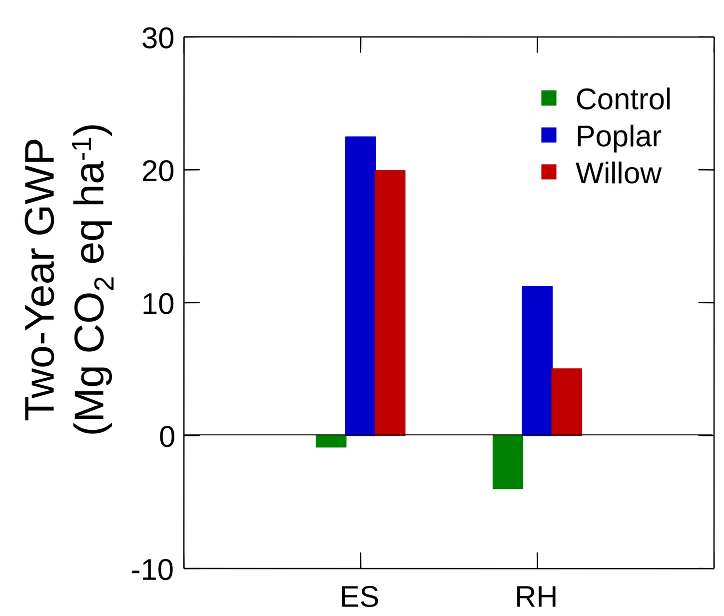

Figure 10. Cumulative, two-year global warming potential for control, poplar and willow plots at ES and RH accounting for both soil GHG emissions and biomass C stock changes. Positive values indicate a net source of GHG emissions to the atmosphere, negative values indicate a net sink.

Results – Land Availability

•Our initial objective was to identify the distribution of open lands in the region and estimate the biomass and energy potential of SRWC on these lands.

•The distribution (Fig. 1) and total area (Table 2) of open lands across the region were derived from the 2006 National Land Cover Dataset (NLCD).

•"Non-agricultural" open lands (Grasslands/Herbaceous + Pasture/Hay) totaled nearly 22,000 km^2 across the study region.

•We estimated the yield potential for willow and poplar biomass across the study region for a scenario in which 10% of the non-agricultural openlands were converted to SRWC energy crops. Cumulative regional feedstock production under this scenario was 1.52 Pg yr^{-1} for poplar and 1.74 Pg yr^{-1} for willow (Fig. 11).

•Cumulative regional electricity generation under this scenario was 435 MW yr^{-1} for poplar and 505 MW yr^{-1} for willow (Fig. 12).

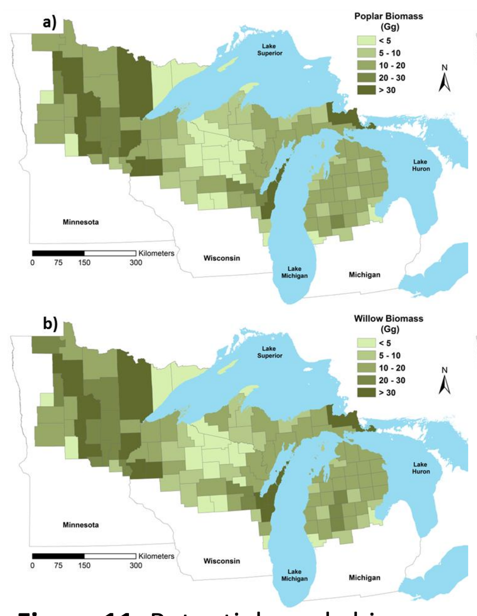

Figure 11. Potential yearly biomass (Gg) yield on 10% of 'non-ag' open lands for poplar (a) and willow (b) assuming 7 and 8 Mg/ha/year biomass production for poplar and willow, respectively.

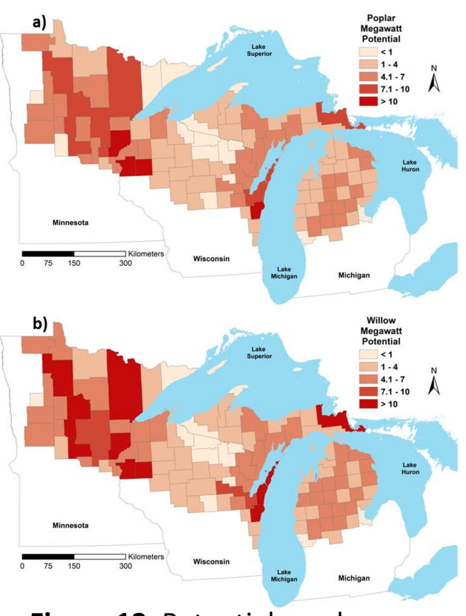

Figure 12. Potential yearly energy generation (MW) from poplar (a) and willow (b) bioenergy plantations. Assumptions include the following: 10% conversion from non-ag open lands (2,173 km^2); 7 and 8 Mg/ha/year biomass production for poplar and willow, respectively; 18 GJ / Mg energy density of biomass; power generation facility running at 70% capacity and 35% efficiency.

Future Directions

- Continue to monitor productivity and GHG balance of plantations as they grow and develop.
- Use field data to calibrate a spatially-explicit, process ecosystem model (EPIC) to simulate realistic feedstock productivity and GHG emissions across the regiobn
- Scale field-based findings to quantify consequences for regional C storage and GHG fluxes of different levels and landscape allocation patterns of SRWC production.
- Develop a GIS-based assessment of the relative suitability of open lands across the region for conversion to SRWC plantations.

Acknowledgements

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