BENEFITS AND OPPORTUNITIES: INTEGRATING BIOMASS GRASSLANDS INTO THE NE WISCONSIN LANDSCAPE

Mathew E. Dornbush, Ph.D.
Dept. Natural & Applied Sciences
University of Wisconsin-Green Bay
OUTLINE

• Rational and constraints of a demanding world
• Relevance for NE Wisconsin and the Oneida Nation – Case Study
• Research Questions
• Preliminary Results
• Future Directions
Rationale from Local to Global

Brooks 2005

Weekly Wisconsin Propane Residential Price

Ness 2014
THE WORLD IS BOTH CONNECTED AND CROWDED

• Must return to our roots; agriculture will again provide:
  1. Food
  2. Fiber
  3. Fuel
  – With Maximum Efficiency!

Kareiva et al. 2007
**Q: WHERE AND HOW?**

- **Marginal land** - areas poorly suited for row crop production due to edaphic or climatic limitations, or areas prone to soil erosion or degradation under traditional production (Cai et al. 2011 *Env. Sci. & Tech.*; Gelfand et al. 2013 *Nature*)

![Maps of land available for bioenergy production under scenario 4 in U.S., Europe, China, India, South America, and Africa.](image-url)
MINIMIZE FOOD FOR FUEL COMPEITION
A LANDSCAPE IS A BIG PLACE

- Somewhat poorly, Poorly, or Very poorly drained soils
  - At a minimum wet at shallow depths for long enough to often limit mesophytic crop growth in the absence of drainage.

Dornbush et al. 2012
ECOSYSTEM SERVICES ALSO HAVE VALUE

- NE Wisconsin has wet, high clay content soils, which are optimal for C-sequestration, but when fertilized emit significant N$_2$O (Cavigelli et al. 2012).
- Green Bay has some serious water quality issues
CONCEPTUAL BASIS FOR BIOFUELS IN NE WISCONSIN

• Planting “wet” areas into annual row crops is often delayed, prevented, or unprofitable, but spring soil saturation can maximize perennial grass production by supplying moisture longer into the summer.

• The juxtaposition of low-lying areas between agricultural uplands and aquatic systems, coupled with their soil properties (high clay, etc), suggests the highest return on ecosystem service improvements per unit converted land.

• The combination of these points facilitate cost-sharing strategies that can improve the economic feasibility of biofuels in NE Wisconsin.
Energy Sovereignty is Energy Security

- Currently, Oneida Conservation delivers wood to elders (hazard trees)
- Deliver 80-100 full cords per year,
  - 1,800 MMBtu, heats about 18 homes based on 100MMBtu / home / heating season
- Can Oneida?
  - convert a % of cropland into an energy crop,
  - pelletize or crush the crop,
  - Distribute to its members for space heating or fuel?
- Local Production, Local Energy, Local Jobs, Energy Sovereignty
- Switchgrass: 1-2 acres/home/heating season
- Challenges: ash content (clinkers), T/ac, marketing

Slide complements of M. Troge
OVERVIEW

• Oneida Indian Reservation: 65,551 acres
  – 59.4% agriculture
  – 3.5% grasslands/pastures

• 43.0% of total area consider somewhat poorly, poorly, or very poorly drained
  – 42.3% of all agricultural and grasslands/pastures
QUESTIONS

• How effectively do biofuel grasslands establish in marginal versus upland soils?

• Does crop and grassland production respond differently to marginal soils?

• How does a focus on marginal soils in NE Wisconsin affect the ecosystem services associated with biofuel grasslands?

• Does a focus on marginal vs. upland soils in NE Wisconsin alter the economic feasibility of biofuels?
1. Evaluated row crop and restored prairie production in upland and lowland soils.

2. Used SWAT modeling to evaluate the effect of row crop conversion to biofuel grasslands on P loss and soil erosion.

3. Evaluated the economic competitiveness of biofuel production in upland and lowland soils.
Q1: DOES CROP AND GRASSLAND PRODUCTION RESPOND DIFFERENTLY TO MARGINAL SOILS?

- 3 upland and 3 lowland paired study plots, over two years.

Dornbush et al. 2012
FOCUS on Energy Report

Corn Silage

![Corn Silage Chart]

Wheat Grain

![Wheat Grain Chart]
Q1: DOES CROP AND GRASSLAND PRODUCTION RESPOND DIFFERENTLY TO MARGINAL SOILS?

Grasslands far outperformed row crops in lowland areas.

Dornbush et al. 2012
FOCUS on Energy Report

von Haden and Dornbush 2014
Agri Eco Env
THESE GRASSLANDS WERE QUITE DIVERSE

Q: How much diversity is enough, and what to expect from establishment?

Dornbush et al. 2012
FOCUS on Energy Report

von Haden and Dornbush 2014
Agri Eco Env
HOW MUCH DIVERSITY ISENOUGH?

Monocultures

Greater Inputs?
Greater Yields?
Lower Eco. Serv.?

Polycultures

Lower Inputs?
Lower Yields?
Greater Eco. Serv.?
LAND SPARING OR LAND SHARING?

- Q: Likely need less diversity if interested in fewer ecosystem services?

Figure 3: The proportion of study species that promoted ecosystem functioning increased when more (a) years, (b) places, (c) ecosystem functions and (d) environmental change scenarios were independently considered. Solid blue lines indicate generalized linear model fits for each study; dashed red line indicates grand mean generalized linear model fitted across all studies. Box plots summarize observed data: black band, median; bottom and top of boxes respectively correspond to lower and upper quartiles; error bars, ± 1.5 times the interquartile range. See Supplementary Data for the specific years, places, functions and environmental change scenarios considered in each study.
PROJECT 2: ONEIDA TRIBE OF INDIANS OF WISCONSIN BIOFUEL PROJECT (ONGOING)

• In 2012 we established four replicated blocks at 2 farms, each with 4 experimental treatment plots.
  – Plots are 25-by-80 m (~0.5 acres)

• Four planting mixtures:
  – Switchgrass (SG)
  – Switchgrass with 4 native legumes (SG-L)
  – Mixed graminoids (MGP)
  – Mixed graminoids with 4 native legumes (MGP-L)
Q: HOW EFFECTIVELY DO BIOFUEL GRASSLANDS ESTABLISH IN MARGINAL AREAS?

• Most strongly related to uplands verses lowlands:
  – Establishment decreased with decreasing elevation, and increasing pH and soil moisture.

• For both MGP and SG!
• High spatial variability
**IMPLICATIONS FOR BIOMASS PRODUCTION**

- Strong diversity by soil type interaction: $F = 6.4, P < 0.02$
- But not as exactly as expected; everything did bad in lowlands, while switchgrass outperformed mixed grasses in uplands.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Biomass (kg ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowland</td>
<td>1000</td>
</tr>
<tr>
<td>Upland</td>
<td>1200</td>
</tr>
<tr>
<td>Mixed Graminoids</td>
<td>1100</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>1400</td>
</tr>
</tbody>
</table>

![Bar chart showing biomass production for different treatments](chart.png)
CONCLUSIONS

• Agriculture must return to its roots and provide food, fuel, and fiber.

• Biomass grasslands provide multiple ecosystem services, and effective biofuel production must consider not only fuel production goals but also environmental goals.

• NE WI represents an ideal location for expansion of home-grown bioenergy: marginal lands within marginal lands, high C-sequestration potential, high N₂O mitigation potential, high water quality benefits, and likely as or more profitable than elsewhere.
CONCLUSIONS

• Challenges appear to relate to the rate or effectiveness of grassland establishment in lowland positions.
  – Work on establishment or breeding?
• Mixed graminoid plantings are underperforming.
  – Breeding issue?
• Continuing directions:
  – planting of grass plugs to better determine production potential.
  – ecosystem services – P mining
  – begin to manage our established stands to increase production.
ACKNOWLEDGEMENTS

- US DOE and UWGB EMBI for current support
- WI FOCUS on Energy for previous support
- WDNR: D. Nikolai (retired)
- UW-Madison: M. Renz
Table 1. Average yield (Tons/acre) of switchgrass varieties across the north central United States. Yield data are a three year average taken during the second through fourth year after planting.

<table>
<thead>
<tr>
<th>Switchgrass variety</th>
<th>Ames IA</th>
<th>DeKalb IL</th>
<th>Lancaster WI</th>
<th>Arlington WI</th>
<th>Marshfield WI</th>
<th>Spooner WI</th>
<th>Rosemount MN</th>
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<tbody>
<tr>
<td>Blackwell</td>
<td>3.04</td>
<td>4.16</td>
<td>4.02</td>
<td>3.35</td>
<td>4.23</td>
<td>4.54</td>
<td>5.57</td>
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<tr>
<td>Cave-in-Rock</td>
<td>2.56</td>
<td>4.37</td>
<td>4.54</td>
<td>3.54</td>
<td>4.45</td>
<td>4.39</td>
<td>5.57</td>
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<tr>
<td>Pathfinder</td>
<td>2.56</td>
<td>3.81</td>
<td>3.89</td>
<td>2.91</td>
<td>4.13</td>
<td>4.33</td>
<td>5.45</td>
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<tr>
<td>Sunburst</td>
<td>2.87</td>
<td>3.67</td>
<td>4.28</td>
<td>3.51</td>
<td>4.57</td>
<td>4.74</td>
<td>5.38</td>
</tr>
</tbody>
</table>
THE AQUOLL SUBORDER IN WISCONSIN

Grassland soil formed under seasonally wet conditions.
MANY HAVE THERE EYE ON NE WISCONSIN

Gelfand et al. 2013 *Nature*
PROJECT OBJECTIVES

1. To evaluate the potential for grassland-based biomass biofuel production in NE Wisconsin.
   a. Evaluate the effect of microtopography on grassland establishment.
   b. Evaluate the effect of microtopography and plant richness on biomass production.
PROJECT 2: ONEIDA TRIBE OF INDIANS OF WISCONSIN BIOFUEL PROJECT (ONGOING)

• Two experimental sites were established in early summer 2012 on the Oneida Nation, WI.

• All study plots contain Kewaunee/Oshkosh soil series (upland soils) and/or Manawa soil series (lowland soil).
  – Same as the FOCUS study
## PLANTED SPECIES LIST

<table>
<thead>
<tr>
<th>Graminoids</th>
<th>Latin Name</th>
<th>Legumes</th>
<th>Latin Name</th>
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</thead>
<tbody>
<tr>
<td>Switchgrass</td>
<td><em>Panicum virgatum</em></td>
<td>Showy Tick Trefoil</td>
<td><em>Desmodium canadense</em></td>
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<tr>
<td>Indian grass</td>
<td><em>Sorghastrum nutans</em></td>
<td>Wild Senna</td>
<td><em>Cassia hebecarpa</em></td>
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<tr>
<td>Big bluestem</td>
<td><em>Andropogon gerardii</em></td>
<td>Round-headed Bush Clover</td>
<td><em>Lespedeza capitata</em></td>
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<tr>
<td>Dark green bullrush</td>
<td><em>Scirpus atrovirens</em></td>
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<tr>
<td>Prairie Cordgrass</td>
<td><em>Spartina pectinata</em></td>
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<tr>
<td>River bullrush</td>
<td><em>Scirpus fluviatilis</em></td>
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<tr>
<td>Soft stemmed bullrush</td>
<td><em>Scirpus validus</em></td>
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</table>
EXPERIMENTAL DESIGN

• A six point topographic gradient within each treatment plot was established in 2012 (n = 192).

• Evaluating changes in ecological services:
  – Plant production
  – Soil C, P
  – Soil bulk density
  – Soil moisture

• All by depth:
  – (0-5; 5-10; 10-20; 20-30; >30 cm)
MANY LONG-TERM GOALS

- Also established an extensive surface (0-10 cm) sampling grid (n = 864)
Distribution of Vol_Moist13 by BY Group
Distribution of Vol_Moist13 by BY Group

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<th>Plot</th>
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<th>4</th>
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