Sustainable bioenergy production utilizing marginal lands

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Joint Global Change Research Institute

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Washington, DC 20009

Talk outline

- Marginal lands: definition and purpose
- A primer on the Great Lakes Bioenergy Research Center (GLBRC)
- Combining data and models to estimate bioenergy production from marginal lands
- Marginal land experiments at the GLBRC
- Social aspects of marginal lands

Marginal lands – definitions

- Marginal lands
  - Lands with low productivity or use limitations (Kang et al. 2013)
    - Low productivity: in the context of crop production
    - Use limitation: erodibility, salinity, water excess, etc.
- Other terms used for marginal lands
  - Unproductive, under-utilized lands, idle, abandoned or degraded lands
- Benefits
  - New revenue for farmers and other land owners
  - No food-vs.-fuel conflict, as food production would not be displaced by fuel production
  - No indirect land-use effects
  - No carbon debt from land conversion

DOE Great Lakes Bioenergy Research Center (GLBRC; www.glbrc.org)

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OUR MISSION

The mission of the Great Lakes Bioenergy Research Center is grand, but simply stated: to perform the basic research that generates technology to convert cellulosic biomass to ethanol and other advanced biofuels.

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<u>OUR MISSION</u>

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OUR RESEARCH AREAS

Sustainability

Plants

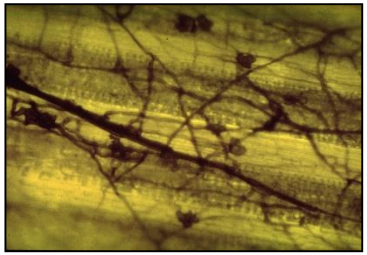
Deconstruction

Conversion

Understanding sustainability at field & farm scales

Plant-Microbe Interactions

Rhizosphere Structure & Function



Biogeochemical Responses

Carbon Cycle – GWP
Water Use & Nutrient Loss

Biodiversity Responses

Invertebrates & Vertebrates
Ecosystem Services

High Input, Low Diversity

Continuous Corn

Corn-Soybean-Canola

Switchgrass

Miscanthus

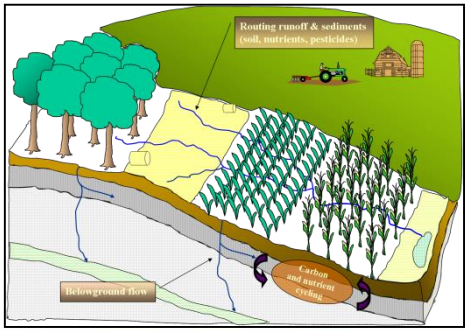
Poplars

Mixed Grasses + Legumes

Low Input, High Diversity

Successional Old Fields

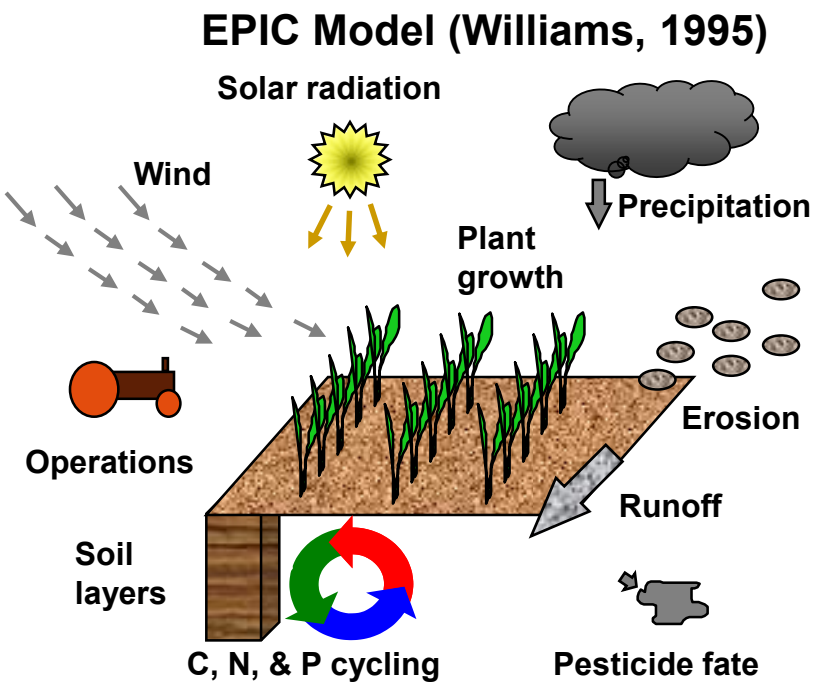
Native Prairie

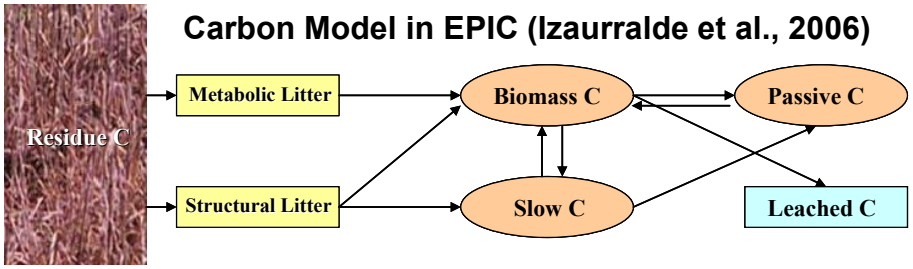


Modeling

Biophysical Modeling with EPIC
Economic Evaluation
Life Cycle Analysis (LCA)

EPIC model: A biophysical and biogeochemical multi-scale simulation tool

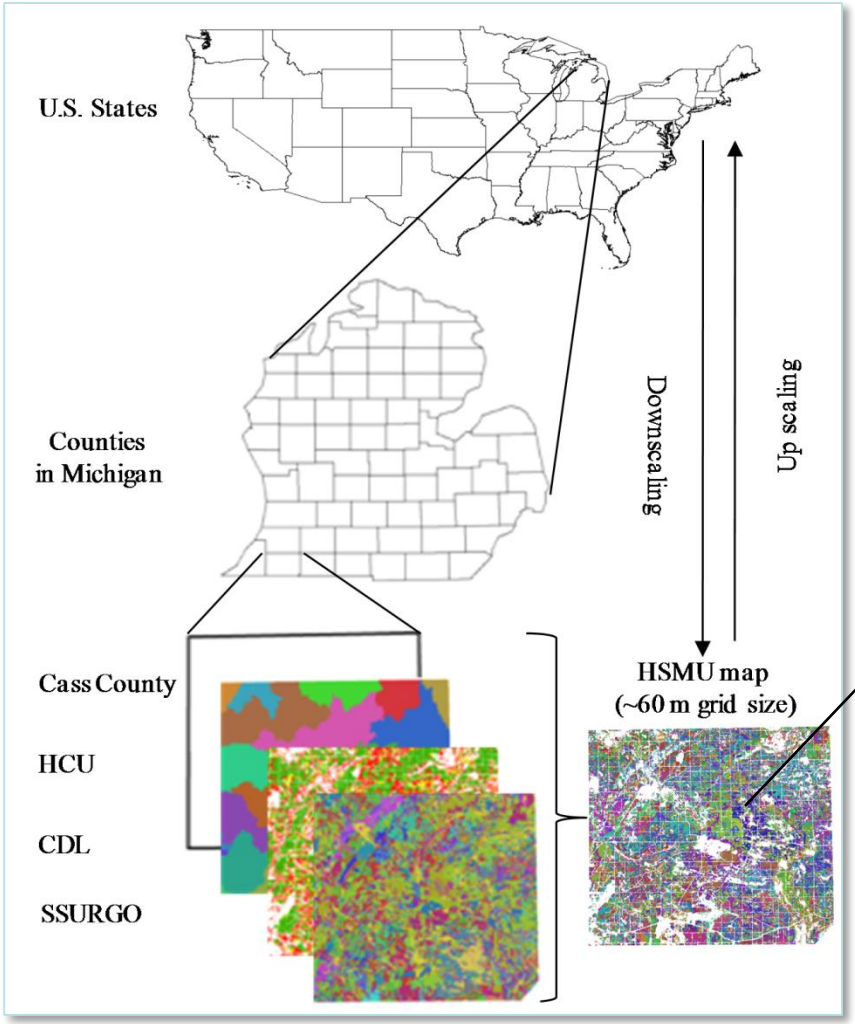


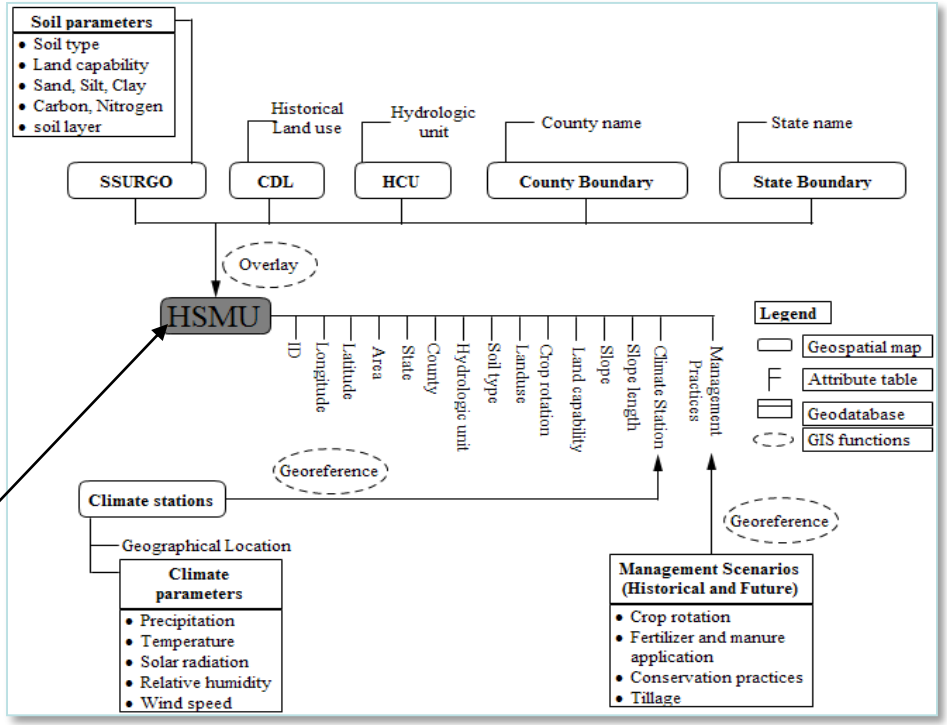


- Weather: generated, historical, climate projections
- Plant growth and yield
  - Radiation use efficiency
  - Crops, grasses, trees
  - Complex rotations, intercropping, cover crops, land use change
  - Plant competition
  - Plant stresses
- Water balance; irrigation, drainage
- Heat balance; soil temperature
- Carbon cycling, including eroded carbon
- Nitrogen and phosphorus cycling
- Erosion by wind and water
- Plant environment control: tillage, fertilizers, irrigation, pesticides

- **Williams et al. 1989. Trans. ASAE 32:497-511.**
- **Izaurralde et al. 2012. Chapter in GRACEnet book.**

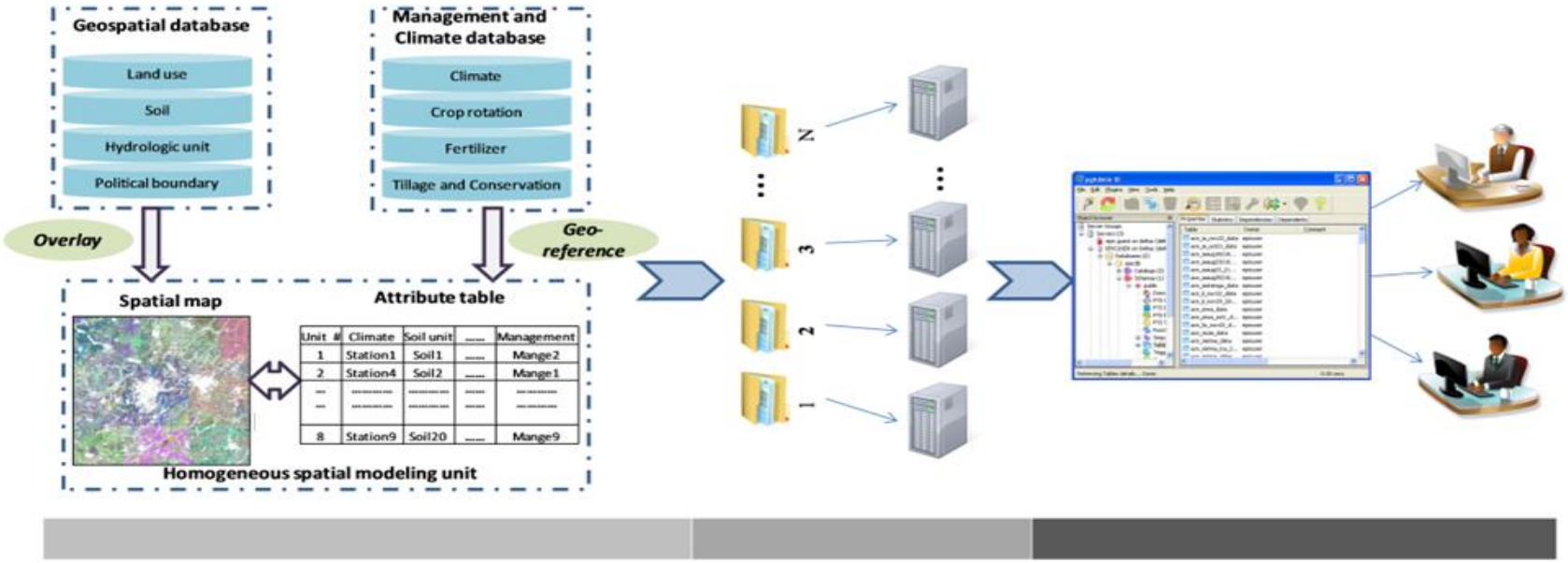
Spatially-explicit modeling system





Zhang X, et al. 2010. Global Change Biology – Bioenergy 2:258-277.

Spatially-explicit and scalable biophysical modeling framework



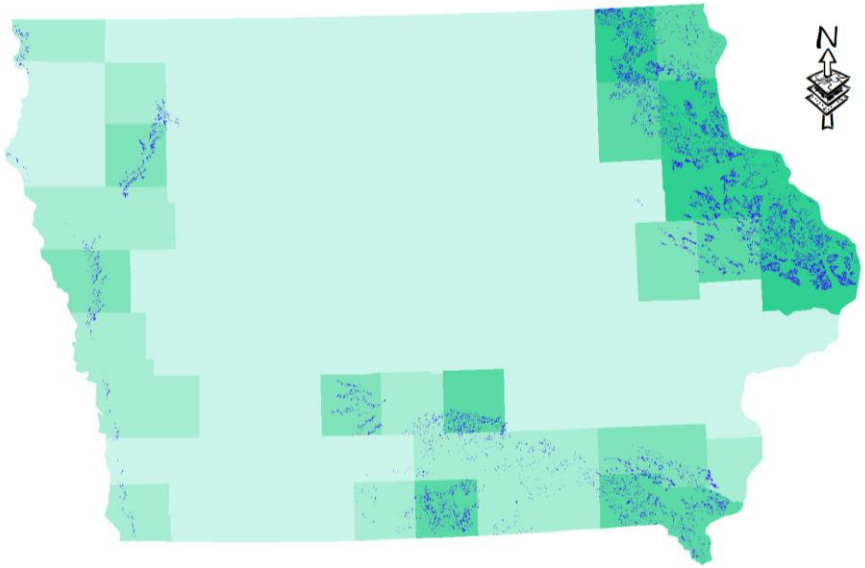
Evergreen Supercomputer @
Joint Global Change Research Institute

- Number of nodes: 274
- Number of processors: 2392
- Memory per node: 48 GB/32 GB (4 GB per core, some nodes having 8 cores and some having 12)
- Total system memory: 9.3 TB
- Total disk space: 1.3 PB

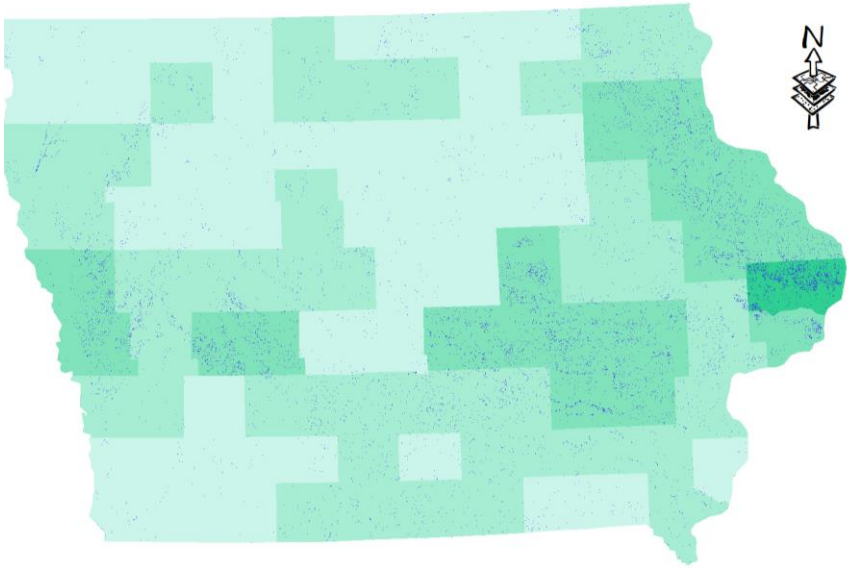
Spatial scale matters in the identification of marginal lands

	STATSGO	SSURGO
Scale	1:250,000	1:24,000
Area of Marginal lands	221,963 ha	129,677 ha

STATSGO



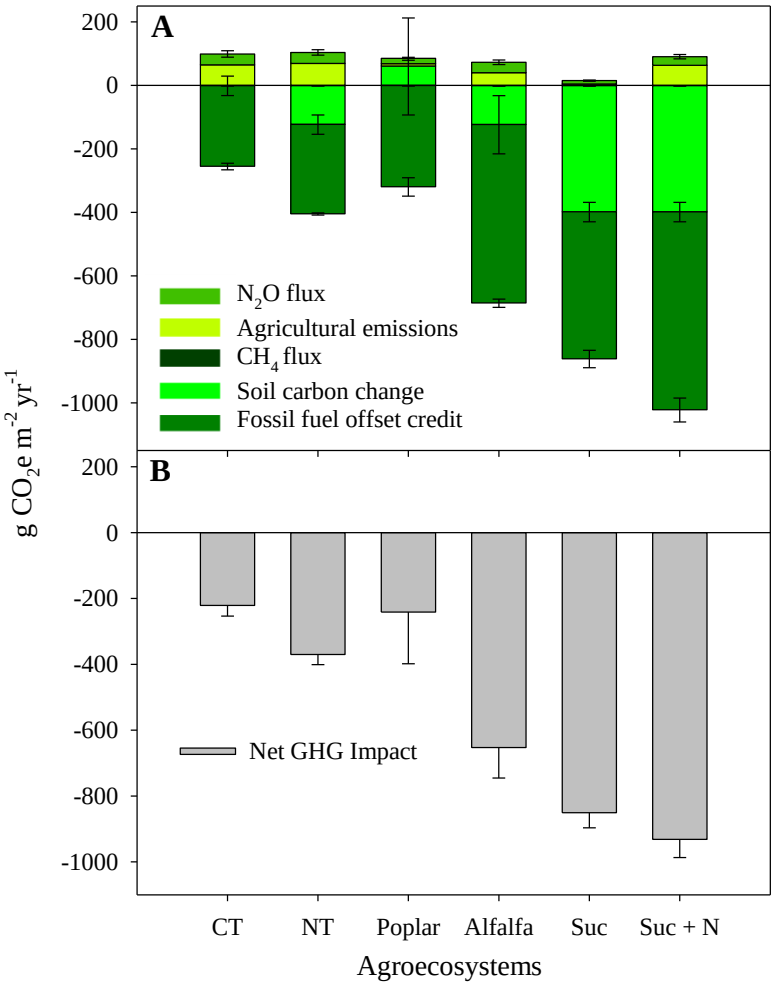
SSURGO



Life-cycle analysis and KBS long-term data revealed potential of native prairie systems for sustainable cellulosic ethanol production

KBS LTER cropping systems experiment
http://news.lternet.edu/Article2697.html

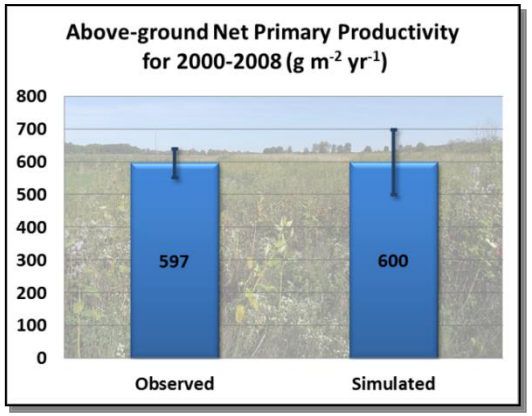
Successional vegetation (foreground), corn and hybrid poplar (background)
http://news.lternet.edu/Article2697.html



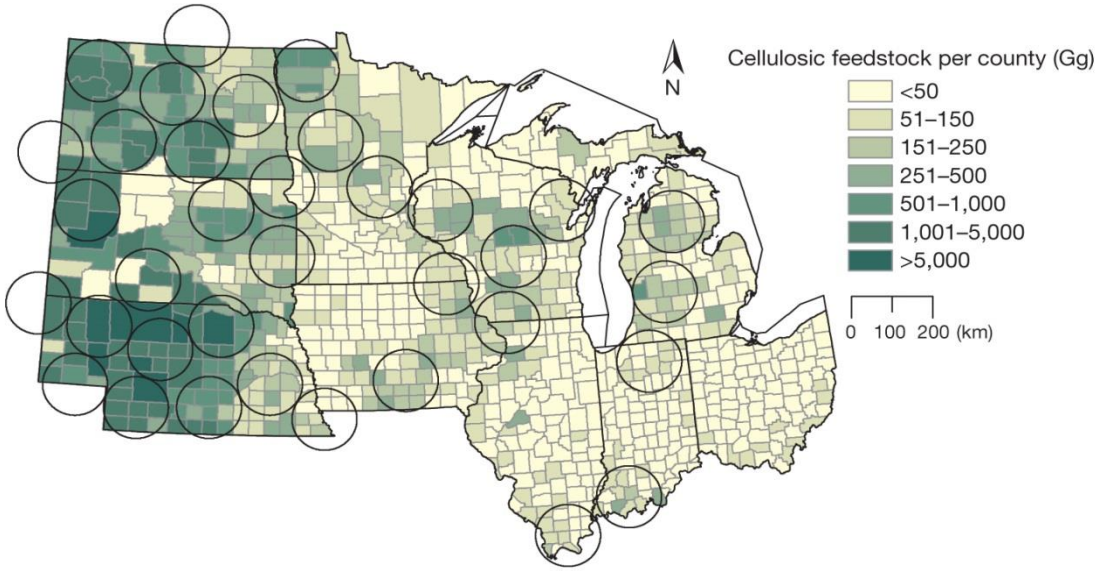
Gelfand et al. 2013. Nature 493: doi:5140519. 10.1038/nature11811.

Modeling the capacity for marginal lands in the US Midwest to produce ethanol and deliver climate benefits

- Analysis of long-term experimental data allowed for identification of treatments with best climate benefits
- Spatial analysis conducted to identify marginal lands based on land capability classification
- EPIC used to simulated cellulosic feedstock using perennial herbaceous vegetation on marginal lands across the US Midwest
- Geospatial analysis conducted to identify potential location of cellulosic ethanol biorefineries



EPIC captures yields from KBS successional communities

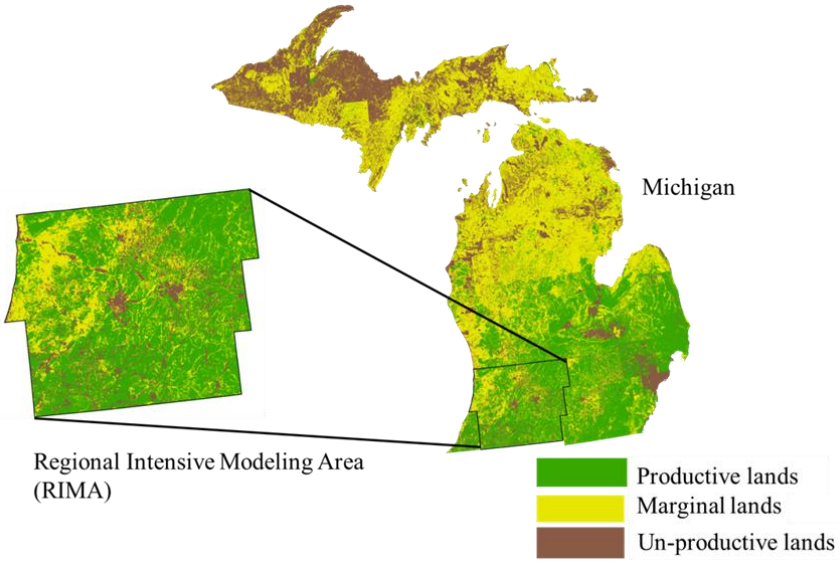


- Potentially, 35 biorefineries on marginal lands in US Midwest
- Potential ethanol production: ~21 GL yr^{-1} ≈ 25% of EISA advanced biofuel target

Gelfand et al. 2013. Nature 493: doi:5140519. 10.1038/nature11811.

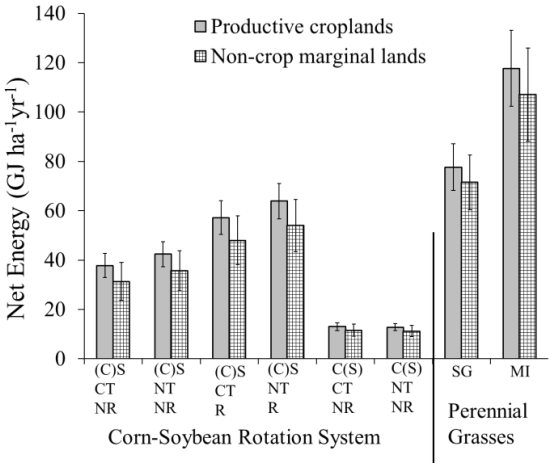
Applying new resources to model biofuel production on marginal lands with EPIC

Enhancing the capability to identify and model bioenergy crops on marginal lands using the USDA - National Crop Commodity Productivity Index (NCCPI) database

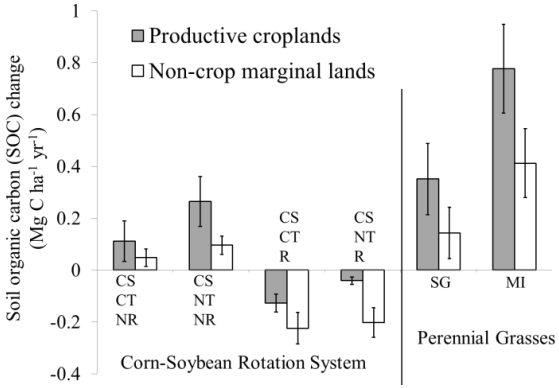


Bandaru et al. 2013. J. Environ. Qual. doi:10.2134/jeq2013.05.0171

Simulated net energy yield was larger with perennial than with annual crops. Perennial crops on marginal lands yielded more net energy than annual cropping systems on productive lands

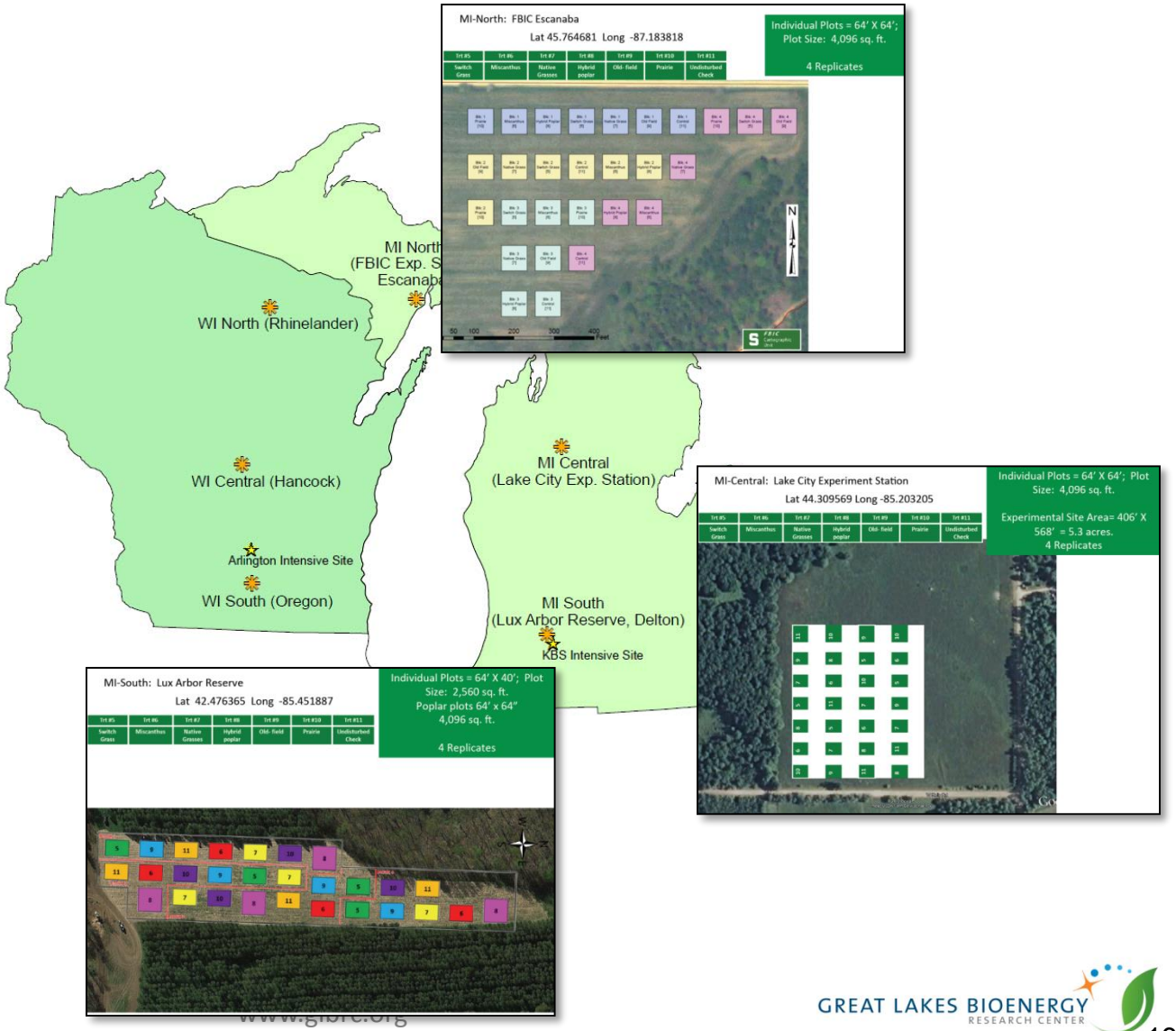


Perennial bioenergy crops led to consistent gains in soil carbon. Removing residues from annual crops led to losses of soil carbon, especially when grown on marginal lands



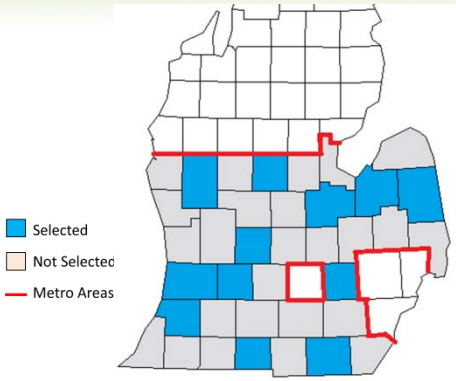
Putting the marginal lands concept to the test: the GLBRC Marginal Land Experiment

- Started at 6 sites; 3 in Michigan and 3 in Wisconsin
- Purpose: evaluate low input bioenergy feedstocks on marginal lands
- Treatments: 6 tratments and a control
  - Switchgrass
  - Miscanthus
  - Native grass mix,
  - Hybrid poplar
  - Early successional community
  - Native prairie

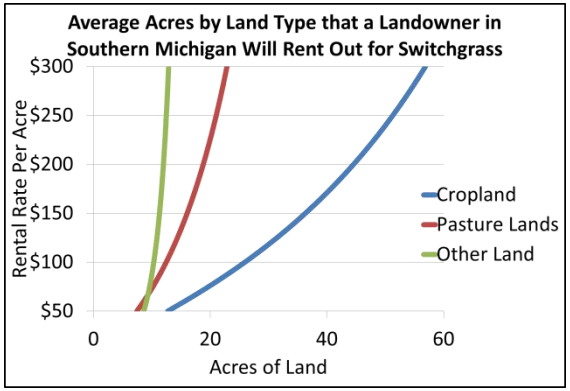


But, will landowners engage?

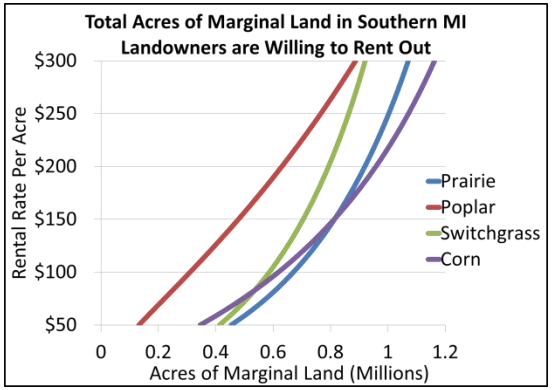
- Noel Hayden and Scott Swinton from MSU asked two questions
  - How much land for biofuels is really available?
  - How willing are land owners to engage in biomass production for bioenergy?
- Study features
  - Used 2010 USDA CDL to identify "marginal lands" parcels
  - Randomly selected 12 counties in Michigan
  - Conducted survey
    - Payments: $50 - $300
    - Contract lengths: 5, 10 yrs
    - Energy crops: corn, switchgrass, poplar, mixed prairie



At same price, rent cropland for switchgrass



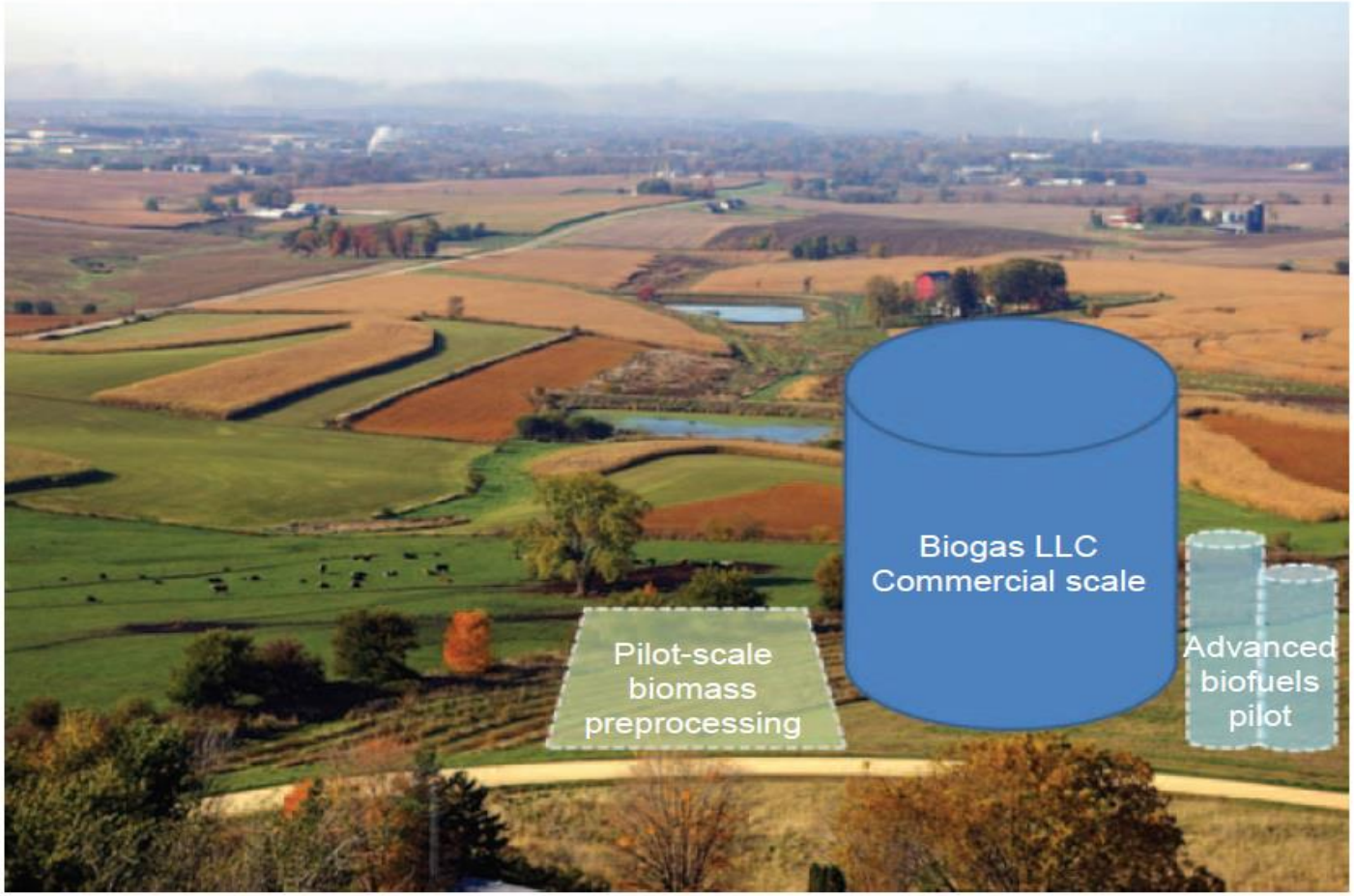
Landowners reluctant to rent out marginal lands for bioenergy crops



Hayden and Swinton. 2013. http://ageconsearch.umn.edu/bitstream/151424/2/HaydenSwinton2013.pdf

Is it time for grass-sheds?

Place-based collaborative design, implementation, and monitoring
Value chains anchored to commercial-scale biomass conversion facilities
Renewable energy, rural development, and environmental conservation



Williams et al. 2013. J. Soil Water Conserv. doi:10.2489/jswc.68.6.141A

Summary

- Experiments and simulations suggest significant potential of marginal lands for sustainable bioenergy production
- Ongoing research expected to yield results on
  - Feedstock productivity
  - Environmental impacts
  - Climate benefits
  - Landowners engagement
  - Landscape design

Acknowledgements

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