Monitoring approaches to assess sustainability metrics at the field and watershed scale

Jeff Volenec

Sylvie Brouder

Ron Turco

Indrajeet Chaubey

Purdue University

jvolenec@purdue.edu

Goals of Today's Discussion

- What are the methods used to assess sustainability metrics?
- What are the practical approaches to measure the impacts of alternative landscapes
- What are the issues in scaling from the field to the watershed?
- How do we validate models?
- What are the research needs?

INPUTS

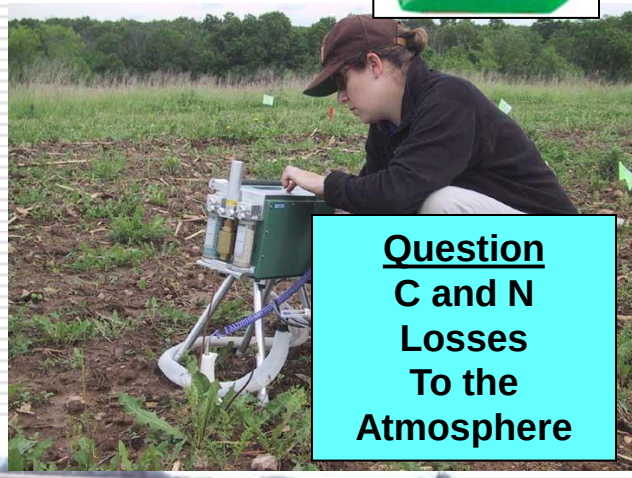
Sunlight | Water | CO_2

Soil Minerals: Fertilizers

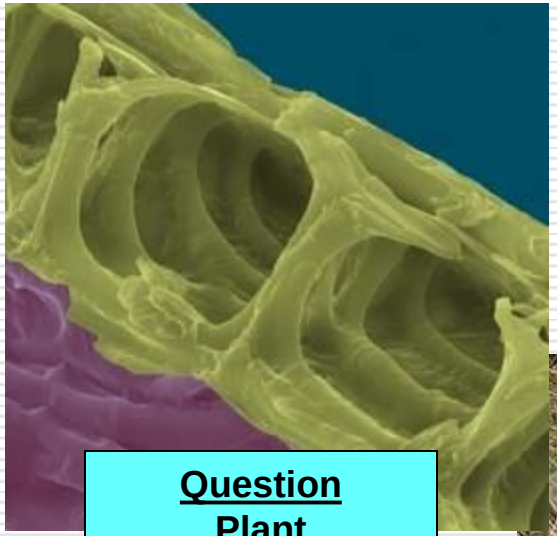
Question
Biomass Yield and Radiation and Nitrogen Use Efficiency

Question
Water Use Efficiency (kg H_20/kg biomass)

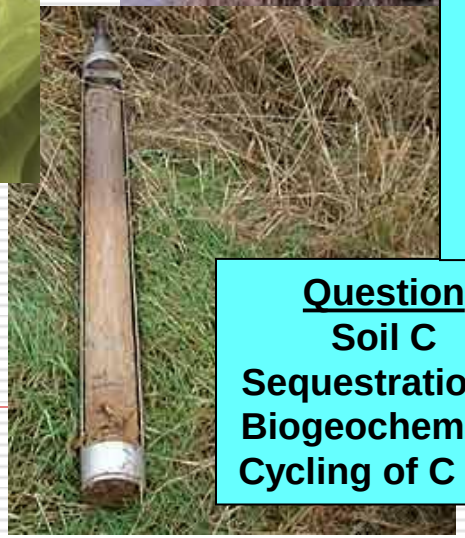
Question
Species Productivity and Persistence: Species and Genotype x Environment Interactions



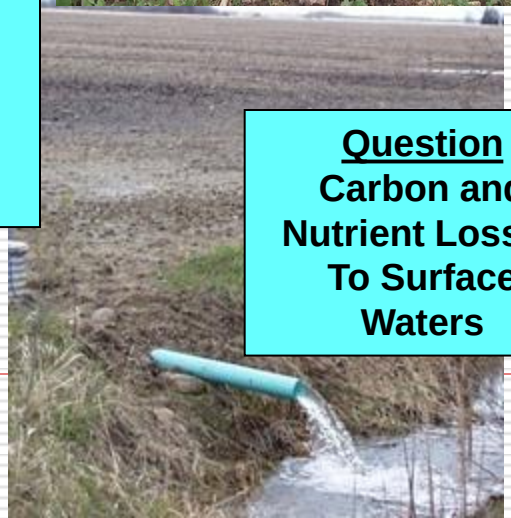
Question
C and N Losses To the Atmosphere



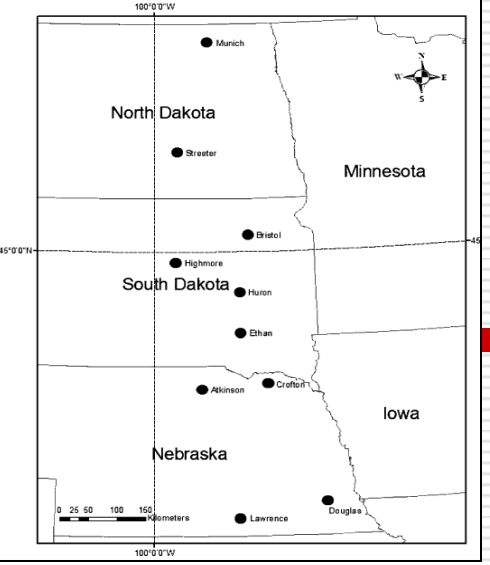
Question
Plant Composition: Effects of Species, Management, Environment, and Development



Question
Soil C Sequestration & Biogeochemical Cycling of C & N

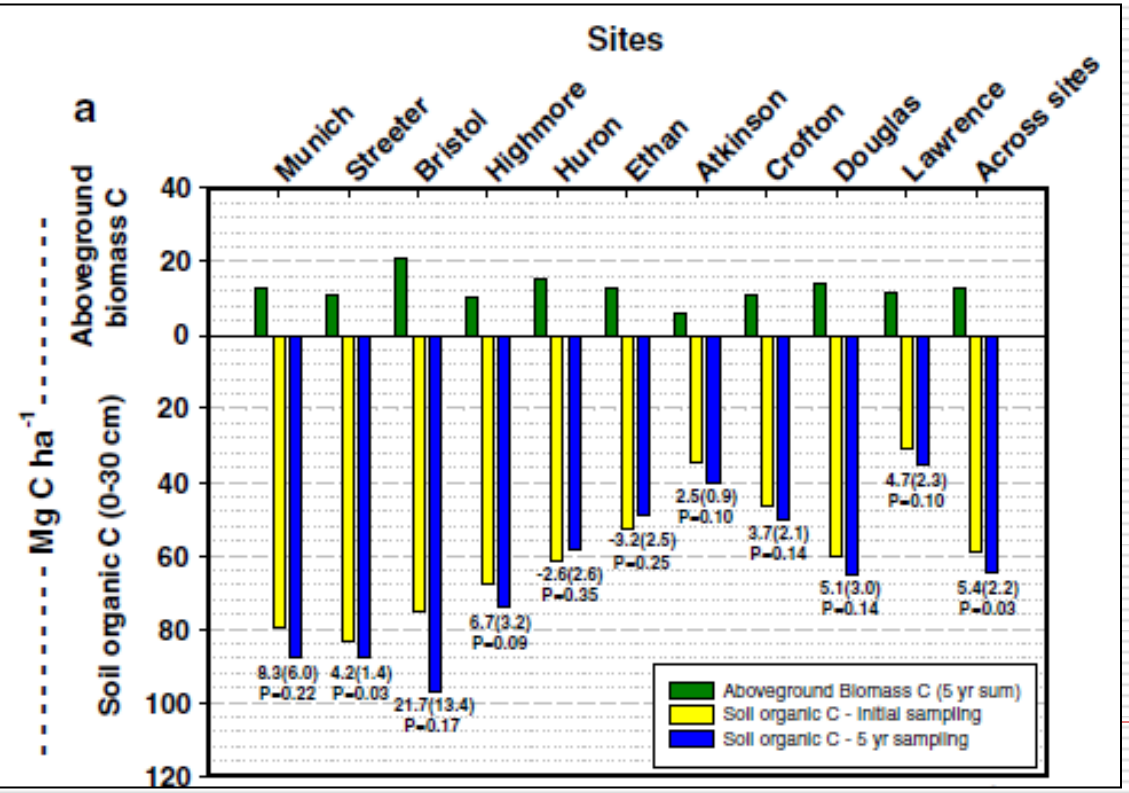


Question
Carbon and Nutrient Losses To Surface Waters



Carbon Sequestration

Biomass Crop – Previous Land Cover- N Rate – Location – Time



Liebig et al. Bioenerg. Res. 1:215. 2008.

Water Flow and Water Composition in Agro-ecosystems

Average monthly tile drain nitrate conc. by cropping system. Establishment of *Miscanthus* and switchgrass decreased nitrate concentrations to values observed in long-term mixed prairie plots within three years.

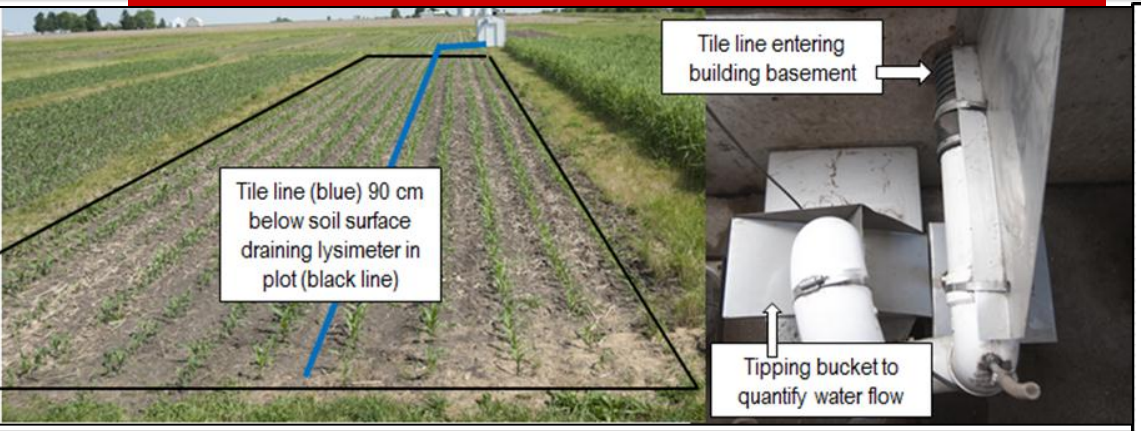
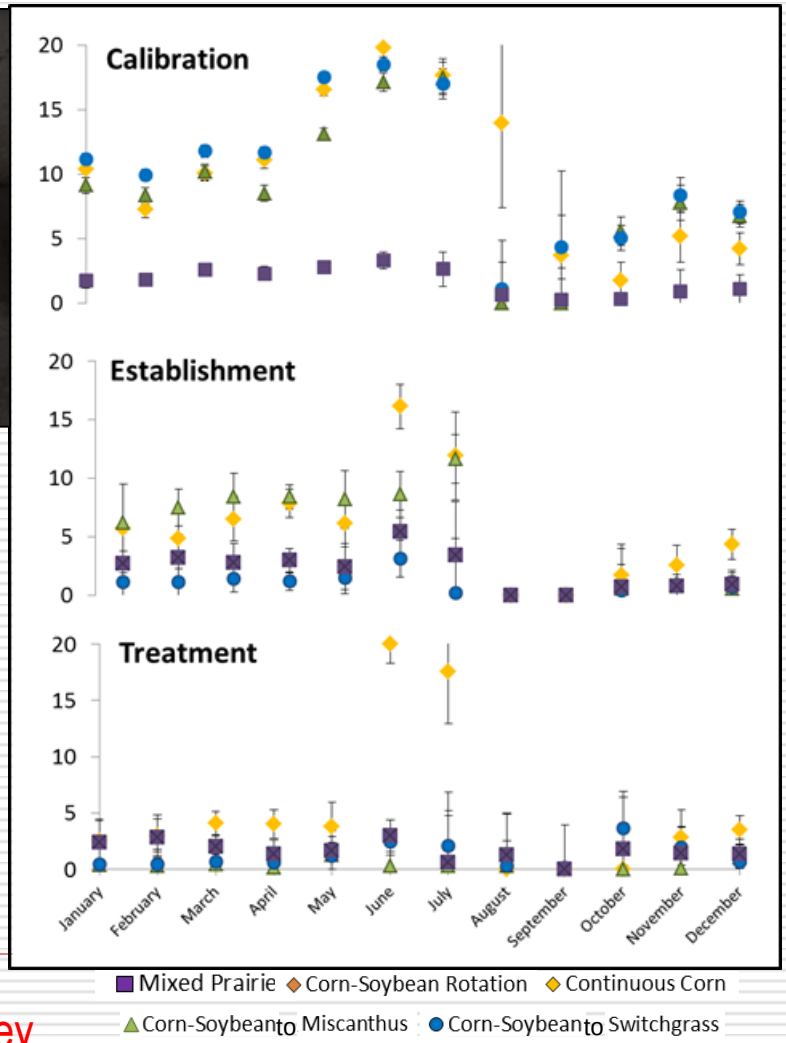
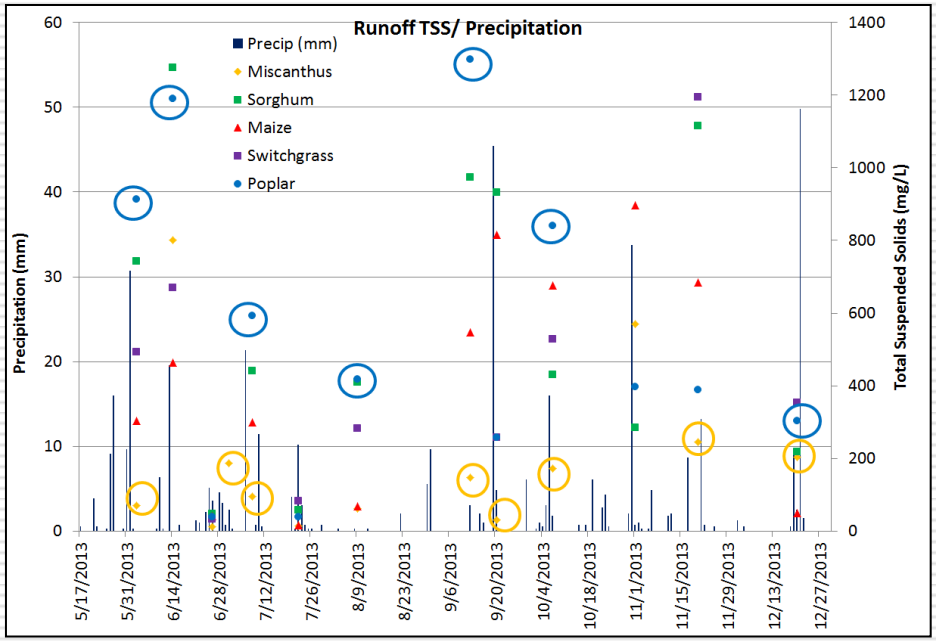


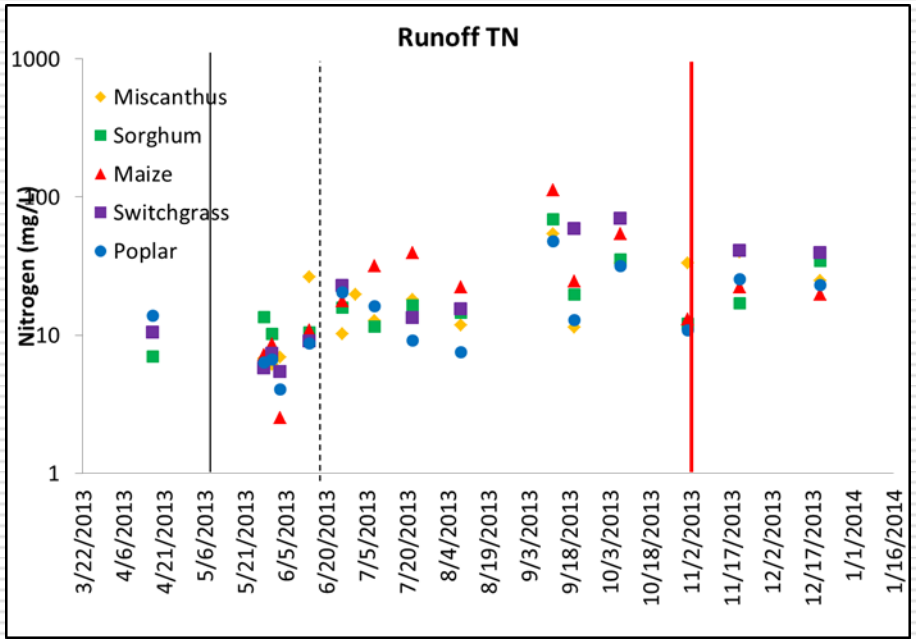
Figure 1. Photo of one of 48 plots (outlined in black) at the Water Quality Field Station (left). A 10 x 30-m lysimeter with impermeable side walls is located in the center of the plot. A 10-cm-diam tile (blue line) drains water from the lysimeter to a basement under an adjacent building. The tile enters the building basement where a calibrated tipping-bucket system is used to measure water volume and a flow-proportional sub-sample is captured for laboratory analysis (right photo).



Applies to Tiled Lands (Marginal?) – Nitrate Mass, Not Conc. Key

Soil Erosion and Nutrient Transport





Soil erosion from bioenergy cropping systems compared to maize. The data indicates a greater loss of soil following rain events from poplar, maize, and sorghum. We observed a consistently low level of erosion from *Miscanthus* and switchgrass plots.

Highly Variable: Landscape Position/Soil/ppt Intensity; Mass of N Key, Not Concentration

Concentration of total N present in run-off from bioenergy cropping systems and maize (control). The vertical lines identify when maize/sorghum were planted (black), N fertilizer was applied (dashed) and harvested (red).

Input Use Efficiency/Nitrogen: Required for High Yield, But NUE Declines With N Fertilizer Application

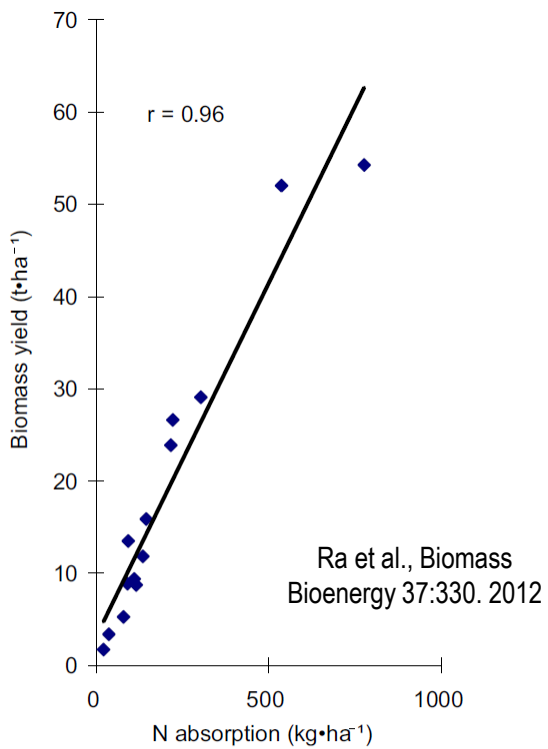
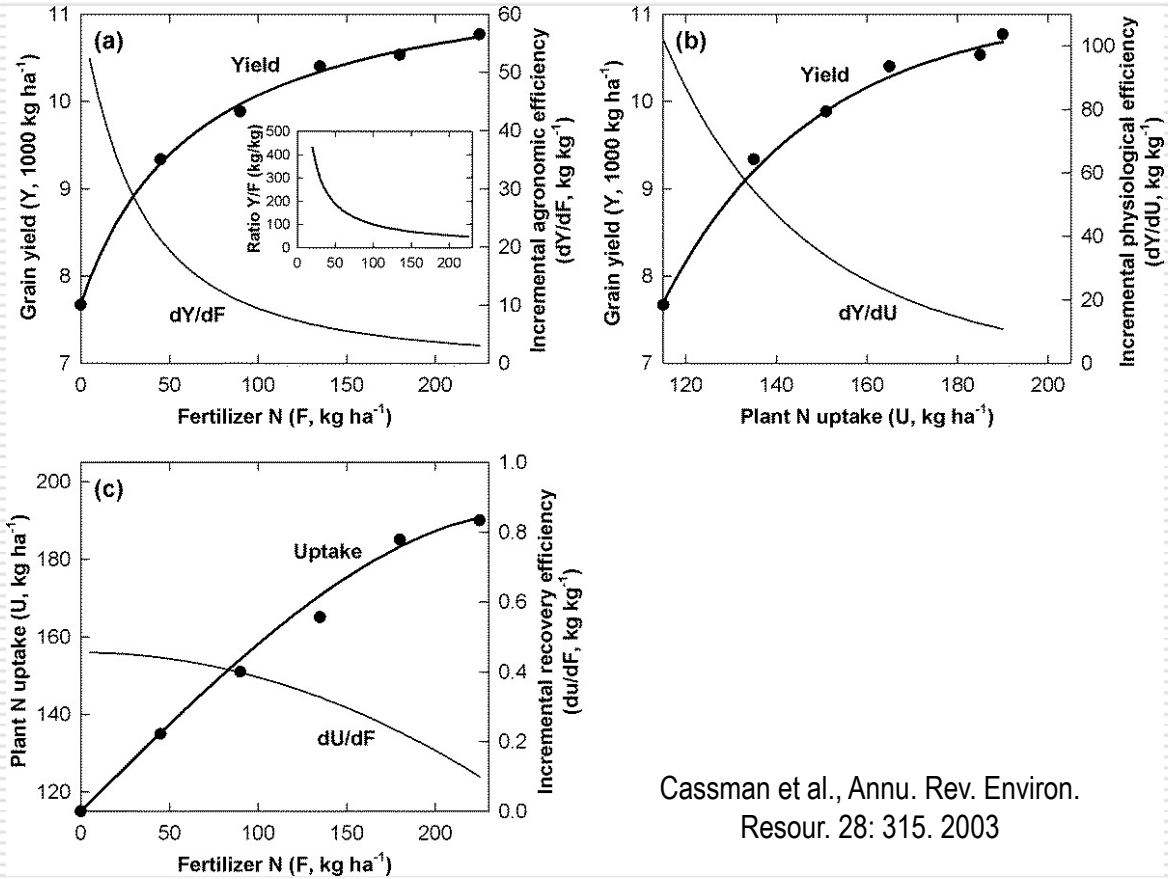


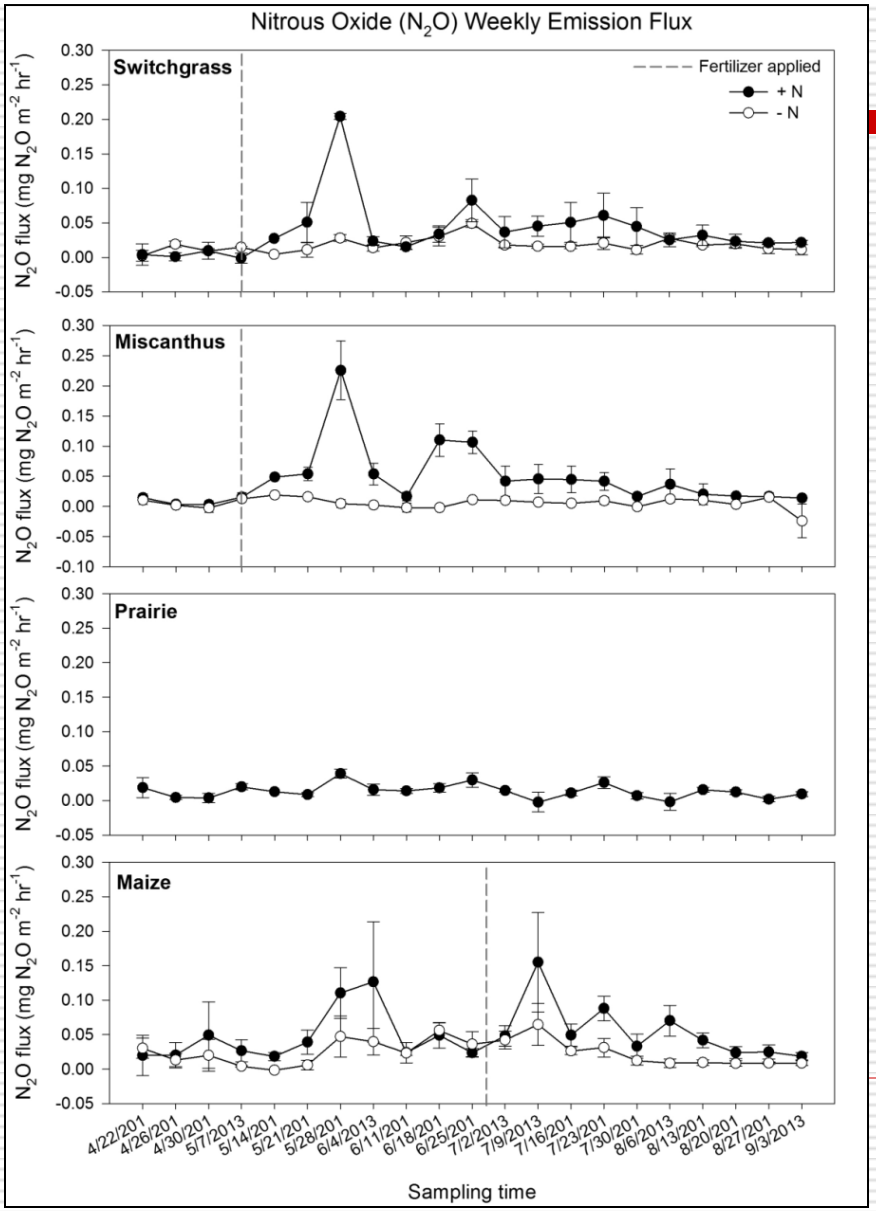
Fig. 1 – Biomass yield showed a significant positive correlation (at the 1% level) with N absorption for cellulosic energy crops.



Cassman et al., Annu. Rev. Environ. Resour. 28: 315. 2003

Intensive N Management - High NUE Varieties – Sustainable Intensification of Biomass Production (different metrics, e.g., biomass/unit GHG)

Greenhouse Gas Emissions



System*	N Fertilizer, kg/ha	NO_2 mg/h/m^2	CH_4 mg/h/m^2	CO_2 mg/h/m^2
Maize	160	0.151	0.011	278
Unmanaged Prairie	0	0.007	0	471
Switchgrass	50	0	0.0003	498
Miscanthus	50	0.009	0	284
DP Sorghum	160	0.068	0	261

Although the GRACEnet chamber system is widely used, estimating seasonal GHG release based on weekly point measurements is far from ideal; We can rank trts.

Genotype x Environment x Mgmt Interactions Complicate Yield (kg/ha) Predictions From Field-to-Landscape

Very Low Yield-No N Response

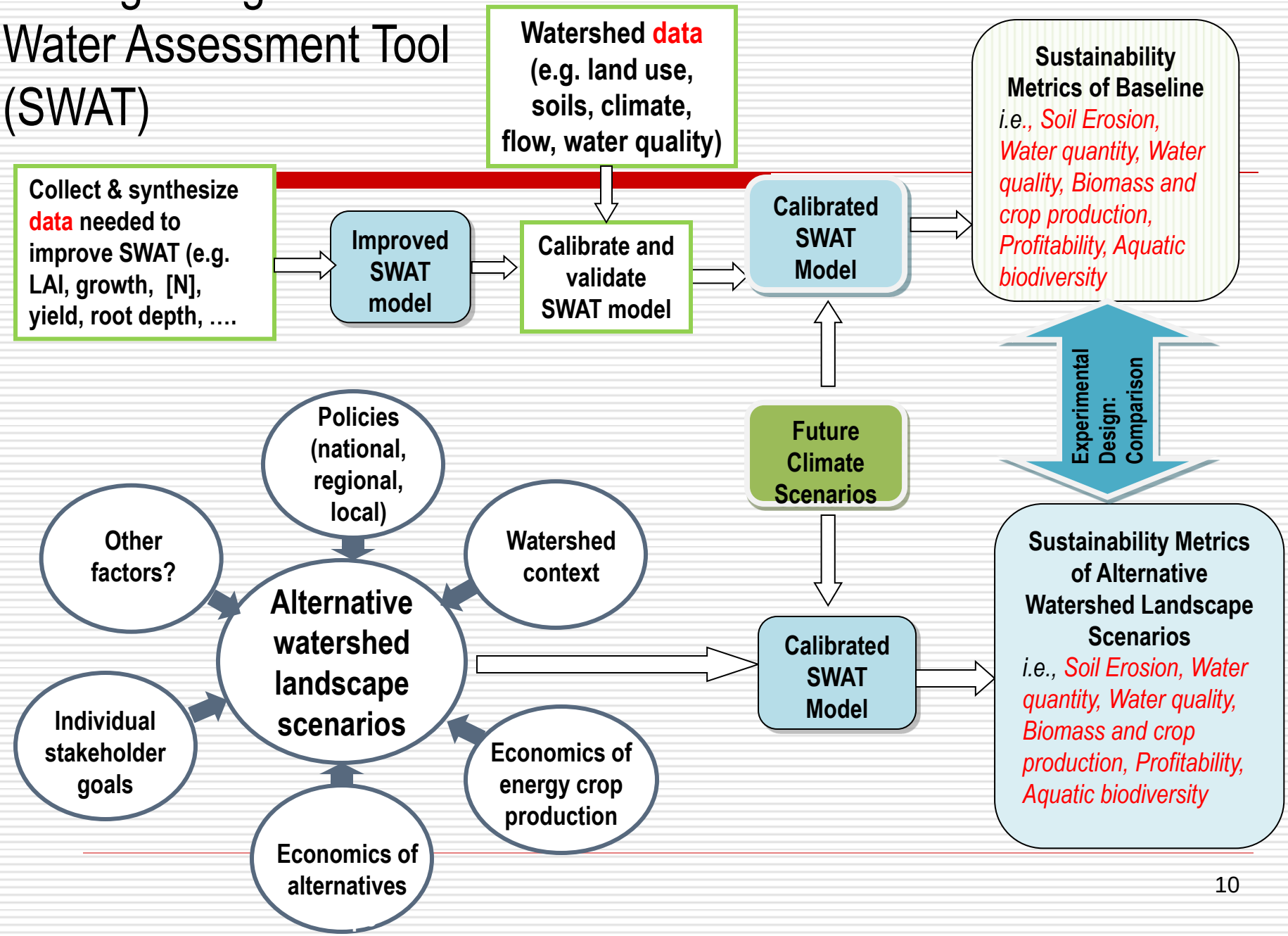
Biomass Species	N Fertilizer kg/ha	Location 1 SEPAC	Location 2 NEPAC	Location 3 TPAC
Maize (Well-studied Agro-ecosystem)	0	700	3361	11479
	50	173	4792	14063
	100	1548	2804	15705
	150	110	9544	14581
	200	195	8053	16896
Photoperiod-sensitive Sorghum (Understudied Biomass System)	0	9501	2746	23100
	50	8934	6702	22253
	100	10143	7468	23861
	150	12695	8974	23827
	200	14593	13081	23519

High Yield ~50% Increase Due To N

Very High Yield-No N Response

Need to understand the biophysical basis for the GxExM; Plants are an important piece of the environmental impacts

Scaling Using the Soil Water Assessment Tool (SWAT)



Single-HRU watershed outlet values for single-crop scenarios using revised SWAT code for *Miscanthus* and Shawnee switchgrass (SG). Corn and Alamo SG simulations used default crop growth database parameter values (from Trybula et al., 2014).

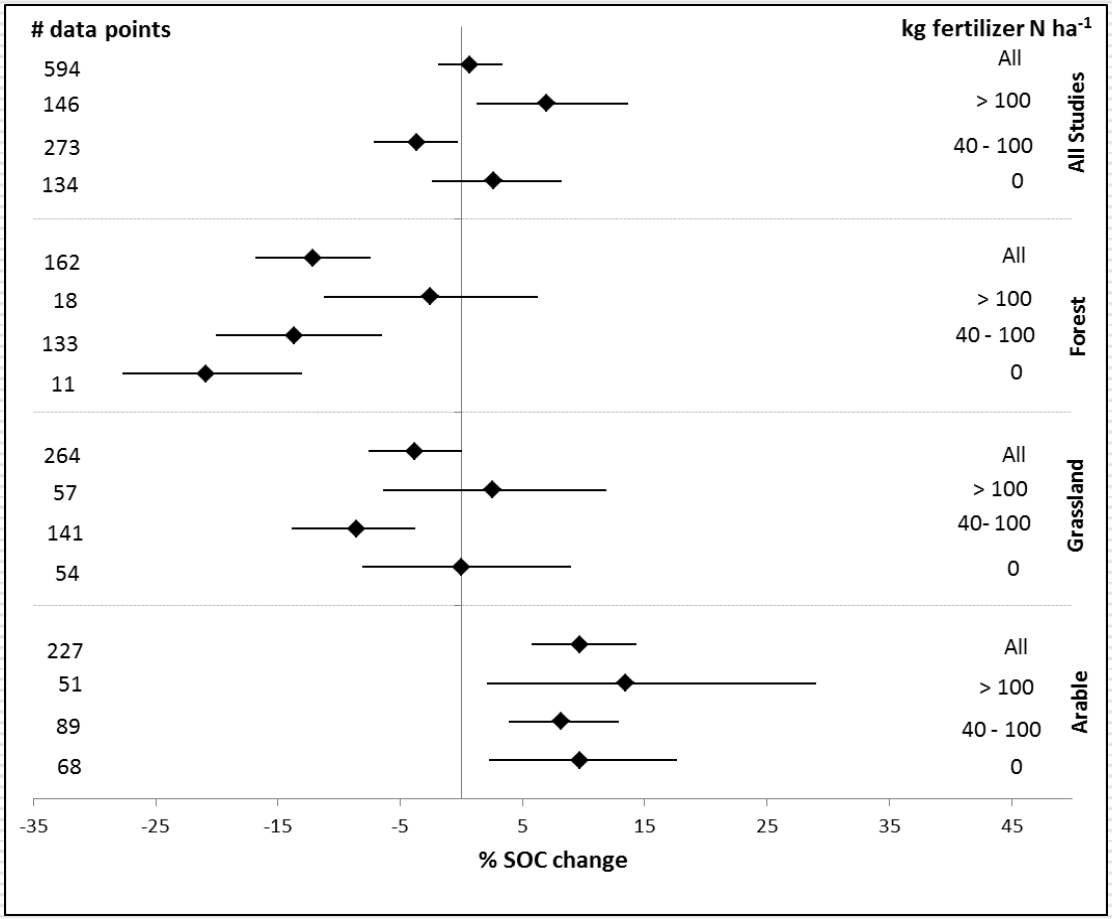
	Evapo-Transp. (mm)	Surface Runoff (mm)	Soil Erosion (Mg/ha)	Organic N loss (kg/ha)	Organic P loss (kg/ha)	Nitrate loss (kg/ha)	Min P loss (kg/ha)
Maize	702	202	4.454	27.96	3.435	30.46	1.141
Alamo SG	610	61	0.021	0.14	0.017	18.39	0.028
Shawnee SG	786	39	0.010	0.07	0.009	14.59	0.020
Miscanthus	845	33	0.009	0.06	0.007	8.20	0.022

Notable Differences Between SG Cultivars

Notable Differences Between SG Cultivars & Miscanthus

Evidence-Based Practice in Agriculture: Meta-analysis/Systematic Reviews of Biomass Cropping System Impact on the Environment

Effects of N fertilization on soil organic C (SOC) responses following the conversion of forest, grassland, or arable cropping to switchgrass or *Miscanthus*. SOC responses are expressed as percent SOC change with 95% confidence interval represented by the *error bars*. Numbers of observations in each category are given as # data points.



Research Need: Open Access Data; Education; Mindset Change Among Researchers

Questions??????