The Technical Potential for Switchgrass as a Bioenergy Crop in the USA

May 28, 2008
GTSP Technical Review

Allison Thomson
Joint Global Change Research Institute
Contributors

- César Izaurralde, JGCRI
- Tris West, ORNL
- Dave Parrish, Virginia Tech
- Don Tyler, University of Tennessee
- Jimmy Williams, Texas A&M University

Sponsors: DOE Center for Carbon Sequestration in Terrestrial Ecosystems (CSiTE), Office of Biomass Programs, and the Great Lakes Bioenergy Research Center (GLBRC)
Bioenergy: Any energy that is derived from plants and other organic materials
- Can be converted to liquid fuels for transporation (ethanol and biodiesel)
- Renewable energy source
- C released in combustion is fixed by regrowth of the feedstock
- Can be produced domestically
Why switchgrass?

Potential biofuels sources:
- sugar for ethanol (corn, sugarcane),
- oil for biodiesel (palm, soybean),
- cellulose for ethanol (switchgrass, poplar),

Switchgrass as a promising feedstock:
- Positive net energy balance
- Native to US, non-invasive
- Co-benefits (wildlife habitat, erosion control)
- Lower fertilizer input than conventional crops
- Homogeneous feedstock

How much can be grown? On what land? What are the environmental consequences?
Simulation Model Development

Objective: Improve an existing ecosystem model to simulate switchgrass productivity.

1. Use field trial results to calibrate EPIC switchgrass simulation
2. Validate calibrated model with an independent set of field trial results
3. Apply model improvements in a regional simulation
EPIC Model Overview

EPIC is a process-based model built to describe climate-soil-management interactions at point or small watershed scales
- Crops, grasses, trees
- Up to 100 plants
- Up to 12 plant species together

Key processes simulated
- Weather
- Plant growth
  - Light use efficiency, PAR
  - CO₂ fertilization effect
  - Plant stress
- Erosion by wind and water
- Hydrology
- Soil temperature and heat flow
- Carbon, Nitrogen, and Phosphorus cycling
- Tillage
- Plant environment control: fertilizers, irrigation, pesticides
- Pesticide fate
- Economics

Representative EPIC modules

Williams (1995)
Izaurralde et al. (2006)
Calibration to Field Trial Results
10-yr trials on 7 sites in the Southeast US

Average Switchgrass Yields 1994-2001

- Lowland 1 Cut
- Lowland 2 Cut
- Upland 1 Cut
- Upland 2 Cut
- 1:1 line
Environmental Consequences: Terrestrial carbon storage

Change in SOC under Switchgrass

![Graph showing change in SOC annual change (Mg yr⁻¹) vs. Initial SOC to 30cm (Mg)]

- Lowland - 1 Cut
- Lowland - 2 Cut
- Upland - 1 Cut
- Upland - 2 Cut

Initial SOC to 30cm (Mg) vs. SOC annual change (Mg yr⁻¹)
Regional Site Validation:

Average and Range of Yield by State

<table>
<thead>
<tr>
<th>State</th>
<th>ORNL - Observed Yield</th>
<th>EPIC - Simulated Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>12 ± 2</td>
<td>10 ± 2</td>
</tr>
<tr>
<td>AR</td>
<td>14 ± 3</td>
<td>13 ± 2</td>
</tr>
<tr>
<td>GA</td>
<td>10 ± 1</td>
<td>11 ± 2</td>
</tr>
<tr>
<td>IA</td>
<td>15 ± 4</td>
<td>16 ± 3</td>
</tr>
<tr>
<td>LA</td>
<td>17 ± 5</td>
<td>18 ± 4</td>
</tr>
<tr>
<td>ND</td>
<td>18 ± 6</td>
<td>19 ± 5</td>
</tr>
<tr>
<td>OK</td>
<td>16 ± 4</td>
<td>17 ± 5</td>
</tr>
<tr>
<td>SD</td>
<td>14 ± 3</td>
<td>15 ± 4</td>
</tr>
<tr>
<td>TX</td>
<td>13 ± 2</td>
<td>14 ± 3</td>
</tr>
<tr>
<td>WI</td>
<td>15 ± 4</td>
<td>16 ± 3</td>
</tr>
</tbody>
</table>
Extension to Regional Simulation

- Extend the model application to an area of interest using revised parameters.
- Extension of lowland and upland ecotype distribution – 41 N line of transition.
- Assume fertilization rate of 50 kg N.
- Adjustments to plant growth determination based on location (latitude) and climate (growing season length).
- Applied to US database over major agricultural soils.
Annual Switchgrass Yield
Do we have enough land to develop biofuels?

- Growth in demand for meat
- Growth in food demand
- High oil prices
- Government subsidies
- Biofuels policies

Source: IFPRI, May 7, 2008
The 2007 Energy Independence and Security Act mandates cellulosic ethanol

- **2012**: 15.2 billion gallons, **0.5** as cellulosic ethanol
- **2022**: 36 billion gallons, **16** as cellulosic ethanol

**EPIC Average Yield = 5.6 Mg ha\(^{-1}\)**

1 kg biomass = 0.1 gallons ethanol

- **2012**: 0.9 million hectares
  - <1\% current cropland
- **2022**: 28.6 million hectares
  - 23\% current cropland

(Schmer et al. 2008, *PNAS*)
Future work

- Assessment of the sustainability of biofuel refinery feedstock production
- Integrated Assessment modeling to understand land-use change dynamics
  - Biofuels scenarios
  - Downscaling land-use from regions to grid
  - Incorporating process-model results on productivity and sustainability
  - Understanding the water requirements for irrigation and processing
Sustainability of a Biorefinery

- Great Lakes Bioenergy Research Center
  - 4 “bioenergy”-sheds
  - Multiple feedstocks
Figure 4-2. Conceptual framework for sustainability research. Production goals on the left are evaluated on the basis of three main system responses (biogeochemical, biodiversity, and socio-economic), which are integrated via modeling to inform the design of landscapes and predict their performance, leading to optimal configurations with known sustainability outcomes.
EPIC model development is the first step in evaluating questions of the sustainability of biofuels production

Work already in progress to simulate productivity of multiple potential feedstocks to a biorefinery

Integration with multiple modeling systems, including Integrated Assessment