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

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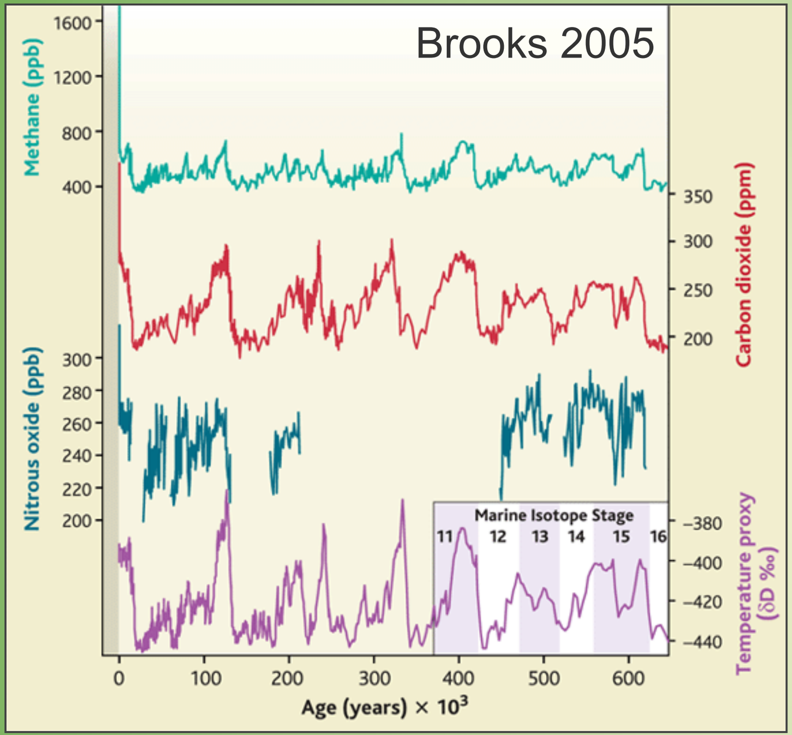
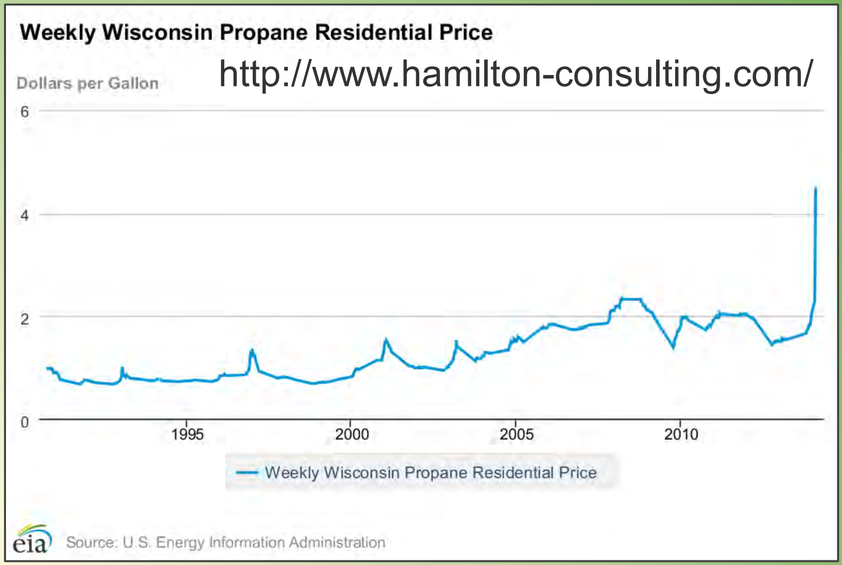
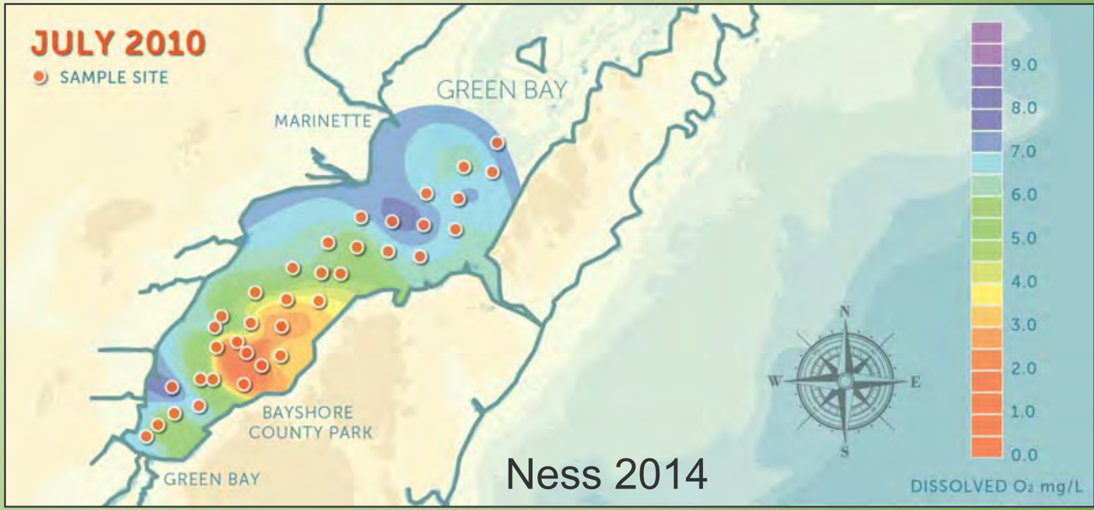
OUTLINE

- Rational and constraints of a demanding world
- Relevance for NE Wisconsin and the Oneida Nation – Case Study
- Research Questions
- Preliminary Results
- Future Directions

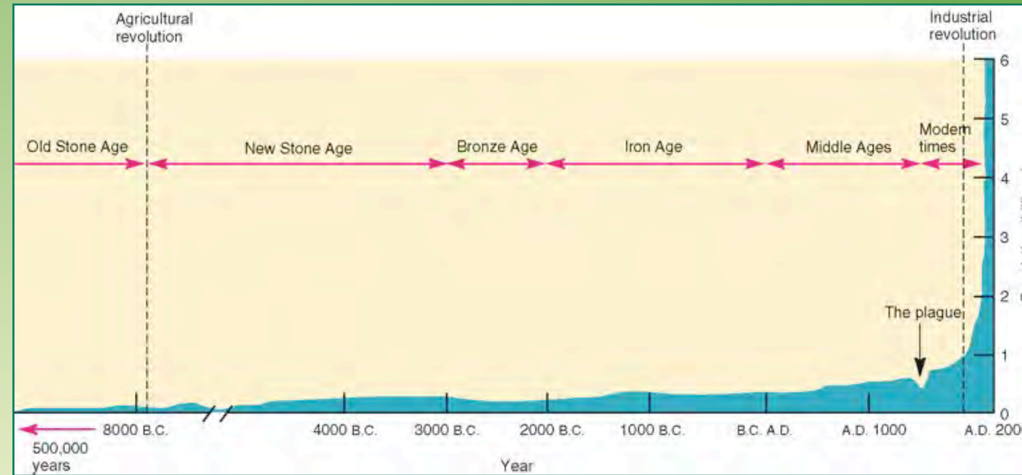
RATIONALE FROM LOCAL TO GLOBAL







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

Fig. 2. Earth's shipping lanes and network of roads. Each shipping lane data point represents the location where an expendable probe was dropped for sampling of ocean temperature from 14 October 2004 to 15 October 2005. Shipping lanes map created from data downloaded at www.aoml.noaa.gov/phod/trinanes/BBXX from the SEAS BBXX database of the Global Ocean Observing System Center from the Atlantic Oceanographic and Meteorological Laboratory of the National Oceanic and Atmospheric Administration. The road network is a 1:1 million scale representation of the paved and unpaved roads of the world. Map created from Environmental Systems Research Institute's (ESRI) Digital Chart of the World (DCW) global vectors, created in 1992.

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*)

Cai et al. 2011 *Env. Sci. & Tech.*

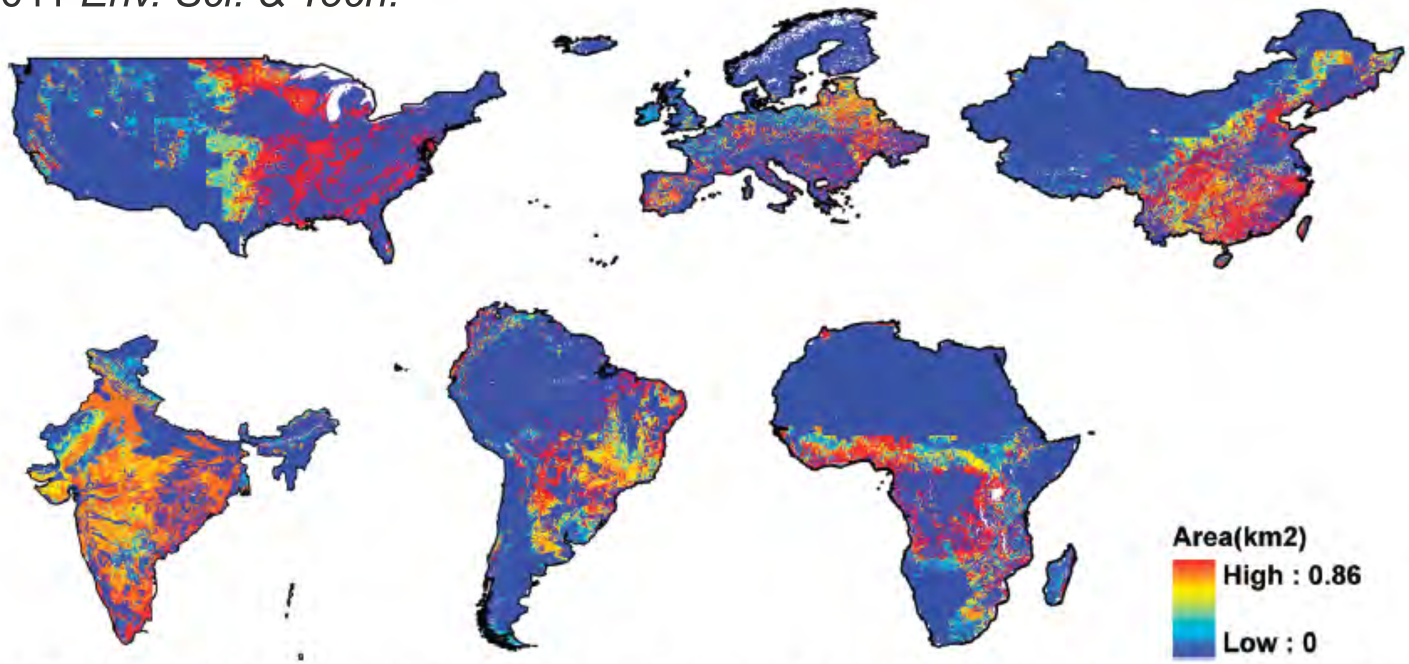
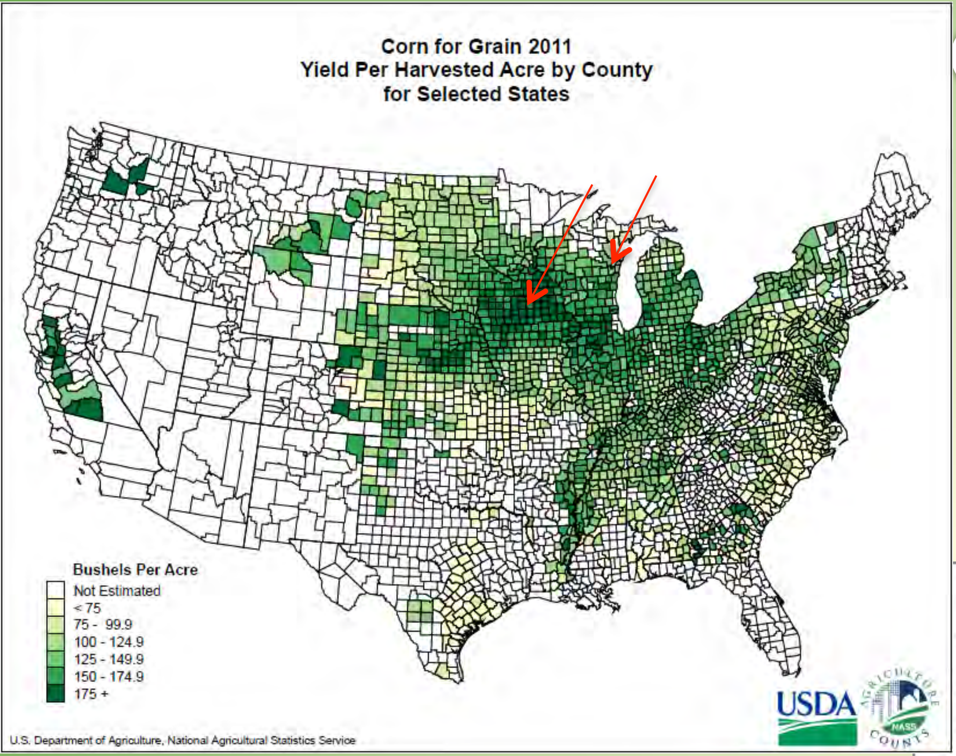
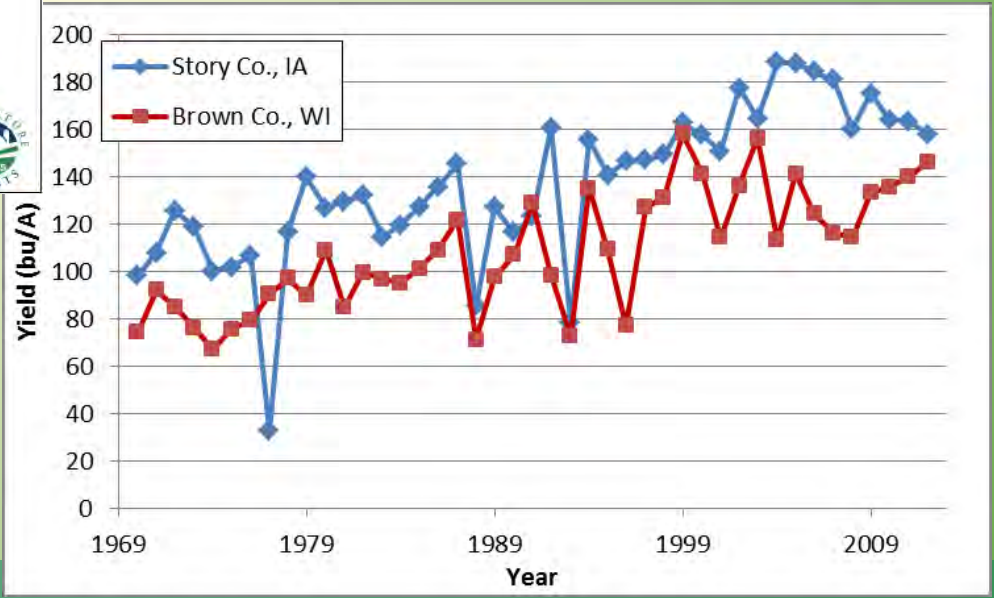


FIGURE 2. Maps of land available for bioenergy production under scenario 4 in U.S., Europe, China, India, South America, and Africa.

MINIMIZE FOOD FOR FUEL COMPETITION





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.

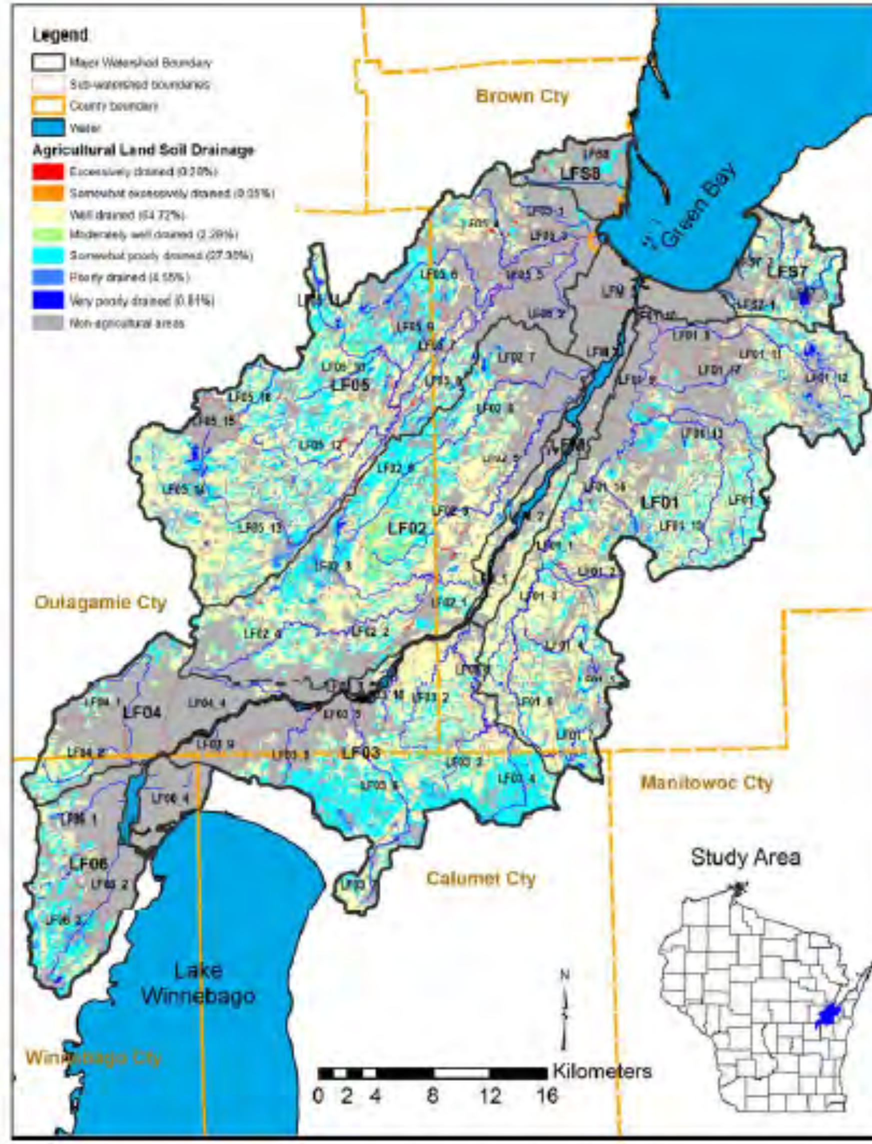


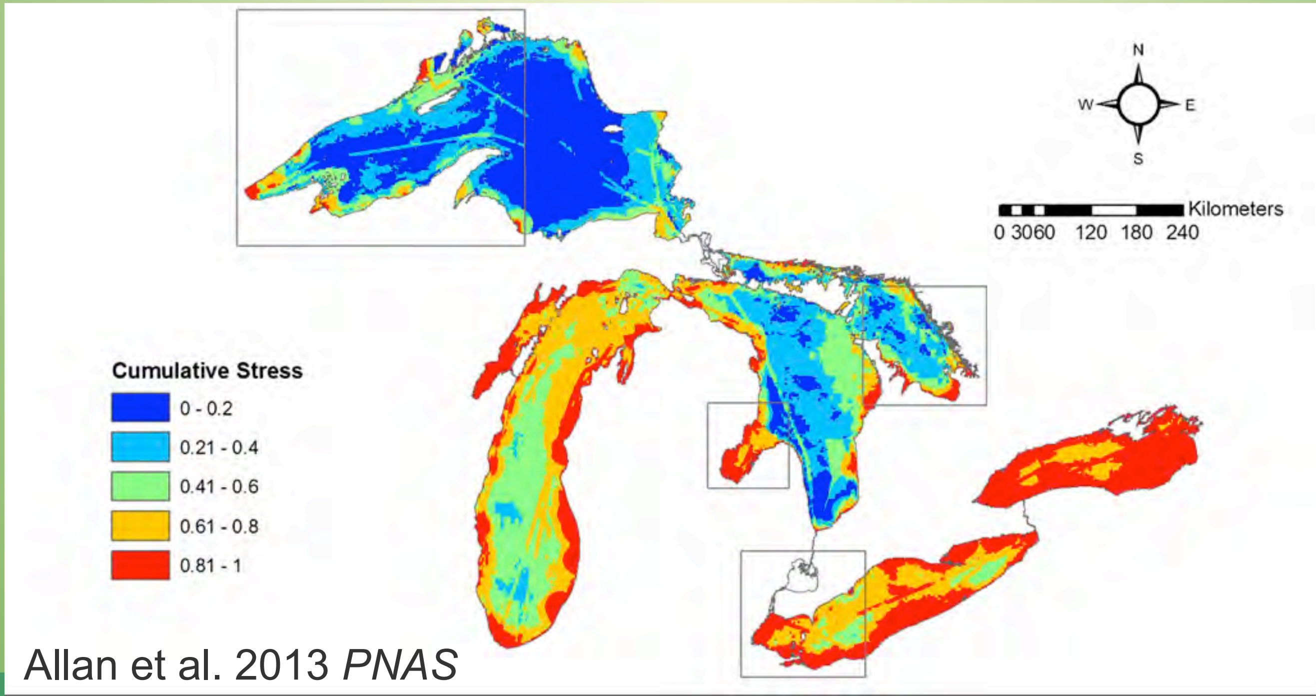
Figure 2. USDA-NRCS SSURGO soil drainage classes on agricultural land in the Lower Fox River sub-basin. Large areas near Green Bay and the Fox Cities are developed and thus unavailable, as are natural areas (background in gray.

Dornbush et al. 2012

FOCUS on Energy Report

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_2O (Cavigelli et al. 2012).
- Green Bay has some serious water quality issues



Allan et al. 2013 *PNAS*

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.

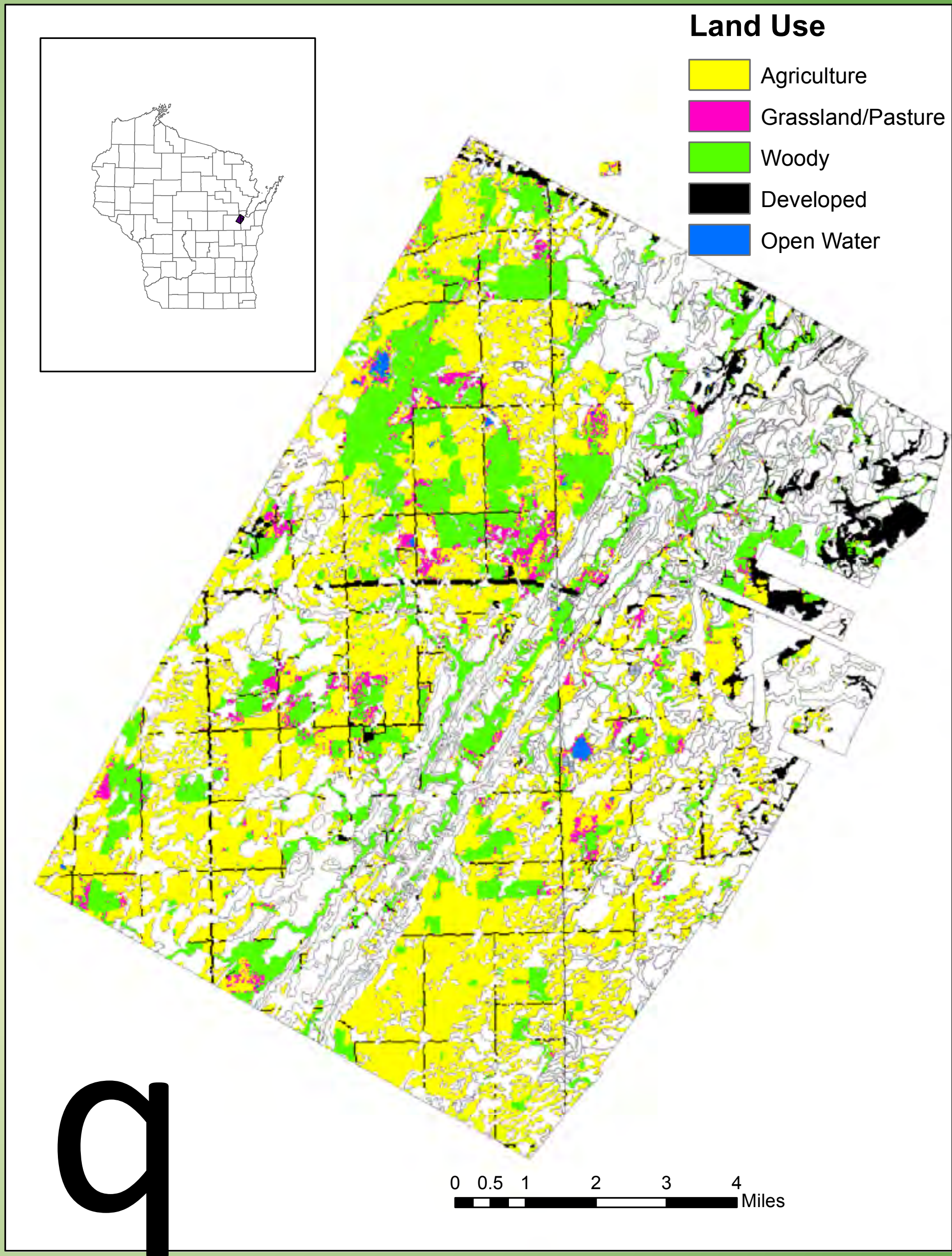
Energy Sovereignty is Energy Security

- 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

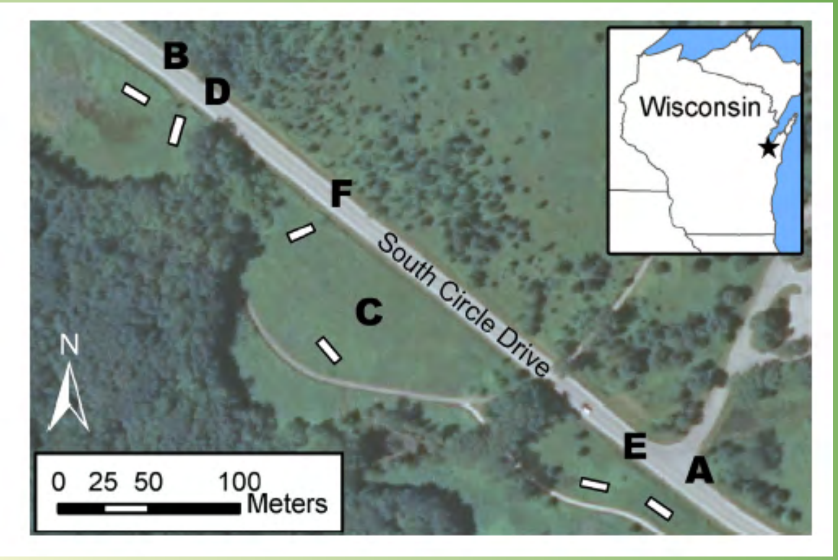
- Oneida Indian Reservation: 65,551 acres
  - 59.4% agriculture
  - 3.5% grasslands/pastures
- 43.0% of total area consider somewhat poorly, poorly, or very poorly drained
  - 42.3% of all agricultural and grasslands/pastures



QUESTIONS

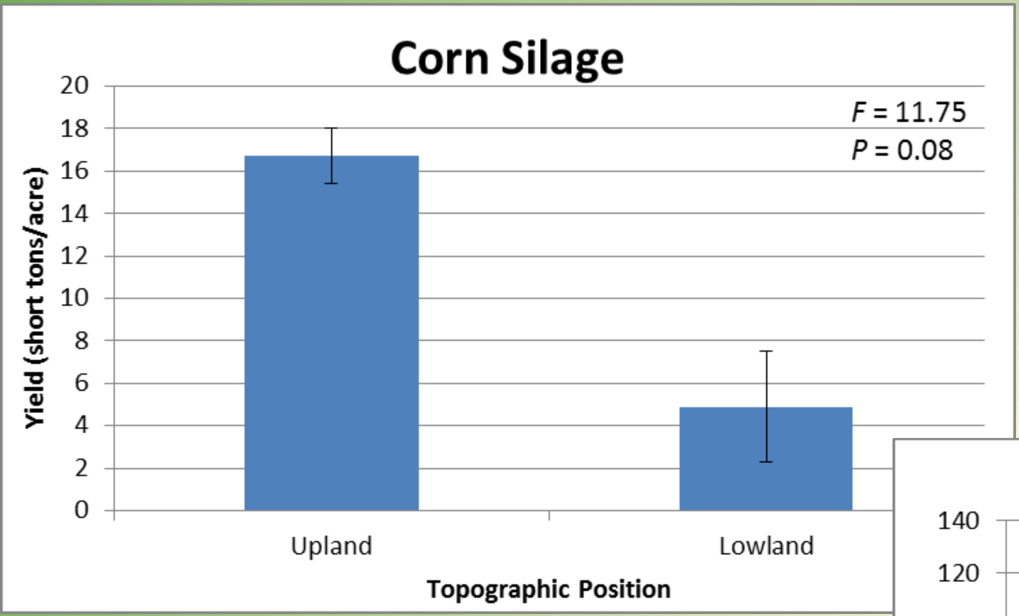
- How effectively do biofuel grasslands establish in marginal verses upland soils?
- Does crop and grassland production respond differently to marginal soils?
- How does a focus on marginal soils in NE Wisconsin affect the ecosystem services associated with biofuel grasslands?
- Does a focus on marginal vs. upland soils in NE Wisconsin alter the economic feasibility of biofuels?

PROJECT 1: FOCUS ON ENERGY (DORNBUSH ET AL. 2012)

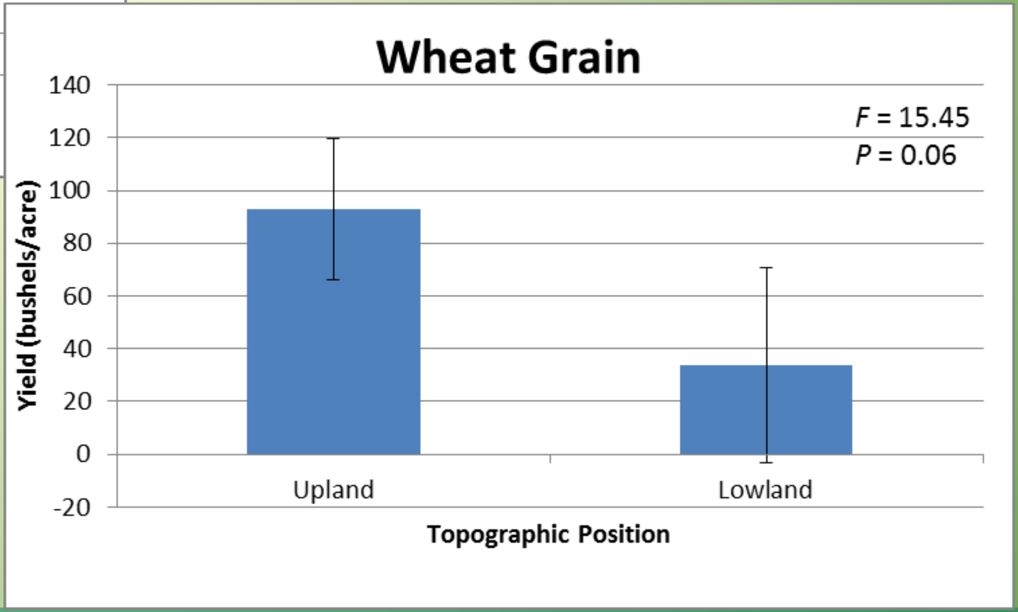


1. Evaluated row crop and restored prairie production in upland and lowland soils.
2. Used SWAT modeling to evaluate the effect of row crop conversion to biofuel grasslands on P loss and soil erosion.
3. Evaluated the economic competitiveness of biofuel production in upland and lowland soils.

Q1: DOES CROP AND GRASSLAND PRODUCTION RESPOND DIFFERENTLY TO MARGINAL SOILS?

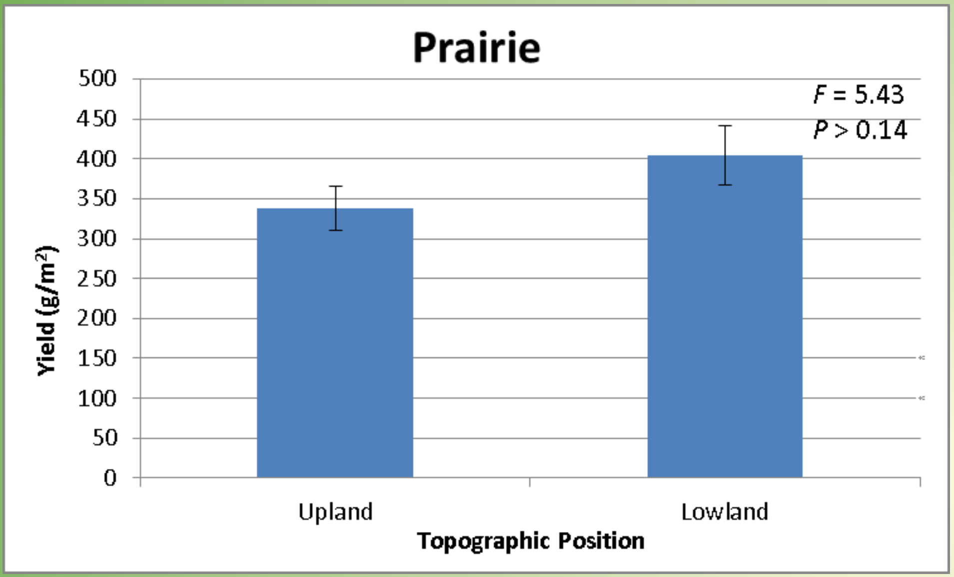


Dornbush et al. 2012
FOCUS on Energy Report



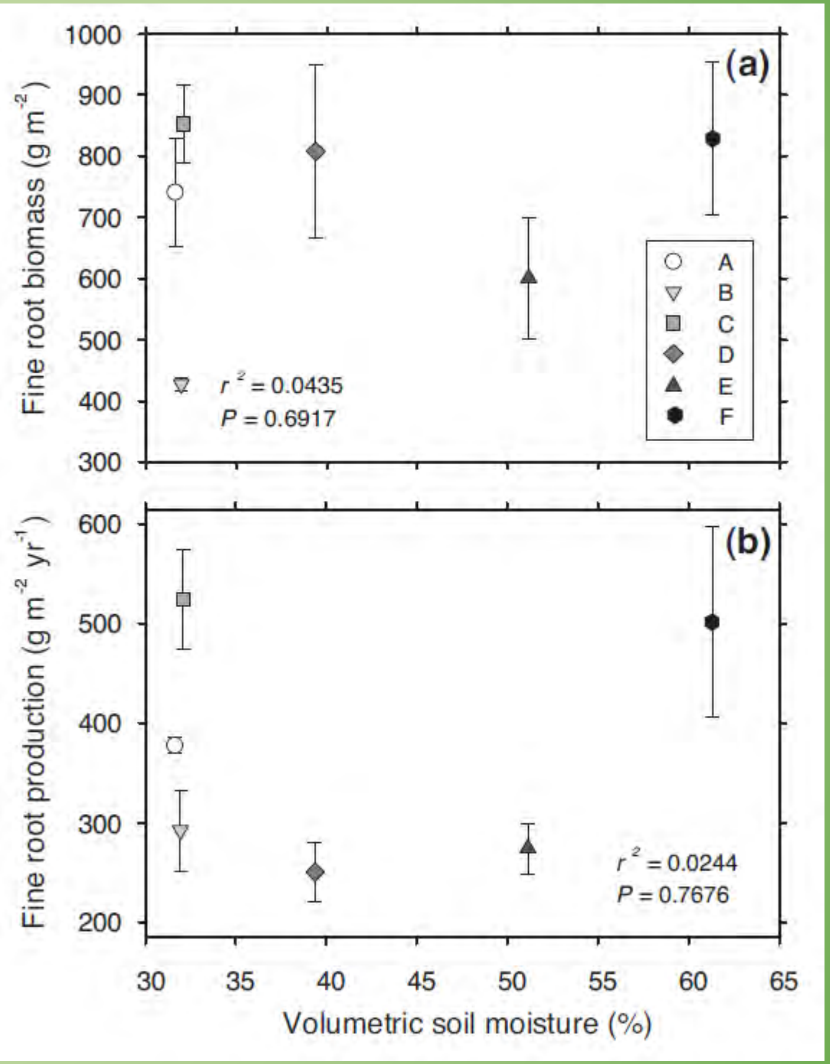
- 3 upland and 3 lowland paired study plots, over two years.

Q1: DOES CROP AND GRASSLAND PRODUCTION RESPOND DIFFERENTLY TO MARGINAL SOILS?



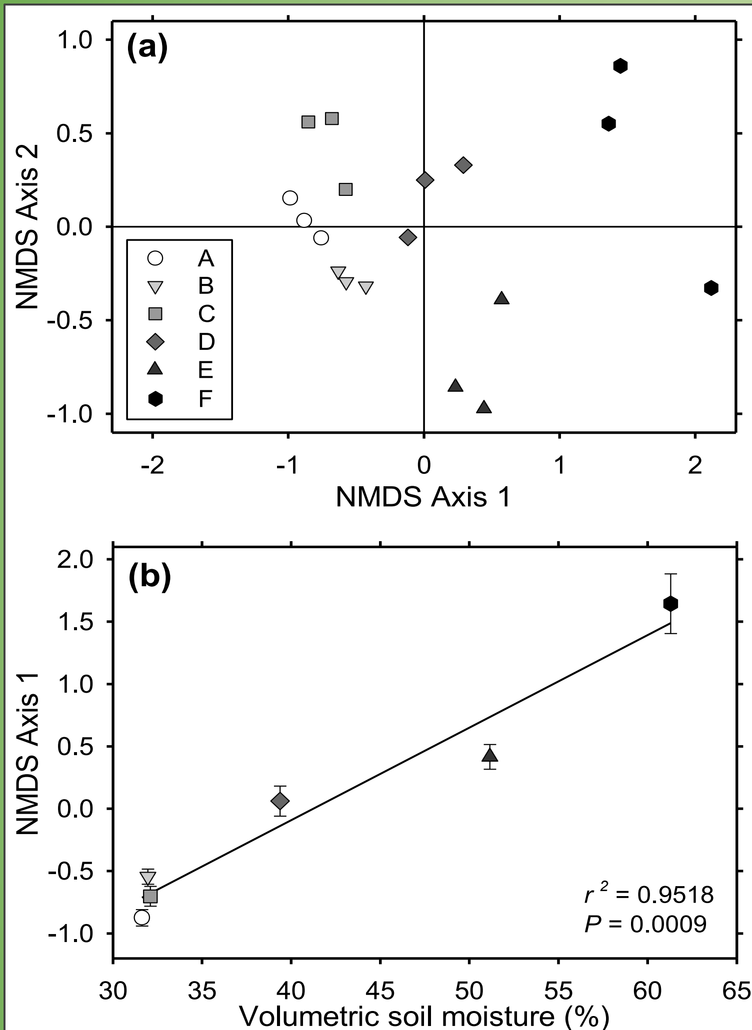
Dornbush et al. 2012
FOCUS on Energy Report

Grasslands far outperformed row crops in lowland areas.



von Haden and Dornbush 2014
Agri Eco Env

THESE GRASSLANDS WERE QUITE DIVERSE



von Haden and Dornbush 2014
Agri Eco Env

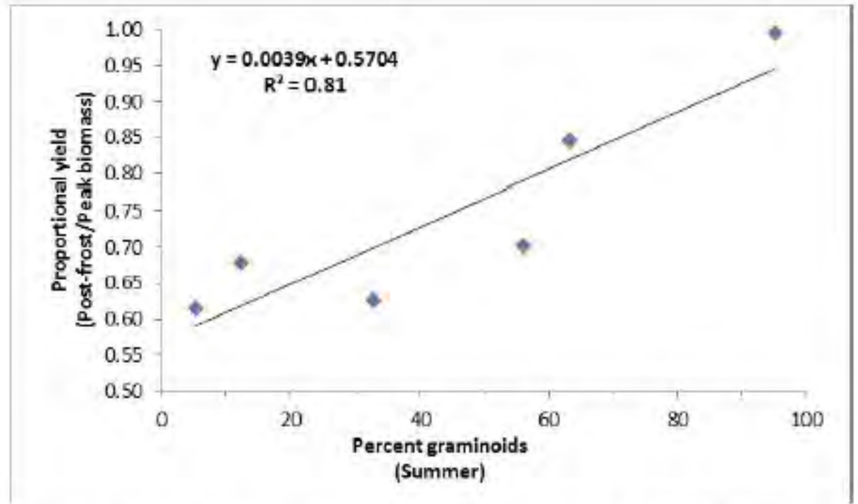


Figure 1. Relationship between proportional yield of native grassland biomass (harvests one week following the first killing frost relative to harvests at peak standing biomass) and graminoid dominance. All samples were taken in 2011.

Dornbush et al. 2012
FOCUS on Energy Report

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

HOW MUCH DIVERSITY IS ENOUGH?

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?*

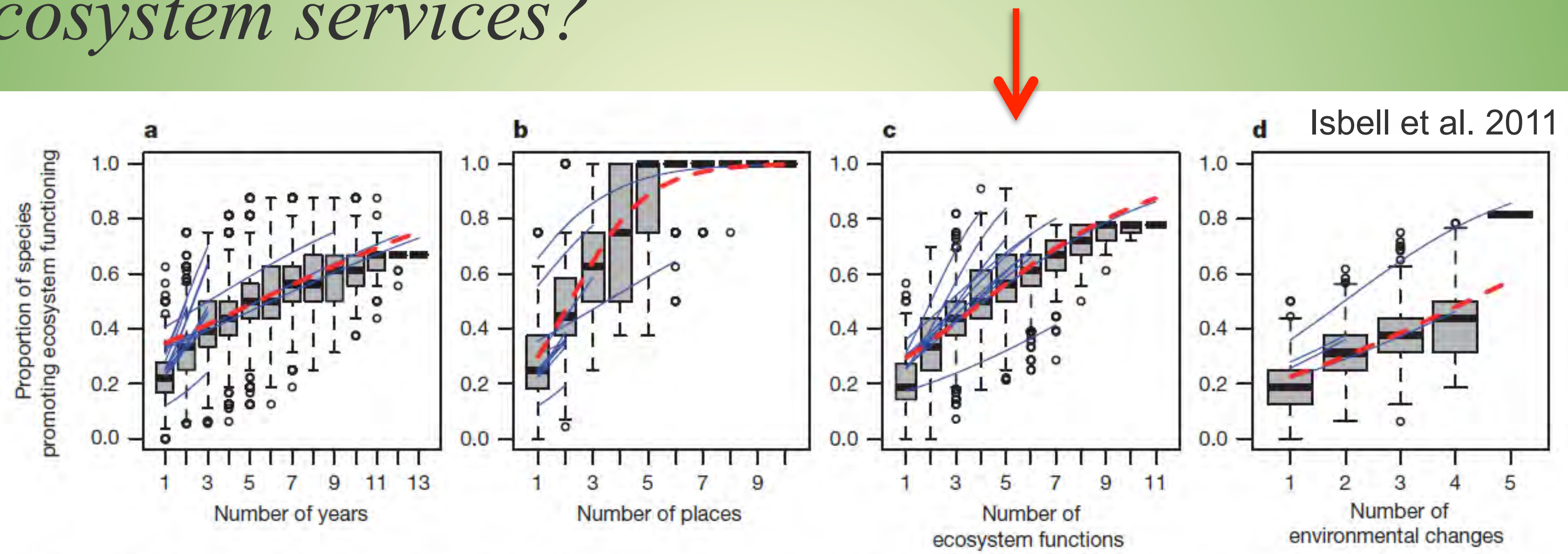


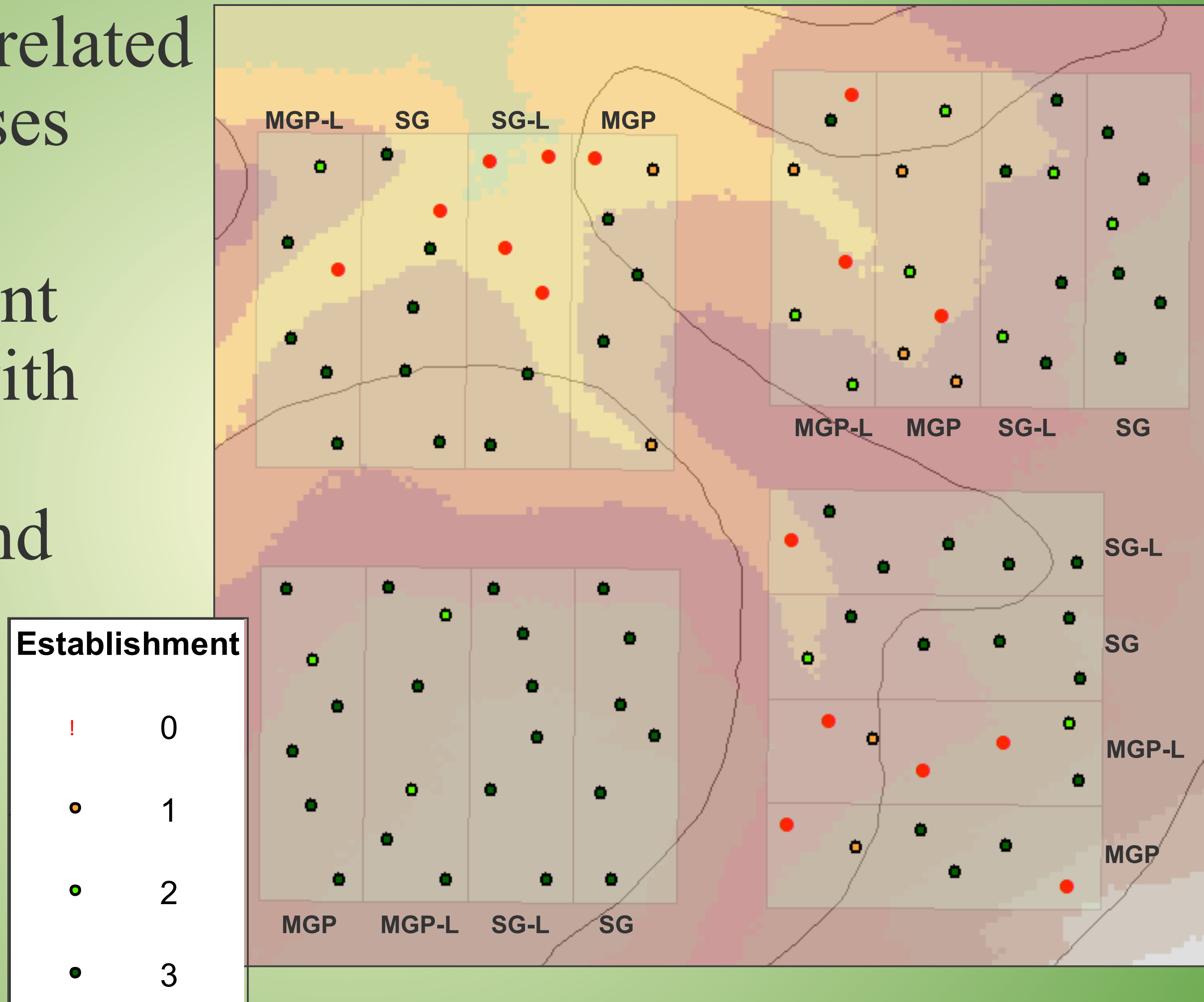
Figure 3 | The proportion of study species that promoted ecosystem functioning increased when more (a) years, (b) places, (c) ecosystem functions and (d) environmental change scenarios were independently considered. Solid blue lines indicate generalized linear model fits for each study; dashed red line 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)

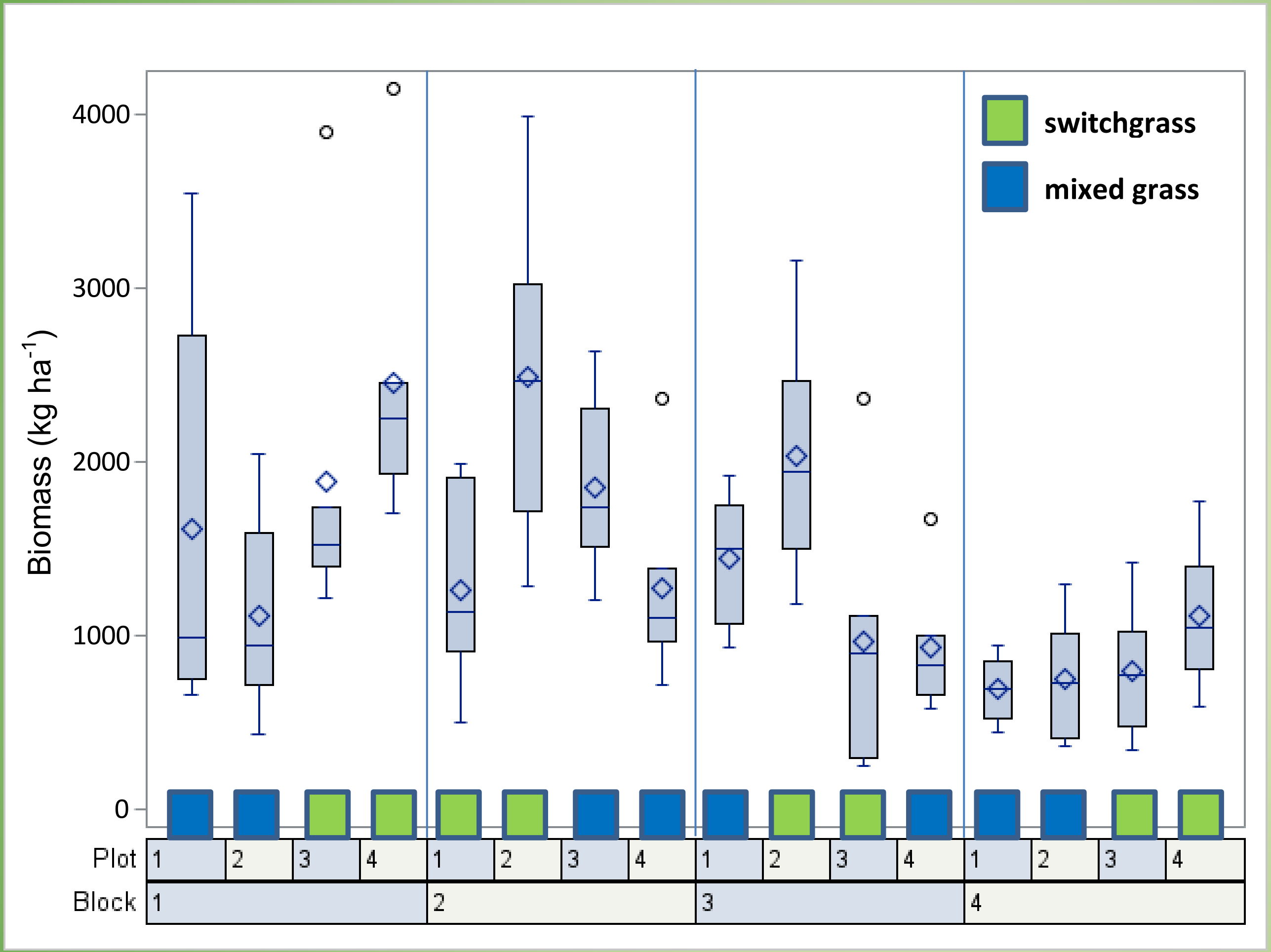
- In 2012 we established four replicated blocks at 2 farms, each with 4 experimental treatment plots.
  - Plots are 25-by-80 m (~0.5 acres)
- Four planting mixtures:
  - Switchgrass (SG)
  - Switchgrass with 4 native legumes (SG-L)
  - Mixed graminoids (MGP)
  - Mixed graminoids with 4 native legumes (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!



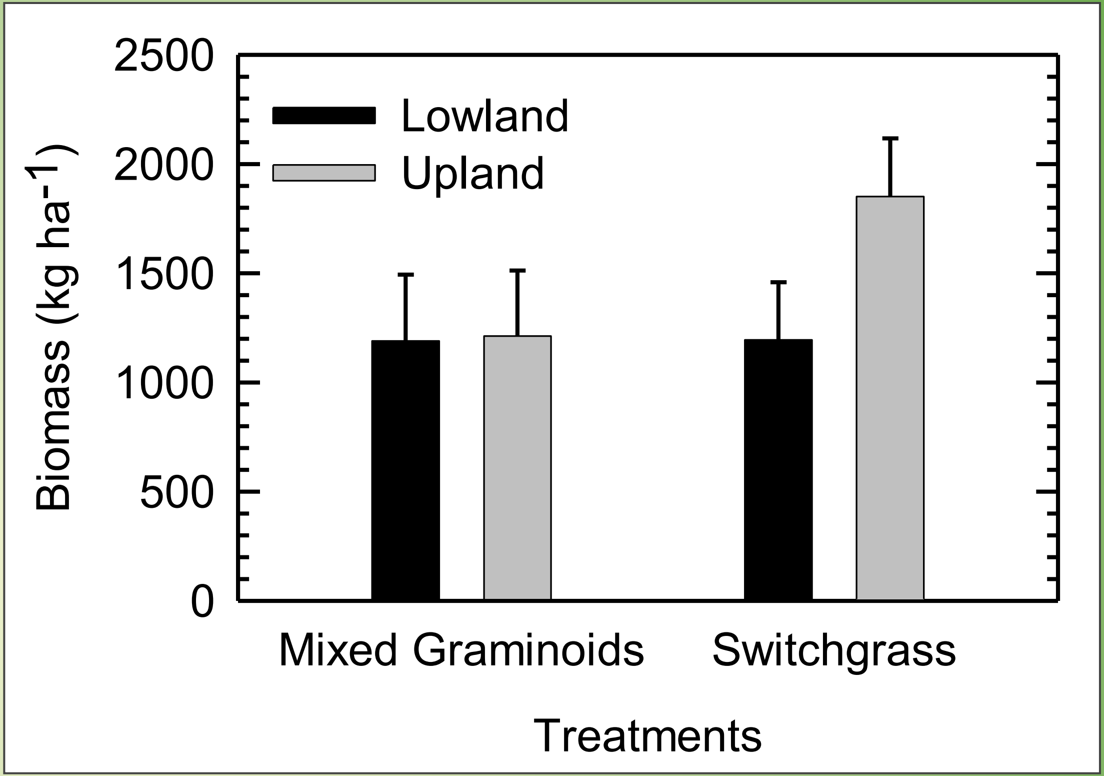
IMPLICATIONS FOR BIOMASS PRODUCTION



- 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.



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 N_2O 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 <u>lowland</u> 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

UNIVERSITY of WISCONSIN GREEN BAY

- US DOE and UWGB EMBI for current support
- WI FOCUS on Energy for previous support
- Oneida Nation: M. Arce, W. Johnson, J. Habeck, D. Vanvreede.
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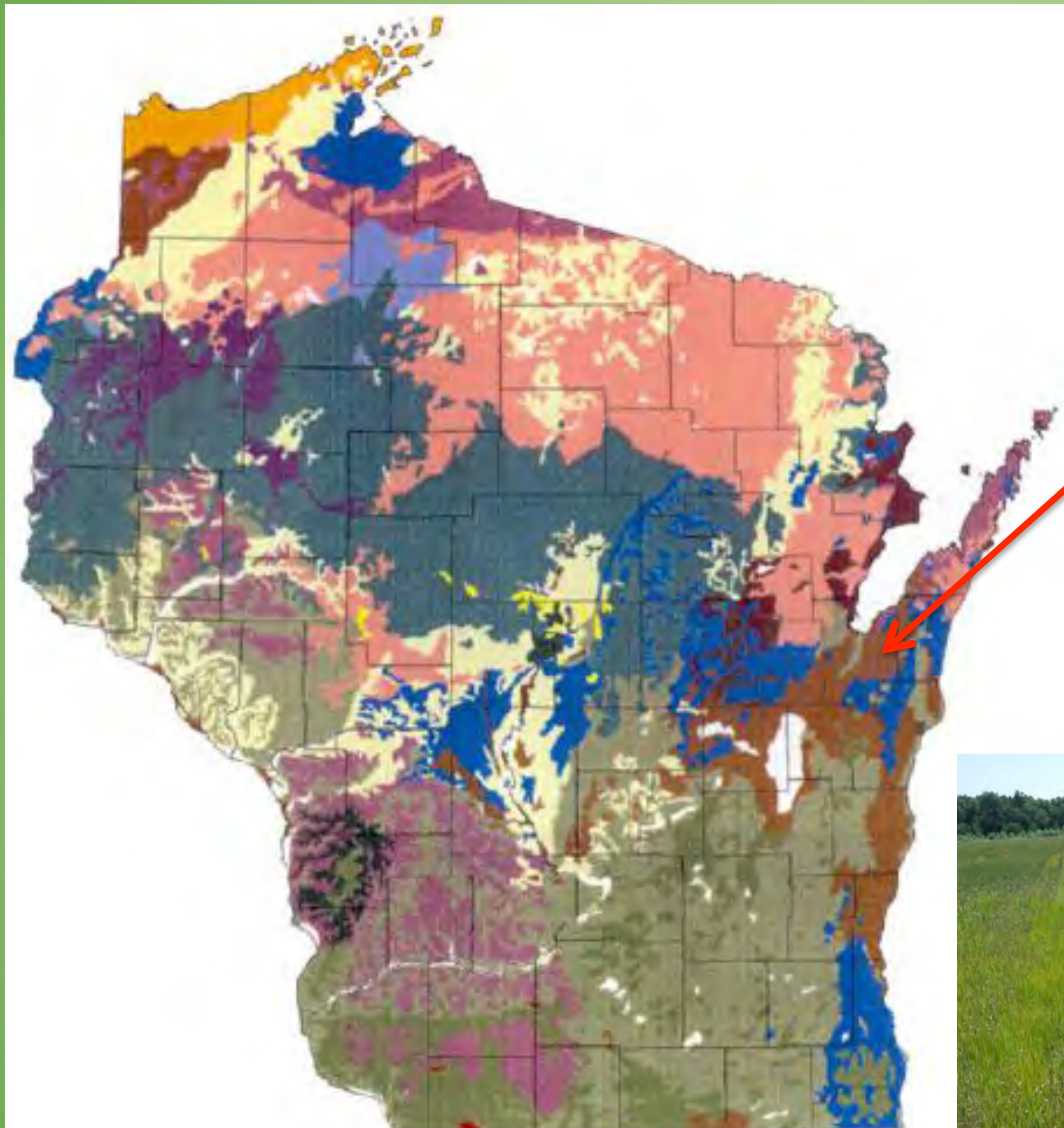
- UW-Madison: M. Renz
- UW-Green Bay: P. Baumgart, K. Fermanich, A. Rieth, J. Stoll, and A. von Haden, J. Nelson, C. Sandahl, A. LaPlant, S. Smith, & B. Kupsky, G. Holley.

RENZ ET AL.

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.

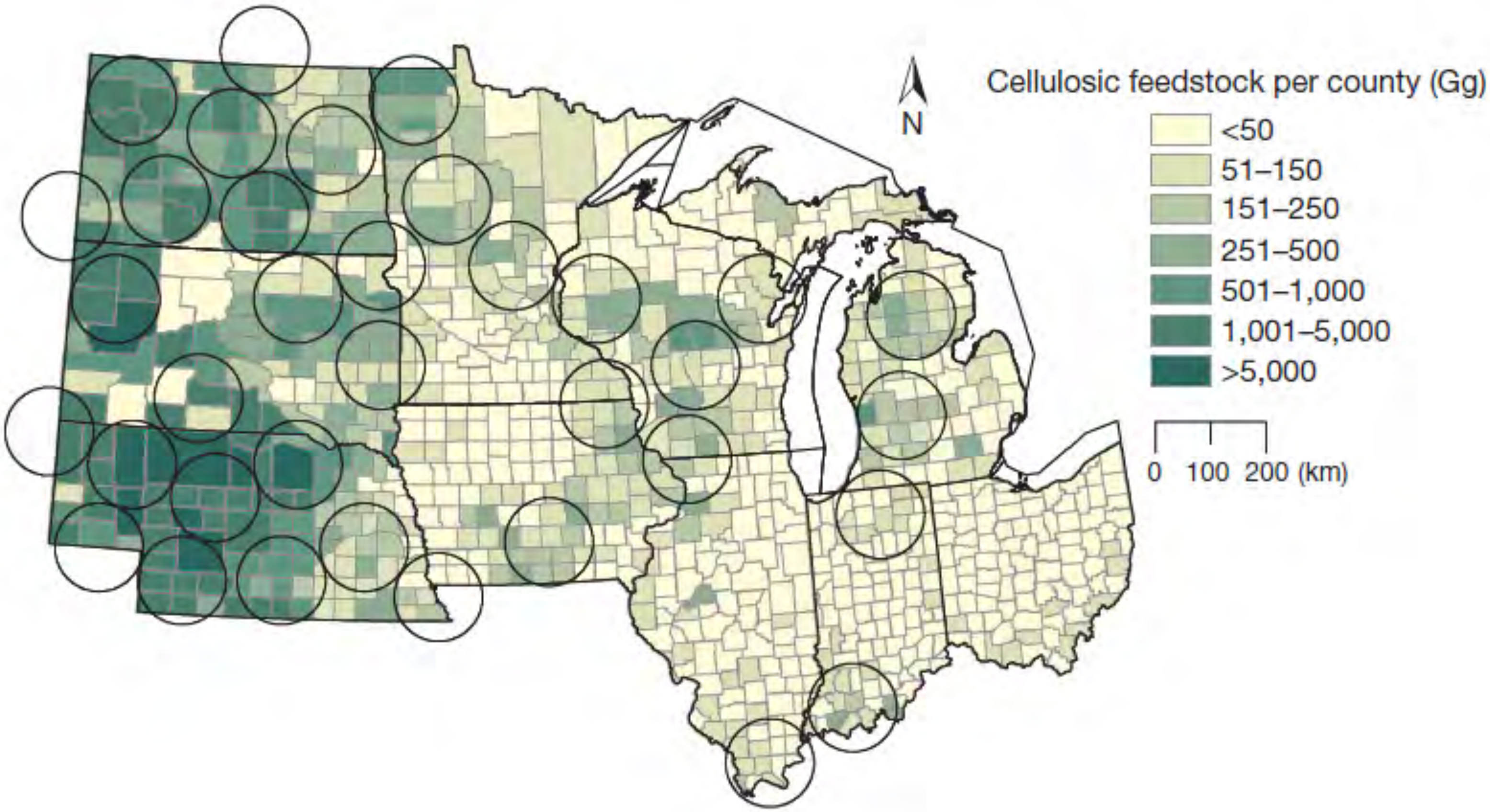
Switchgrass variety	Ames IA	DeKalb IL	Lancaster WI	Arlington WI	Marshfield WI	Spooner WI	Rosemount MN
Blackwell	3.04	4.16	4.02	3.35	4.23	4.54	5.57
Cave-in-Rock	2.56	4.37	4.54	3.54	4.45	4.39	5.57
Pathfinder	2.56	3.81	3.89	2.91	4.13	4.33	5.45
Sunburst	2.87	3.67	4.28	3.51	4.57	4.74	5.38

THE AQUOLL SUBORDER IN WISCONSIN



Grassland soil formed under seasonally wet conditions.

MANY HAVE THERE EYE ON NE WISCONSIN



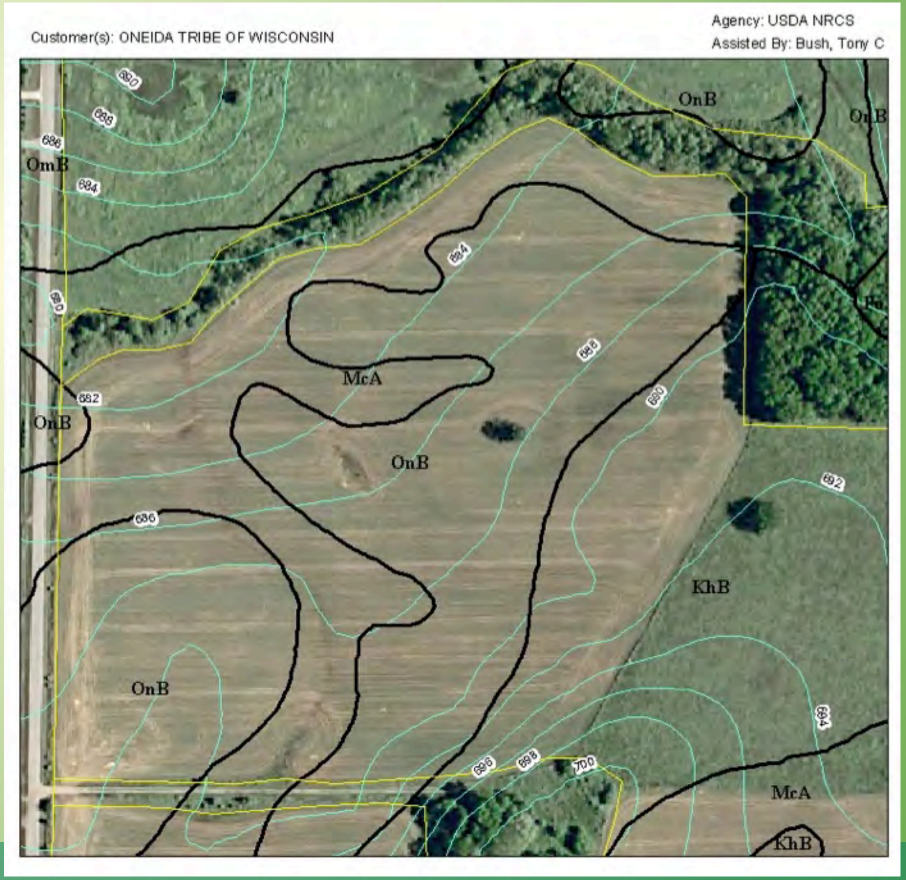
Gelfand et al. 2013 *Nature*

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

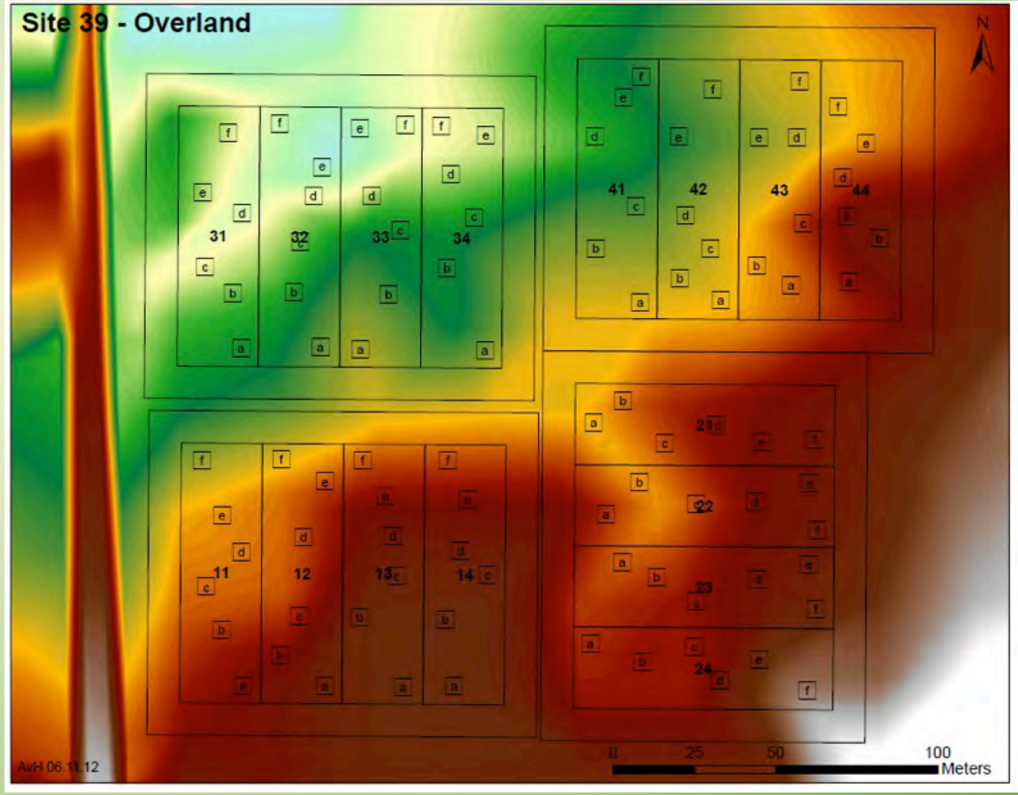


PLANTED SPECIES LIST

Graminoids	Latin Name	Legumes	Latin Name
Switchgrass	*Panicum virgatum*	Showy Tick Trefoil	*Desmodium canadense*
Indian grass	*Sorghastrum nutans*	Wild Senna	*Cassia hebecarpa*
Big bluestem	*Andropogon gerardii*	Round-headed Bush Clover	*Lespedeza capitata*
Dark green bullrush	*Scirpus atrovirens*		
Prairie Cordgrass	*Spartina pectinata*		
River bullrush	*Scirpus fluviatilis*		
Soft stemmed bullrush	*Scirpus validus*		

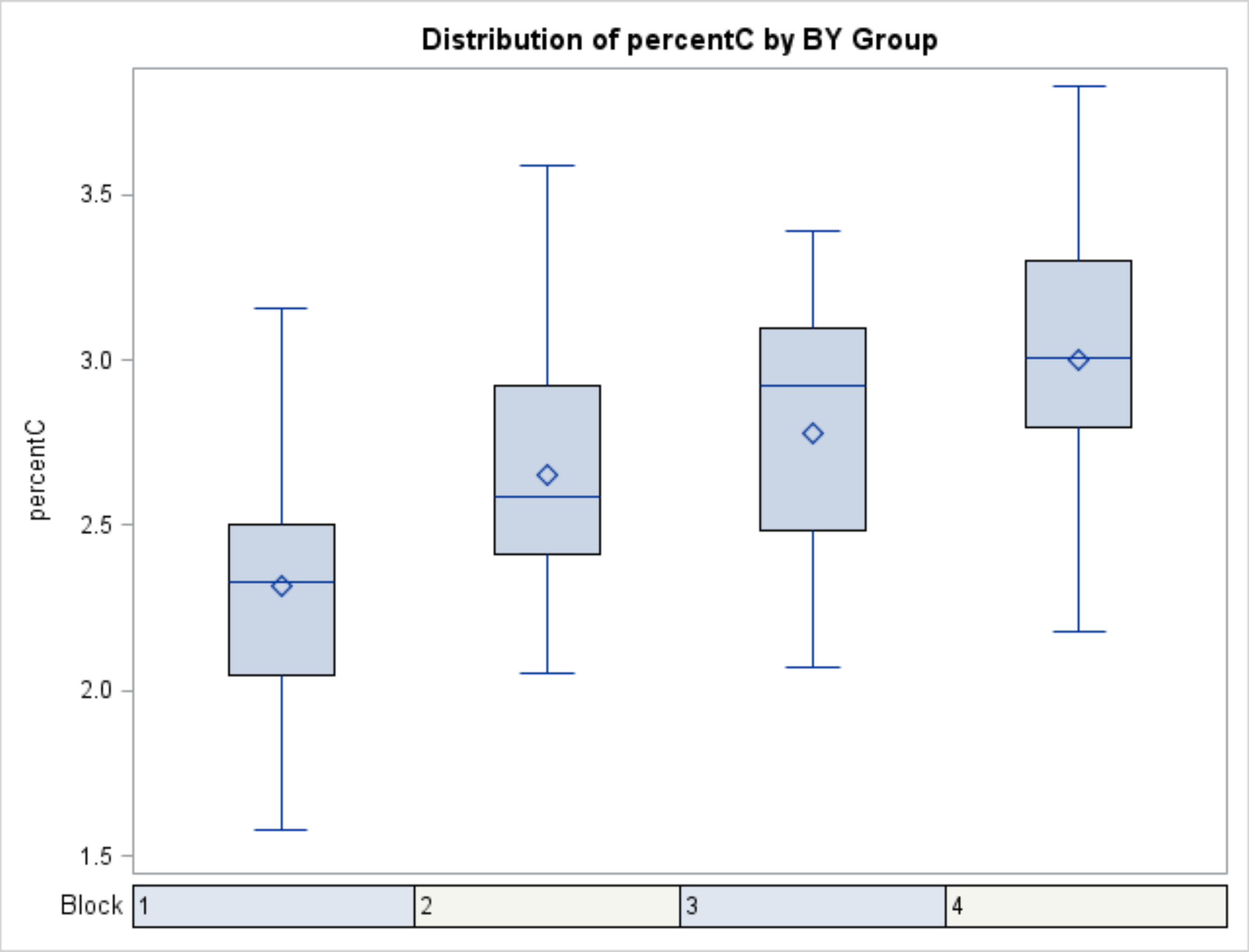
EXPERIMENTAL DESIGN

- 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)

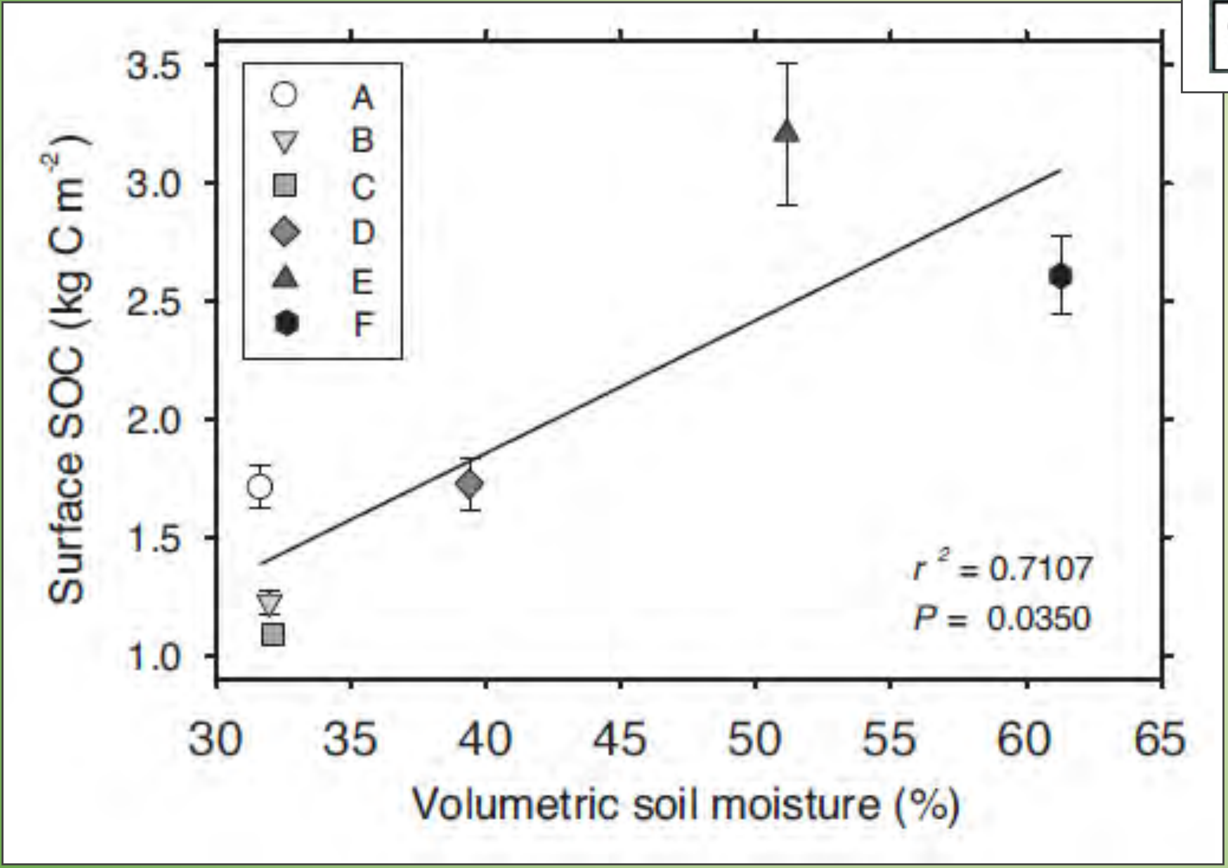


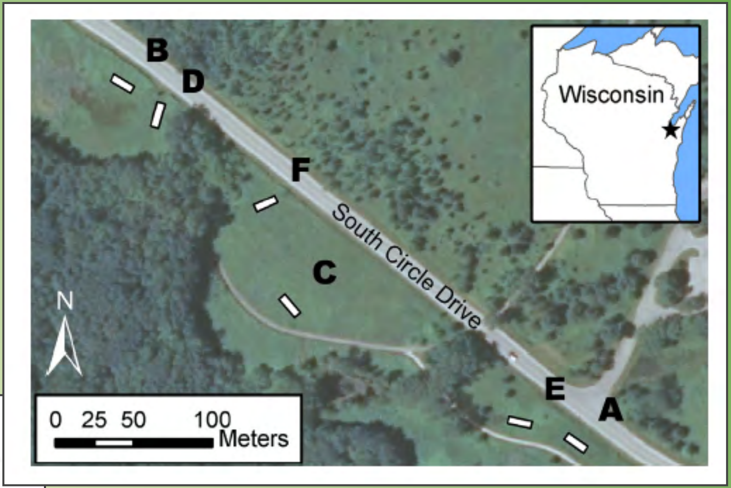
MANY LONG-TERM GOALS

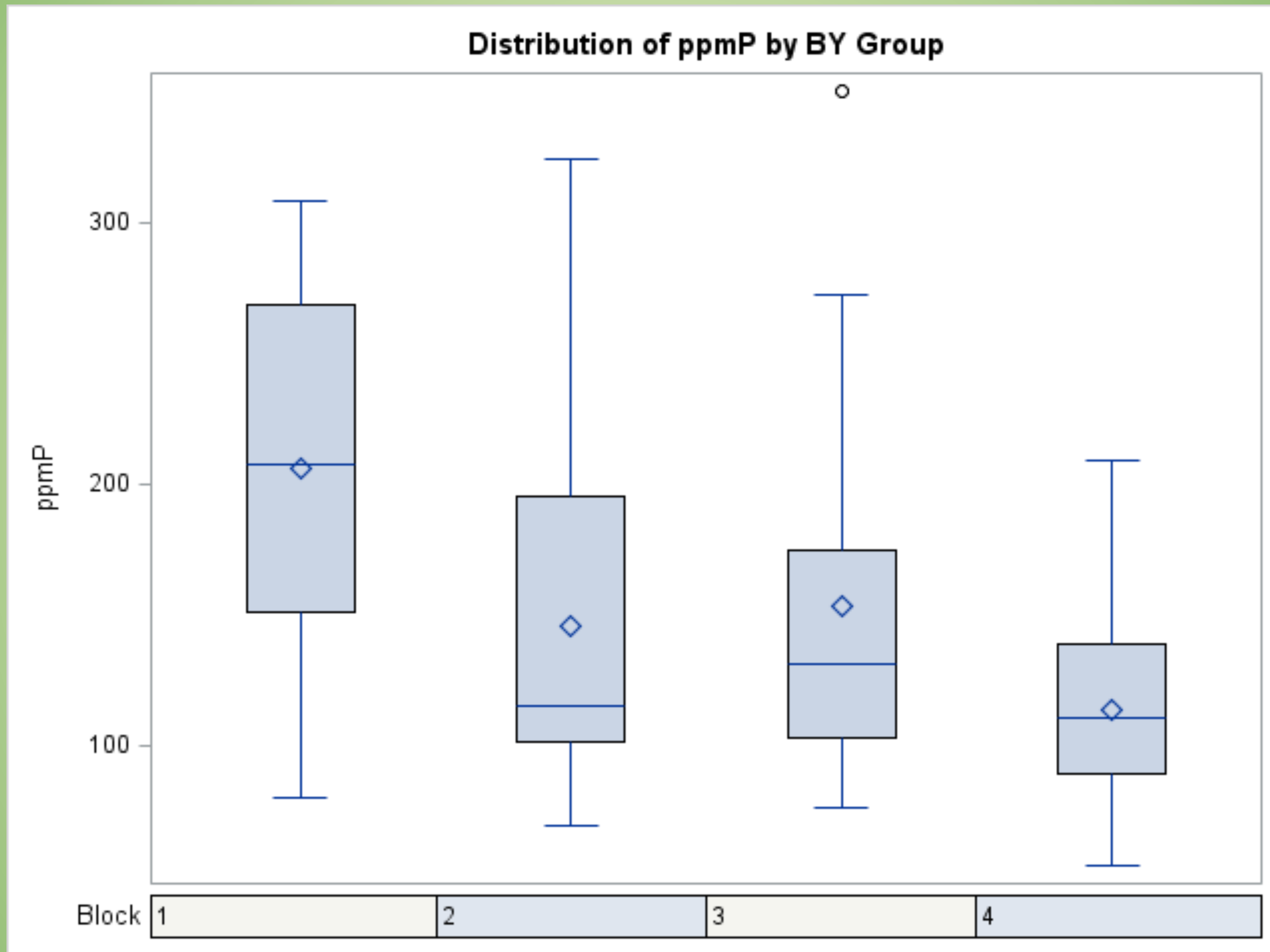
- Also established an extensive surface (0-10 cm) sampling grid (n = 864)



Distribution of percentC by BY Group
percentC
3.5
3.0
2.5
2.0
1.5
Block
1
2
3
4


Surface SOC (kg C m-2)
Volumetric soil moisture (%)
A
B
C
D
E
F
r 2 = 0.7107
P = 0.0350
3.5
3.0
2.5
2.0
1.5
1.0
30
35
40
45
50
55
60
65


B
D
F
C
E
A
South Circle Drive
Wisconsin
N
0 25 50 100
Meters



Distribution of ppmP by BY Group
300
200
100
ppmP
Block
1
2
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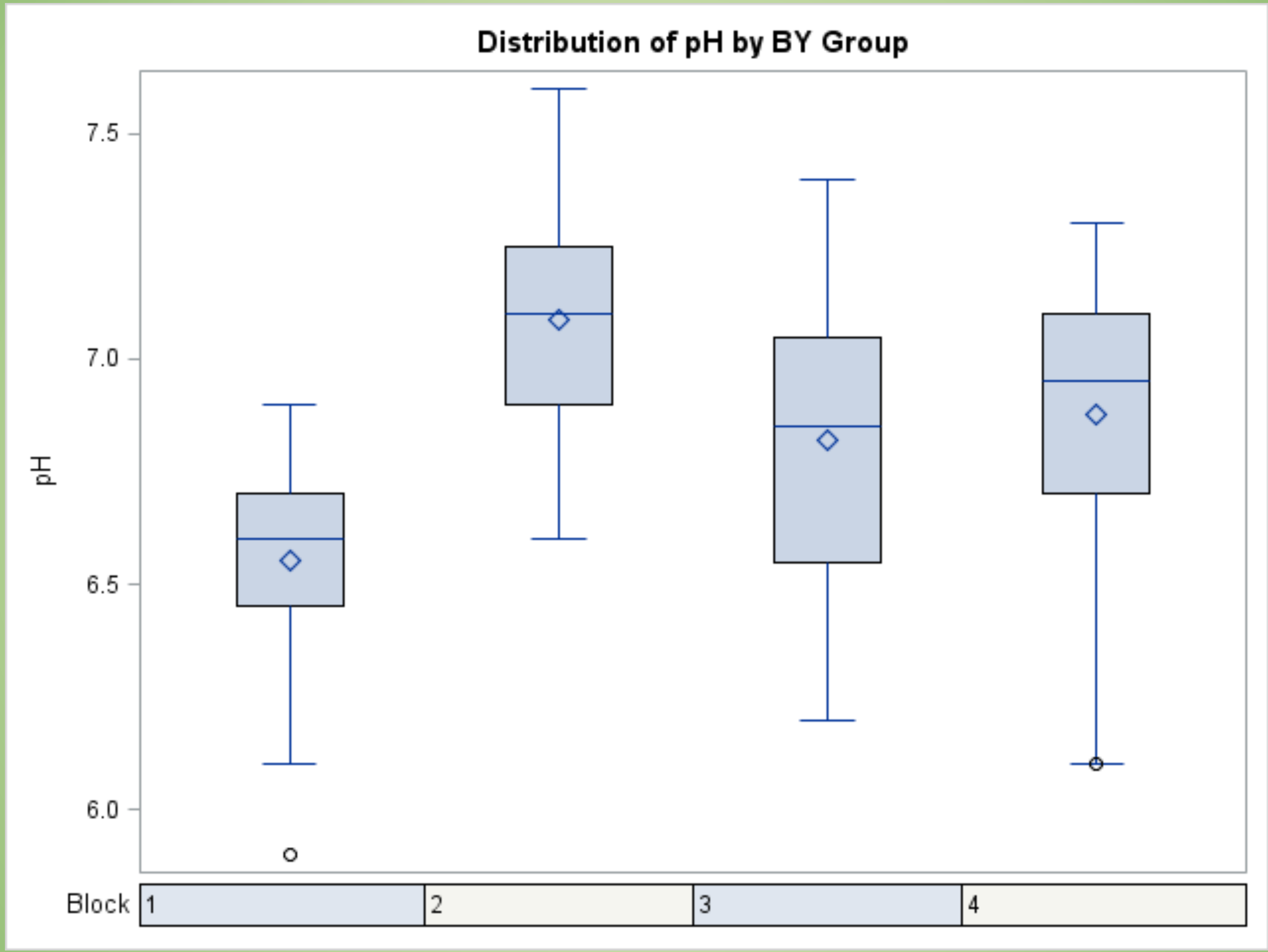
Distribution of pH by BY Group
7.5
7.0
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6.0
pH
Block
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2
3
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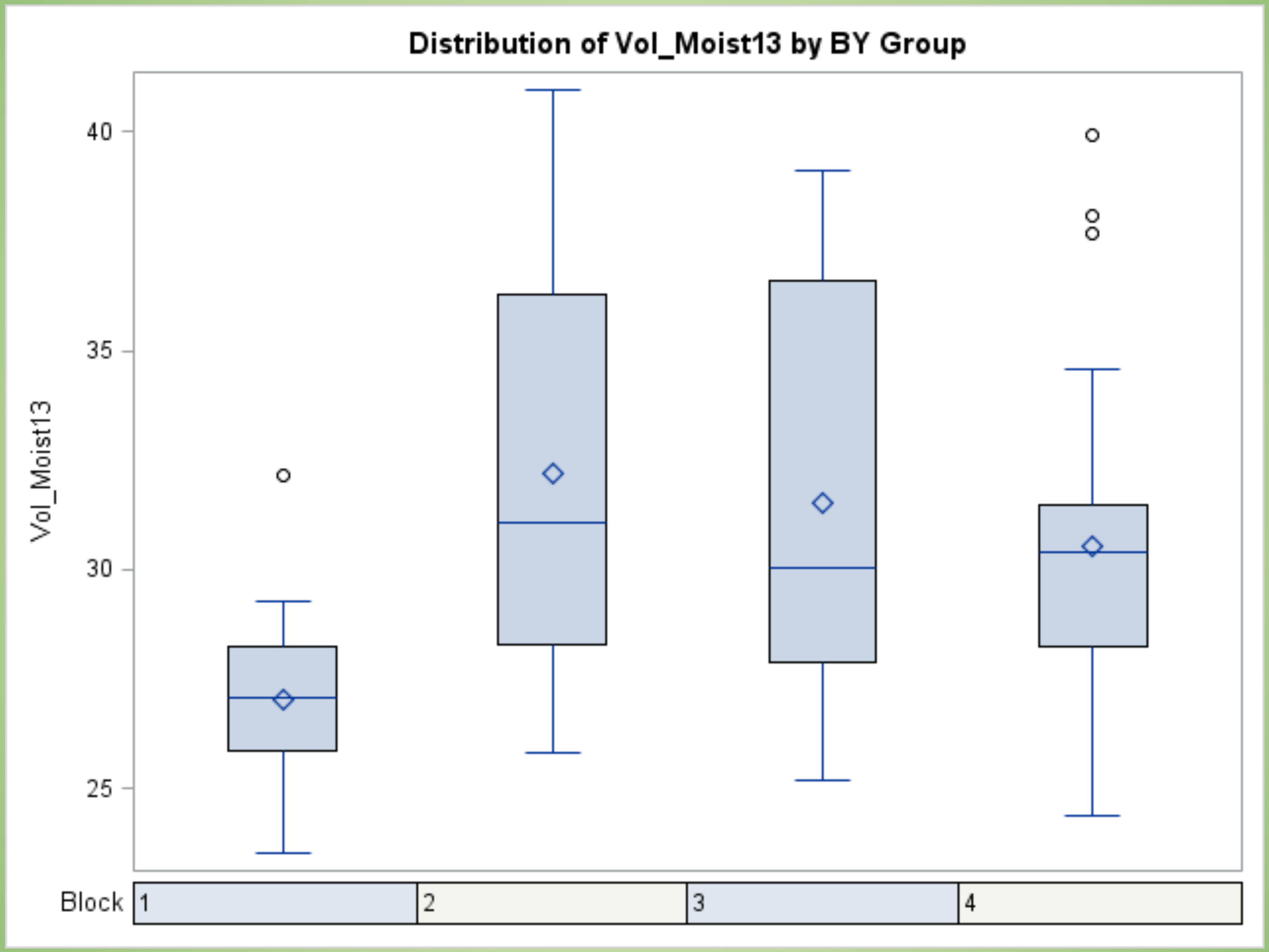
Distribution of Vol_Moist13 by BY Group
Vol_Moist13
40
35
30
25
Block
1
2
3
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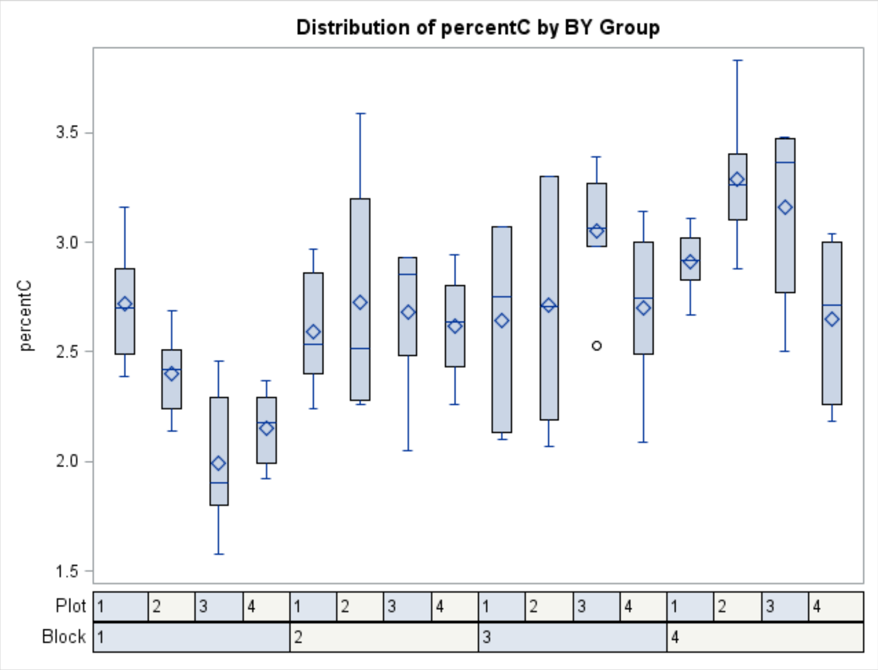
Distribution of percentC by BY Group
percentC
3.5
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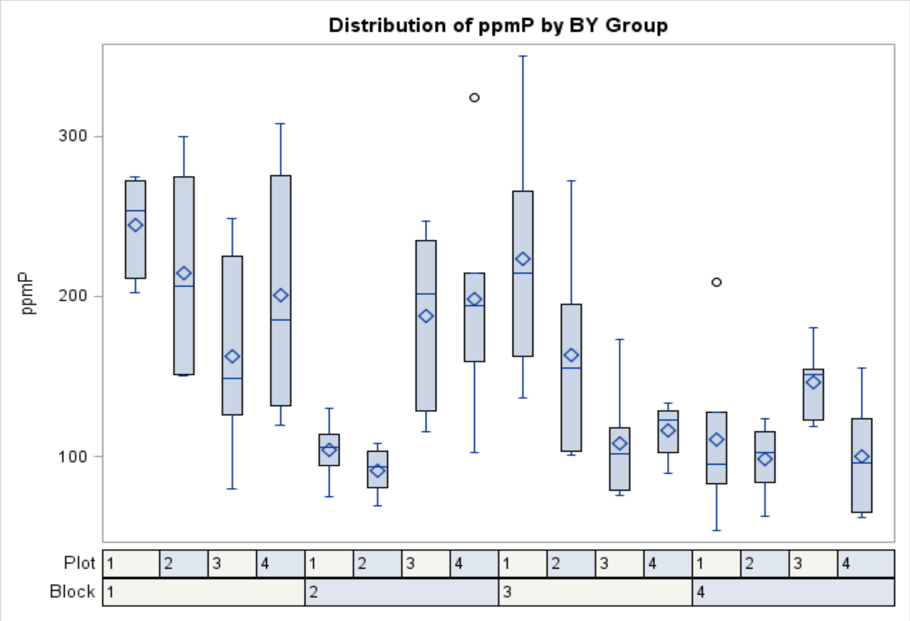
Plot 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Block 1 2 3 4


Distribution of ppmP by BY Group
ppmP
300
200
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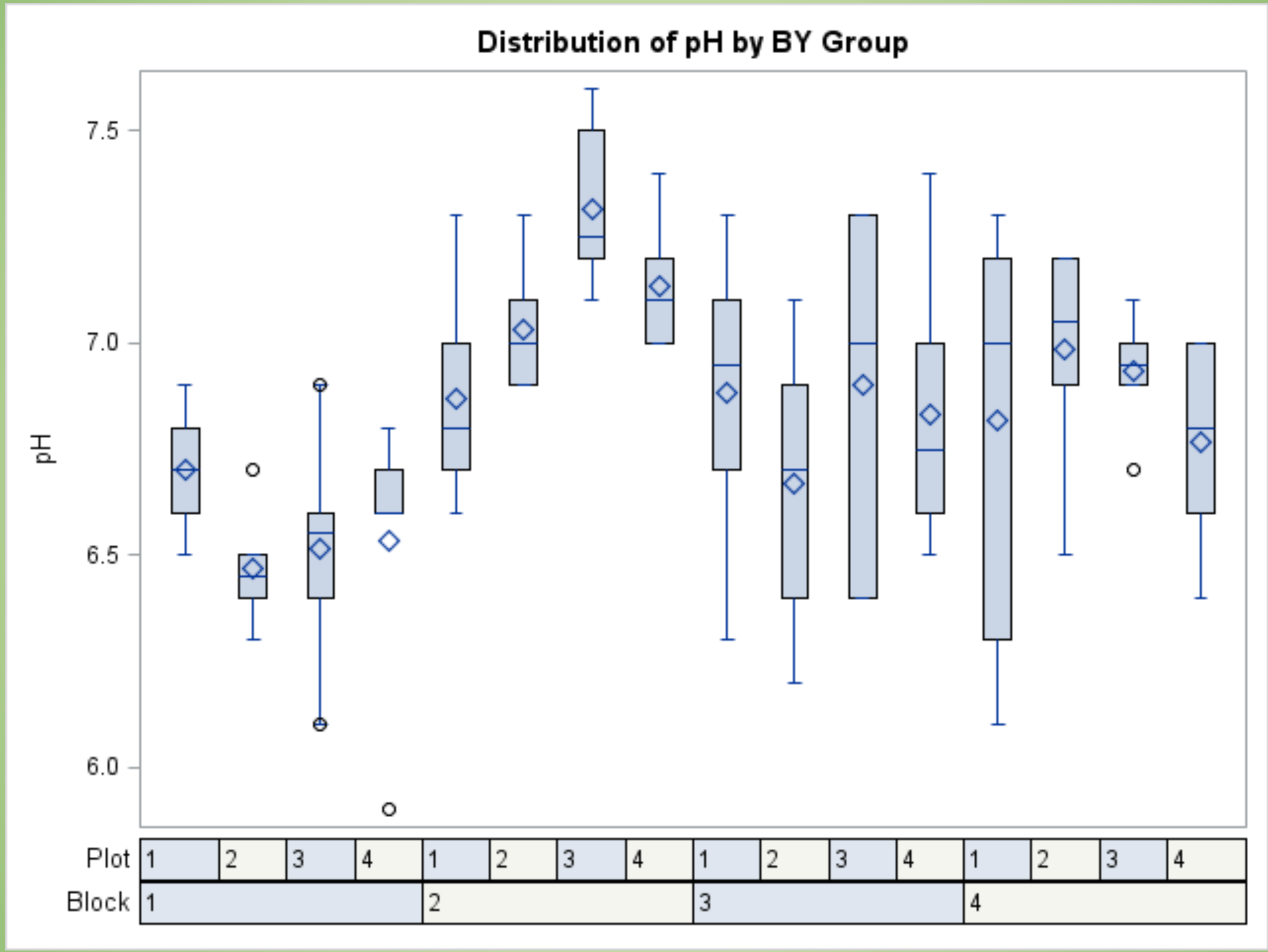
Plot 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Block 1 2 3 4



Distribution of pH by BY Group
pH
7.5
7.0
6.5
6.0
Plot
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Block
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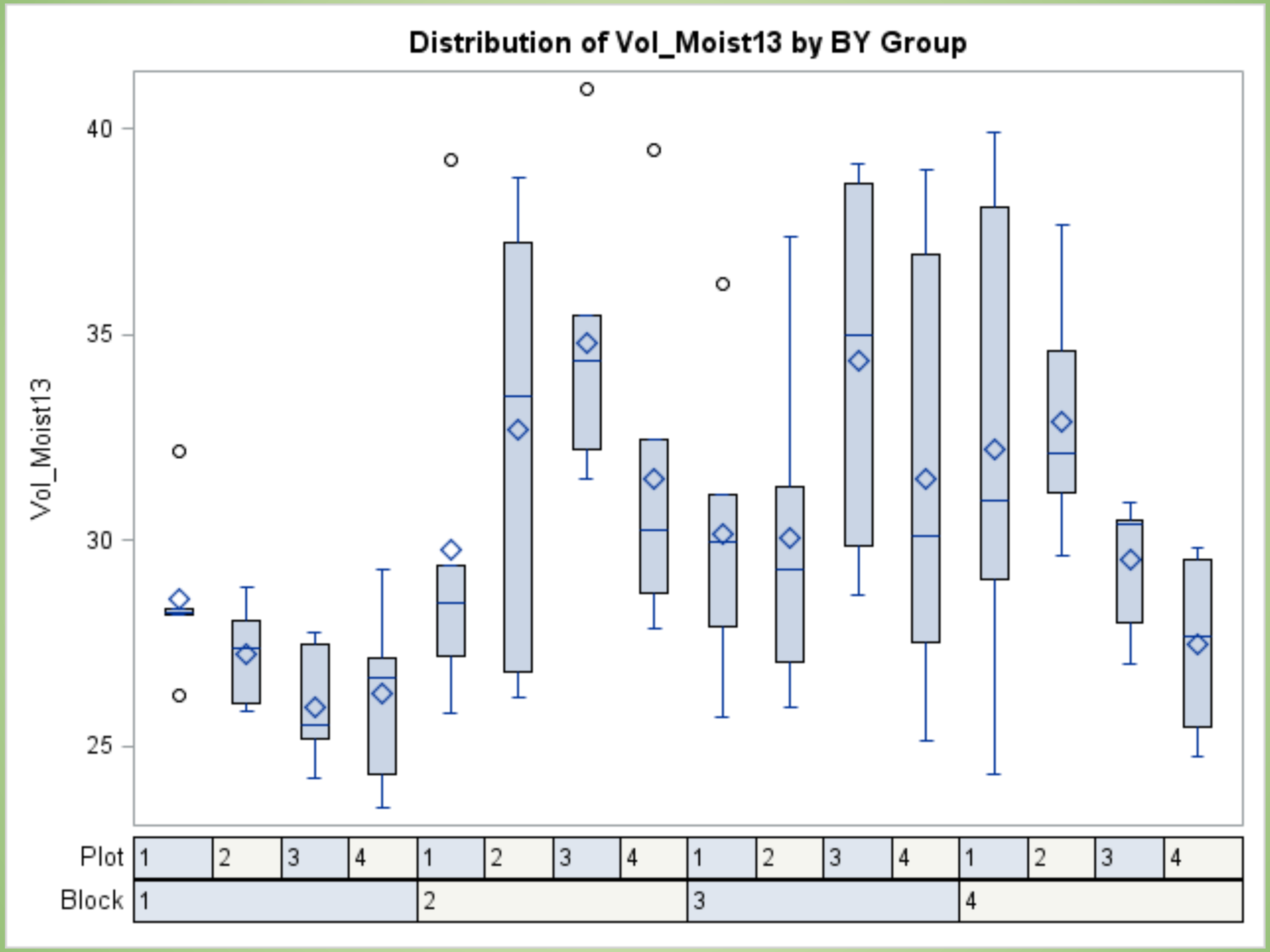
Distribution of Vol_Moist13 by BY Group
Vol_Moist13
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30
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Plot
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Block
1 2 3 4