Energy Crop Production

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Introduction

Multifunctional Agriculture

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Multifunctional Agriculture

World map of bioenergy plants
http://maps.nrel.gov/biomass
Outline

• What makes a good energy crop
• Crop choice for the upper Midwest
• Integrating food and fuel
The “Ideal” Biomass Crop?

Must be high yielding but what else?

A biomass crop should be...

(Carruthers et al. 1991; Heaton et al. 2004)

Auburn, AL
YIELD $F(X)$
Efficient Solar Capture

$C_4$ Photosynthesis can be 40% more efficient than $C_3$ (Long 1999)
Long Canopy Duration

Miscanthus and Maize Biomass Accumulation

- **Miscanthus**
- **Maize**

**Peak Dry Biomass (t ha⁻¹)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Miscanthus</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>2008</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

Significance:
- Different letters indicate significant differences.
Carbohydrates, nutrients

Translocation from rhizomes to growing shoot

SPRING/SUMMER

Nutrient Recycling

FALL

Translocation from senescing shoot to rhizomes

Mineral nutrients

WINTER

Harvested biomass is lignocellulose; nutrients stay in rhizomes
Translocation of nitrogen

Nitrogen moves from roots to shoots as growing begins.

Nitrogen moves back to roots as shoot senescence begins.
Clean fuel
Nitrogen concentration of switchgrass biomass and fast pyrolysis products (bio-oil*, char and non-condensable gas)

*Bio-oil is normalized to moisture free biomass.

Low Input

Nutrient cycling reduces need for annual N applications
Efficient Water Use
The Ideal Biomass Crop

No Pest/Disease Problems
The Ideal Biomass Crop

Non-Invasive (Sterile)
Winter Standing
The Ideal Biomass Crop

Use Existing Equipment
## The “Ideal” Biomass Crop?

<table>
<thead>
<tr>
<th>Feature</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 photosynthesis</td>
<td>★</td>
</tr>
<tr>
<td>Long canopy duration</td>
<td></td>
</tr>
<tr>
<td>Recycles nutrients to roots</td>
<td></td>
</tr>
<tr>
<td>Clean burning</td>
<td></td>
</tr>
<tr>
<td>Low input</td>
<td></td>
</tr>
<tr>
<td>Sterile – non-invasive</td>
<td>N/A</td>
</tr>
<tr>
<td>Winter standing</td>
<td></td>
</tr>
<tr>
<td>Easily removed</td>
<td>★</td>
</tr>
<tr>
<td>High water use efficiency</td>
<td></td>
</tr>
<tr>
<td>No known pests/diseases</td>
<td></td>
</tr>
<tr>
<td>Uses existing farm equipment</td>
<td>★</td>
</tr>
</tbody>
</table>

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**Iowa State University**

[Logo]

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**i'm an agronomist**

[Logo]
<table>
<thead>
<tr>
<th>The “Ideal” Biomass Crop?</th>
<th>Maize</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 photosynthesis</td>
<td>⭐</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>⭐</td>
</tr>
<tr>
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<tr>
<td>The “Ideal” Biomass Crop?</td>
<td>Maize</td>
<td>SRC</td>
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<td>--------------------------</td>
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Based on this rationale, what are some ‘ideal’ energy crops in your area?

Turn to your partner on the right
WHAT PLANTS WORK BEST FOR BIOENERGY IN THE UPPER MIDWEST?
Energy Crop Production

Perennial Herbaceous Crops
- Switchgrass
- Miscanthus

Annual Herbaceous Crops
- High Biomass Sorghum
- Sorghum Sudan

Short Rotation Woody Crops
- Hybrid Willow
- Hybrid Sorghum

Crop Residues Ryegrass
Wood & Forest Residues

Feedstock opportunities are region-specific
Imperative that biomass feedstock systems are sustainable
Purpose grown energy crops offer long term scale, sustainability, and affordability
More than half of the US biomass market expected to be based in the Southeast
Sorghum (*Sorghum bicolor*)

- High yielding crop
- High sugar content
- Highly efficient crop
  - Low nitrogen use
  - Drought tolerant
  - C4 metabolism
- Widely adapted and commonly grown in the US

Starkville, MS, 2006
Multiple uses for sorghum

A versatile annual crop

- Grain
- Sweet
- Forage & Biomass
Switchgrass

US model biomass species

- Native prairie grass
- Widely adapted
- US DOE breeding and evaluation programs
- Yield 3-9 t ac\(^{-1}\) (8-22 Mg ha\(^{-1}\))
- High yielding hybrids to be released in ~2010

Auburn, AL
Planting Switchgrass

Planting
Harvesting Switchgrass

Mowing

Baling

Moisture 15—20% at post-frost harvest
Switchgrass Challenges

- **Planting**
  - Precision planting
  - Must improve
    - Seed metering
    - Seed placement

- **Harvesting**
  - Single pass systems needed
  - Must improve feeding of tall, high yielding types
  - Reduce harvest losses (15-40%)

*Monti et al. 2007*
Miscanthus yields more

Urbana, IL.
Photo courtesy of Matt Liebman

3 year average yields

30
25
20
15
10
5
0
Mg ha⁻¹

Harvestable Dry Biomass

- Miscanthus
- Switchgrass
Giant Miscanthus
(*Miscanthus x giganteus*)

- High Yielding (6-15 t/acre)
- Sterile clone
- Must be planted vegetatively
- New to US: 10’s to 100’s of acres
- Widely planted in Europe: thousands of acres
- Used for heat and power with coal
Rhizomes

Plugs
Planting - Rhizomes
Planting – Plugs (small plants)

Easton, IL 2009
Photo credit: Brian Barnick
Cane Harvest Options
## Tentative Recommendations

### N
- Not limiting – late spring nitrate test if possible
- Maintenance
  - 10 lb/ton cane

### P
- Not limiting at planting – soil test
- Maintenance
  - 1.5 lb/ton cane

### K
- Not limiting at planting – soil test
- Maintenance
  - 10-12 lb/ton cane

### LIME: pH = 5 – 7.5
Weed Control – ESSENTIAL!!

• Pre-emergent:
  - Prowl (pendimethalin)
  - Harness (acetochlor)
  - Harness Extra (acetochlor + atrazine)
  * GREEN = LABELED

• Post-emergent
  - Callisto (mesotrione)
  - 2,4-D
  - Dicamba
  - Atrazine
  - CULTIVATION

Anderson et al. (2010). Weed Technology 24:453-460
## Challenges: Mainly planting

<table>
<thead>
<tr>
<th>Planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Consistency of rhizomes</td>
</tr>
<tr>
<td>▪ Lifting</td>
</tr>
<tr>
<td>▪ Grading</td>
</tr>
<tr>
<td>▪ Storing</td>
</tr>
<tr>
<td>▪ Planting</td>
</tr>
<tr>
<td>□ Irrigation of live plants</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Feeding of long, slick, brittle material</td>
</tr>
<tr>
<td>□ Harvest losses of chopped material if windy</td>
</tr>
<tr>
<td>□ Equipment design for tall, dry, high yield</td>
</tr>
</tbody>
</table>
Integrating Food and Fuel
Expected Acreage of Energy Crops

- Biomass needed annually ≈ 1,000,000,000 Mg
- Biomass yields range 5-40 Mg ha$^{-1}$
- Land area needed annually = 25-200 million ha (~60-500 million acres)
Complementing Corn

• Integrating perennial vegetation can ameliorate damage crop annual row crops.

• Those perennials can (and should be!) dedicated biomass crops.

Source: Iowa NRCS
High Yield, Low Input vs. High Yield, High Input

<table>
<thead>
<tr>
<th>Miscanthus</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 10 t/ac</td>
<td>• 150 bu/ac</td>
</tr>
<tr>
<td>• $50/t</td>
<td>• $6/bu</td>
</tr>
<tr>
<td>• = $500/ac</td>
<td>• = $900/ac</td>
</tr>
<tr>
<td>• Costs - after</td>
<td>• Costs???</td>
</tr>
<tr>
<td>establishment,</td>
<td></td>
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<tr>
<td>have only</td>
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<tr>
<td>annual harvest</td>
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<tr>
<td>and some low</td>
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<tr>
<td>fertilizer</td>
<td></td>
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<tr>
<td>• NO ANNUAL</td>
<td></td>
</tr>
<tr>
<td>PLANTING</td>
<td></td>
</tr>
<tr>
<td>COSTS</td>
<td></td>
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</table>
Feedstock Production Costs

- Key factors:
  - Land rent
  - Establishment cost
    - Seeded establishment costs are less than 25% than that of vegetative propagation
  - Management of inputs
  - Yield
    - A ½ ton per acre increase in yield has the same impact as a 5 gallon increase in conversion efficiency
  - Transportation
    - Maximum load densities and short hauls are important
The Landscape Biomass Project

Photo credit: Tom Schultz
Scaling It Up

An Alternative

Food & Feed

Fuel & Fiber

Larsen, Atwell and Schulte 2010
Integrated Feedstock Modeling Capability

• Proprietary database-driven feedstock optimization and logistics modeling system
  – Integrates land selection, establishment, maintenance, harvesting, collection, aggregation, storage, transportation, inventory management, and risk management.
  – Simulates feedstock supply and costs under a range of scenarios
  – Interactions among management decisions
  – Integrated optimization across supply and logistics chain
• Land acquisition planning & analysis
• Multi-feedstock system
• Logistics & inventory management modules
Genera provides a range of biomass feedstock production and supply chain management services
• For a variety of energy crops and feedstocks
• Under a range of self-performance and management arrangements
• Tailored to the needs of a particular Biomass Conversion Facility (BCF) Project or user
Biomass Field Day

• 2012 From Grow to Go: A Biomass Field Day and Workshop
• Oct. 24-25, 2012 in Vonore, TN
• Visit http://www.biomassfieldday.com to register or for more information!
• Over 1,000 attended last year!