Sustainable bioenergy production utilizing marginal lands

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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
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.
Understanding sustainability at field & farm scales

High Input, Low Diversity
- Continuous Corn
- Corn-Soybean-Canola
- Switchgrass
- Miscanthus

Low Input, High Diversity
- Poplars
- Mixed Grasses + Legumes
- Successional Old Fields
- Native Prairie

Plant-Microbe Interactions
Rhizosphere Structure & Function

Biogeochemical Responses
Carbon Cycle – GWP
Water Use & Nutrient Loss

Biodiversity Responses
Invertebrates & Vertebrates
Ecosystem Services

Modeling
Biophysical Modeling with EPIC
Economic Evaluation
Life Cycle Analysis (LCA)
EPIC model: A biophysical and biogeochemical multi-scale simulation tool

EPIC Model (Williams, 1995)
- Solar radiation
- Wind
- Operations
- Soil layers
- Plant growth
- Erosion
- Precipitation
- Runoff
- C, N, & P cycling
- Pesticide fate

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

Carbon Model in EPIC (Izaurralde et al., 2006)
- Metabolic Litter
- Biocass C
- Passive C
- Structural Litter
- Slow C
- Leached C

Spatially-explicit modeling system

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

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<tr>
<td>Scale</td>
<td>1:250,000</td>
<td>1:24,000</td>
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<tr>
<td>Area of Marginal lands</td>
<td>221,963 ha</td>
<td>129,677 ha</td>
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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.ternet.edu/Article2697.html

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

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

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

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.

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

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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Earth Sciences Applications

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