Integrating Bioenergy Crops into the Landscape

Jeffrey J. Volenec
Sylvie M. Brouder
Dept. of Agronomy

Indrajeet Chaubey
Dept. Of Ag. Biol. Engineering

Ben Gramig
Dept. of Ag. Economics

Purdue University
West Lafayette, IN

jvolenec@purdue.edu

Knowledge for the Choice-
and there will be many…..

INPUTS

Sunlight | Water | CO_2

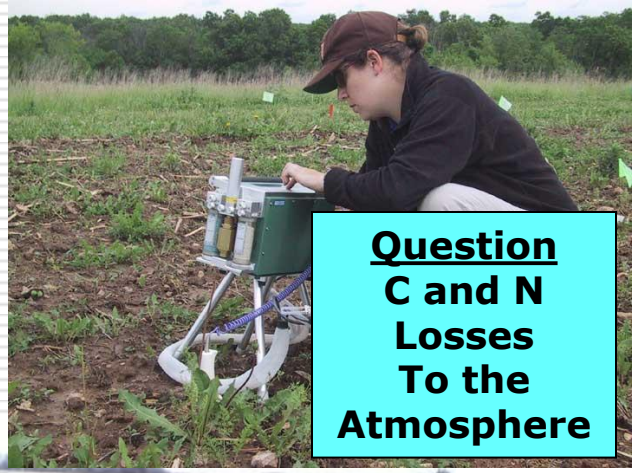
Soil Minerals: Fertilizers

Question
Biomass Yield and Radiation and Nitrogen Use Efficiency

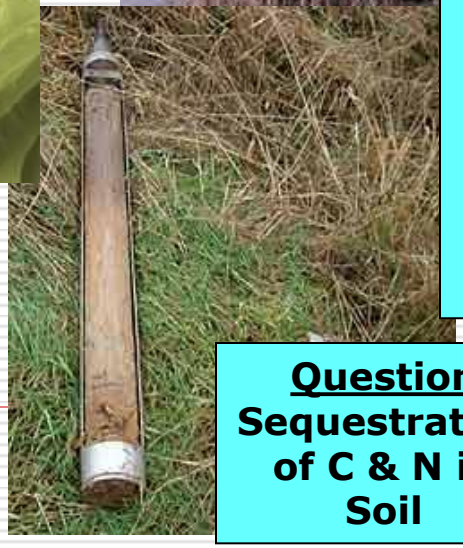
Question
Water Use Efficiency (kg H_20/kg biomass)

Central Question
Species Suitability and Genotype x Environment x Management Interactions

Question
Biomass Composition Impacts on Conversion



Question
C and N Losses To the Atmosphere



Question
Sequestration of C & N in Soil

Question
C and N Losses To Surface Waters

Using a nested array of experiments to study biomass production across the field lab-to-landscape continuum (*we appreciate the support of these sponsors!!*)

3) DOE ~ Development of methods for watershed scale land use optimization 2011

- Modeling land use optimization
- Uses 1 & 2 results for model calibration / validation / optimization

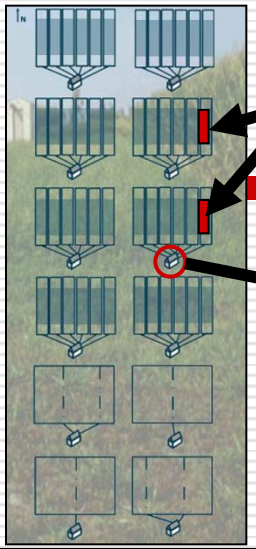
2) Sun Grant Proj./ DOE 2010; cenUSA CAP Project USDA 2011

- Extends study #1 to marginal lands w/ benchmark trts
- More trts & environments, less intensive measurements

1) USDA-NRI Managed Ecosystem Project 2008

- "Complete" C/N/H_2O cycle characterization for representative systems
- Intensive air, soil, plant measurements

System Performance of Biomass Cropping Systems



The Scientific Approach

Field Scale Drainage Lysimeters

Purdue University Water Quality Field Station (WQFS)

- Unique, highly instrumented, in-field lab. for integrated studies of agricultural productivity and environmental impacts
- Integrated team approach: Agronomy, Physiology, Breeding & Genetics, Ecology, Soil Science, Economics, Sociology, Agric. Engineering, Modeling, Life Cycle Analysis

WQFS Research Capabilities: Can understand biomass and grain yields, biomass composition, and radiation, water and N use efficiencies of cropping systems in the context of …

Capabilities Cont.
1) Nutrient (C and N) losses to surface waters in tile drainage water, and

Capabilities Cont.
2) Greenhouse gas (CO_2, CH_4 and N_2O) emission from soil

Treatments

1) Low-input prairie
2) Maize grown in rotation with soybean using rec. N rates
3) Continuous Maize using rec. N rate w/o residue removal
4) Continuous Maize plus residue removal using rec. N rates
5) *Miscanthus* using best known N management
6) Switchgrass using rec. N rates
7) High yielding, high sugar biomass sorghum using rec. N rates

Anticipated Outcomes

Cropping systems-level analysis of switchgrass, *Miscanthus*, sorghum, and maize-based and low-input native prairie feedstock yields, water use efficiency, soil C & N losses to water and as GHG.

Intensive N balance calculations reveal an N balance deficit of 68 kg/ha for *Miscanthus*, while N nutrition needs of switchgrass and the unfertilized prairie are met.

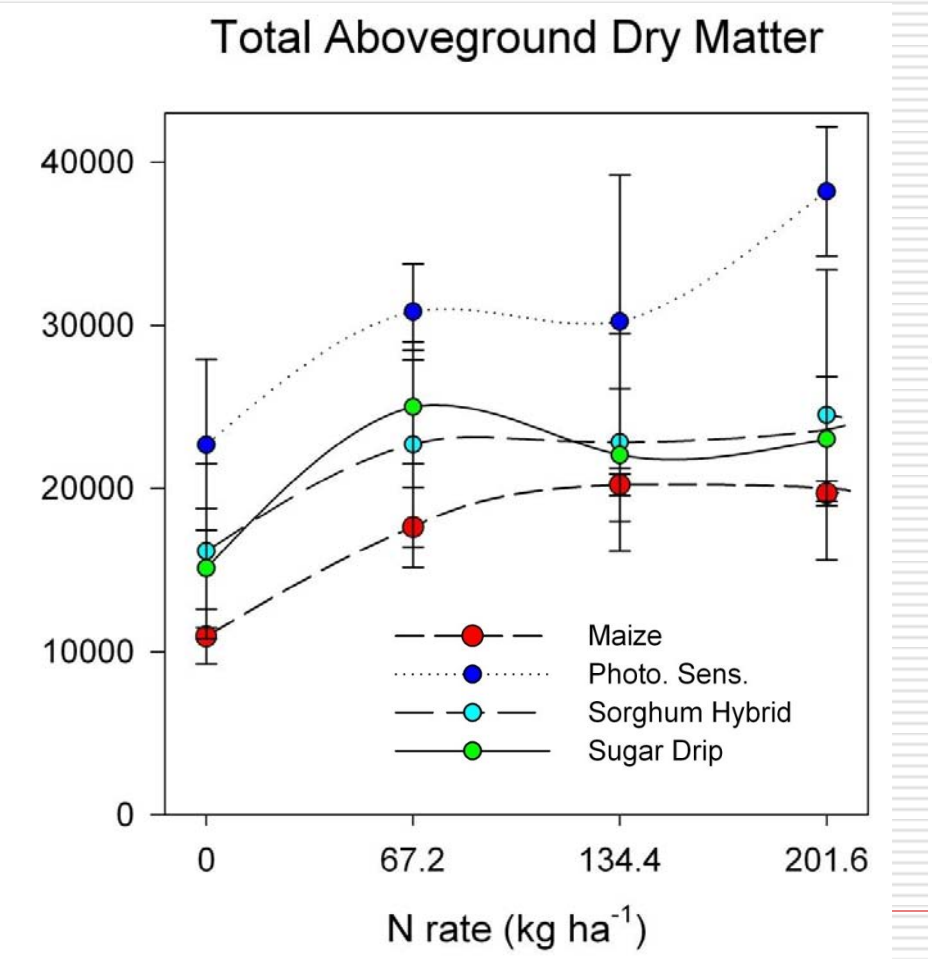
	N Sources, kg/ha					N Sinks, kg/ha			Net, kg/ha
Species	**Fertilizer**	**Atm. Dep.**	**Mineralized***	**Mobilized**	**Total**	**GHG****	**Leach ****	**Biomass**	**Difference**
Miscanthus	56	11	129	44	240	-5	-20	283	-68
Switch.	56	11	129	26	222	-5	-20	157	40
Prairie	0	11	129	19	159	-5	-20	89	45

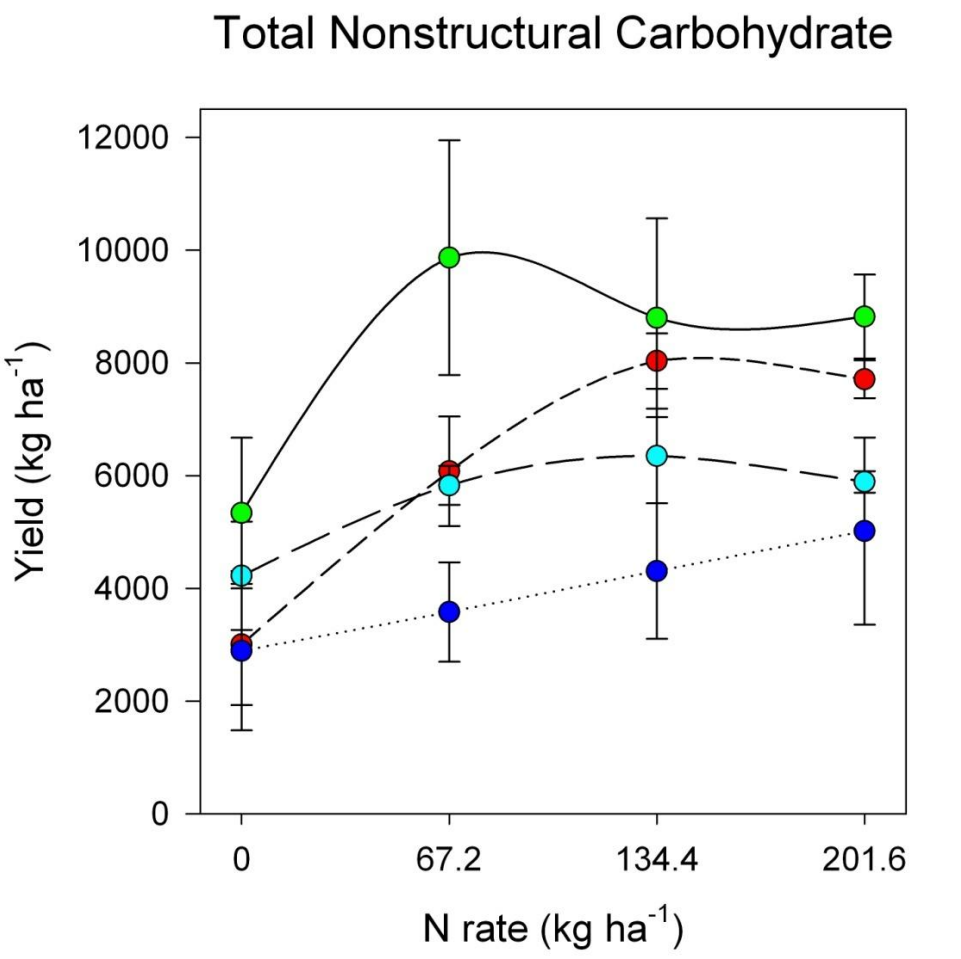
*Based on N uptake by unfertilized maize (shoots and roots) in adjacent field, and root N/shoot N ratio data from Brye et al., 2003.

**Maize-soybean rotation at this site (Hernandez-Ramirez et al., 2009, 2011)

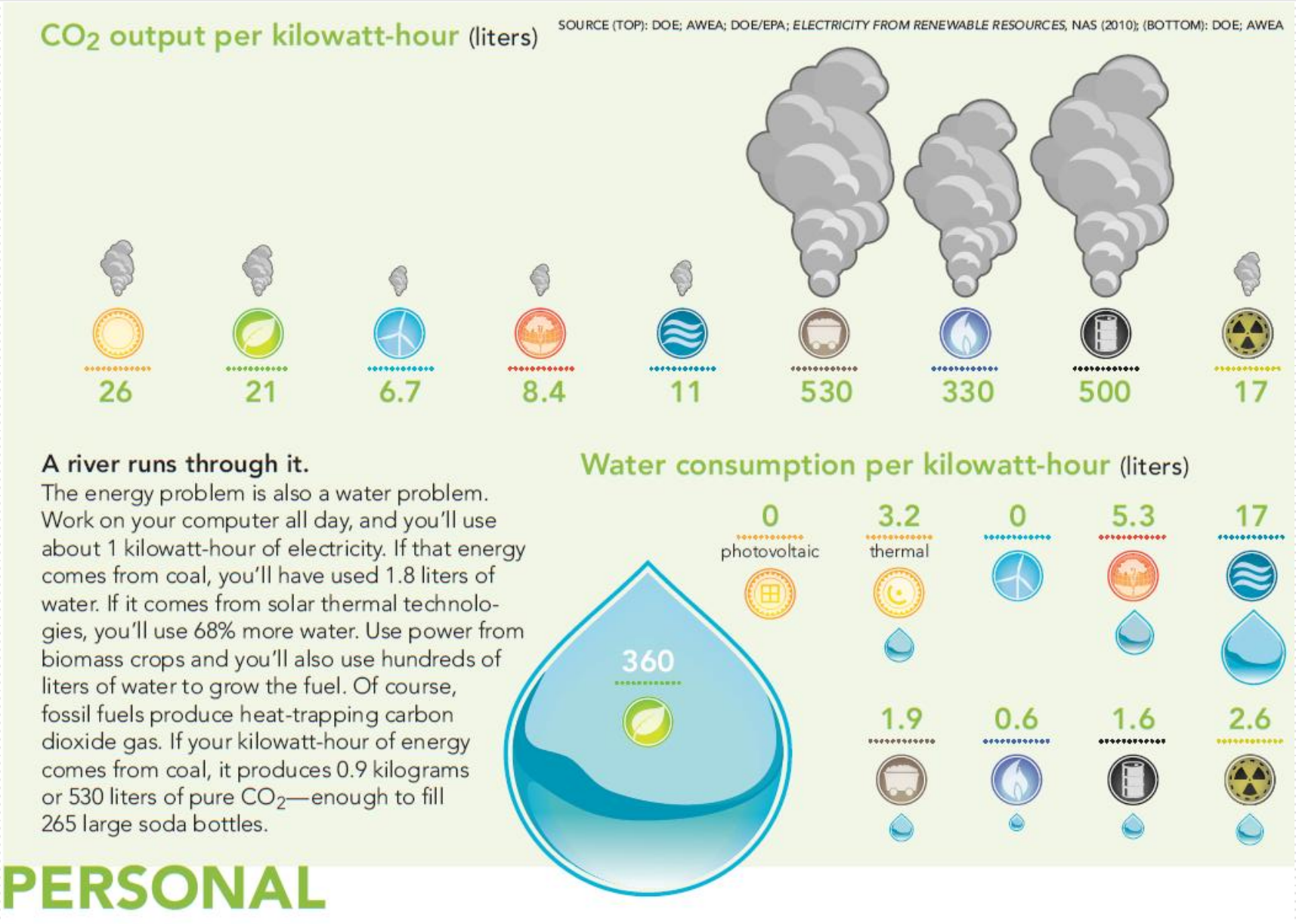
Initial research in the 1980's revealed that sorghum has high biomass yield potential on marginal soils

Nitrogen Use Efficiency: sorghum has high biomass, varied composition, and high NUE on marginal soil; Generation 1.5? (Long et al., unpublished)



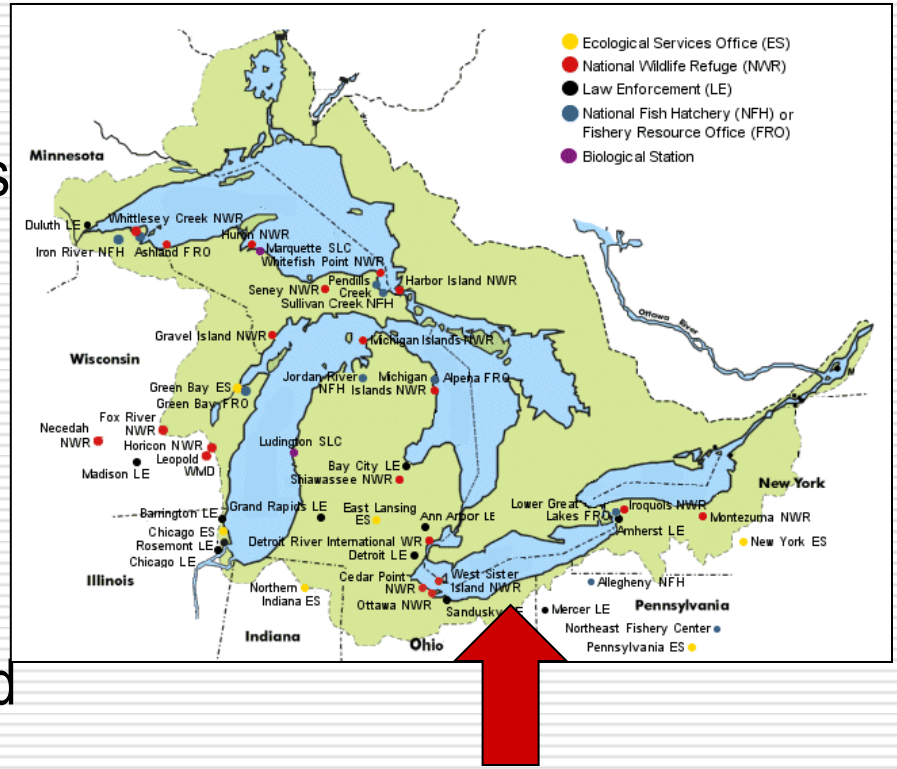


CO_2 Emissions vs Water Use: System environmental performance metrics are needed-no clear "win-win" (Cho, Science Aug. 2010)

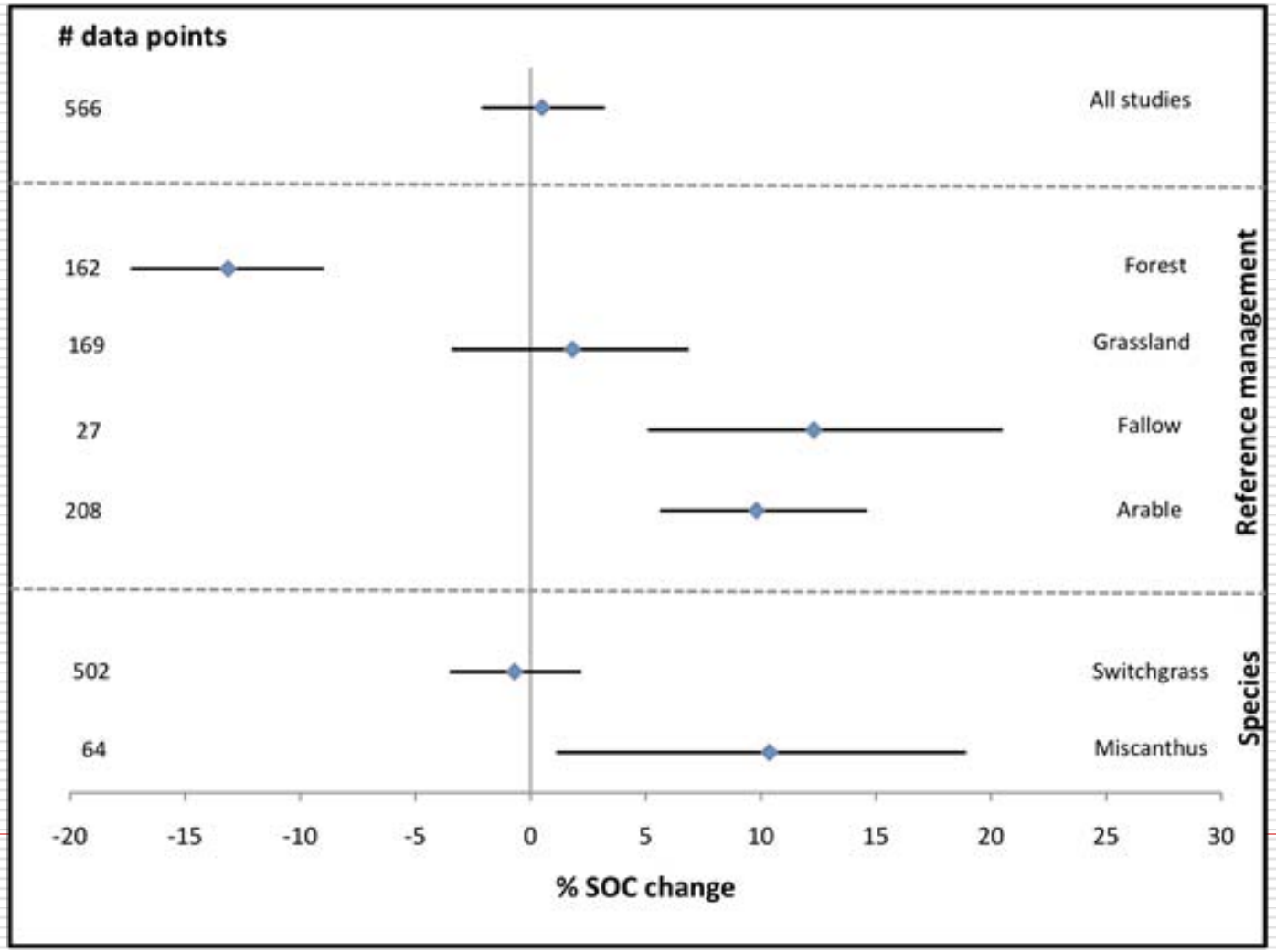


Biomass production will be rainfed: The DOE "Billion Ton Report" and annual water use for biomass production

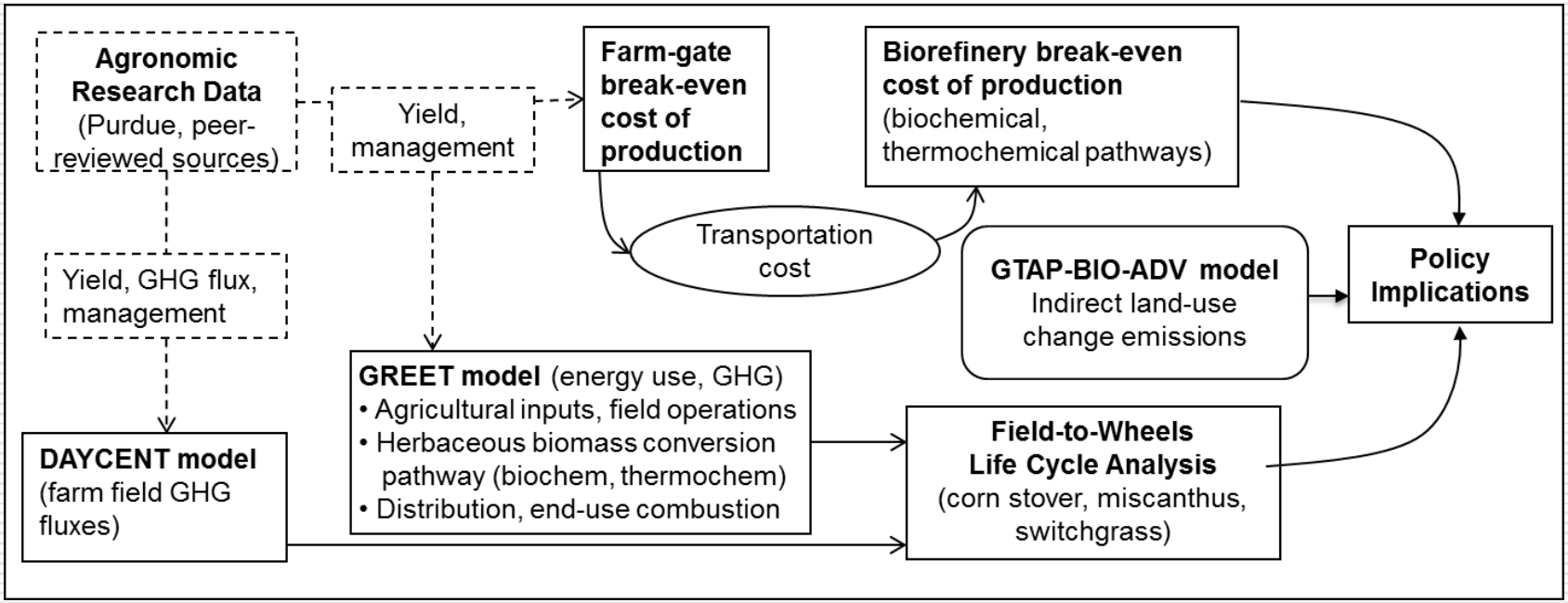
- 1×10^9 Tons DM=2×10^{12} lbs DM
- Water Needed (WUE of 500 lb water per lb dry biomass)=1×10^{15} lbs water
- Volume (8.3 lbs/gal)=1.2×10^{14} gallons water
- Volume (2.64×10^{11} gal/km^3)=456 km^3 water
- Equivalent to <u>ALL</u> the water in Lake Erie <u>Each</u> Year (plus a little from ONT)
- Great Lakes: 84% North America's and 21% of World's Fresh Water



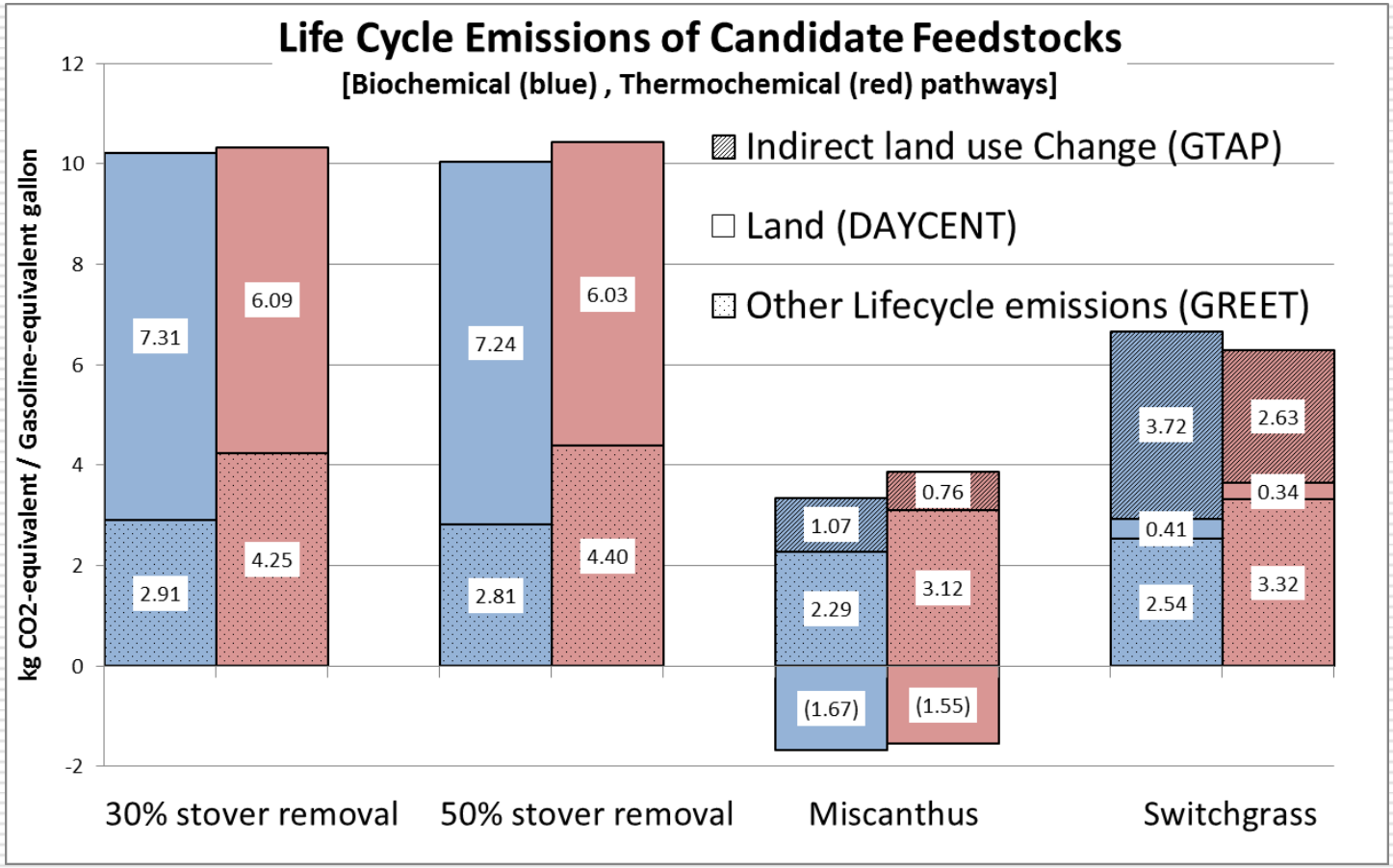
Soil Carbon Sequestration: Soil organic C (SOC) responses following the conversion of forest, grassland, fallow, or arable cropping to biofuel crops; *Miscanthus* or switchgrass (Nhamo et al., unpublished)



Data and modeling components of integrated economic, energy and greenhouse gas life cycle analysis (Gramig et al., submitted)



Estimated life cycle emissions from land (DAYCENT), other elements of the supply chain (GREET), and indirect land use change (Gramig et al., submitted)



- Corn stover removal has the highest total emissions
- Stover alone does not induce any indirect land use change emissions.
- *Miscanthus* generates ILUC emissions that are more than offset by the net decrease in land emissions from C sequestration where the feedstock is grown.
- Switchgrass has lower biomass yield and sequesters less C, resulting in large ILUC emissions
- Higher yields for perennial grasses, holding all else constant, would result in lower ILUC emissions.

Short-term: maize and sorghum; N and water use efficiencies of sorghum high; adapted to marginal soil; tech=maize.

Long-term: A site-specific portfolio of species with high yield, NUE, RUE, C sequestration, and WUE, plus deliver ES