Woody Energy Crop Production

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Renewable Fuel Standard

- Annual production of 36 billion gallons of biofuels by 2022
- Ethanol production from corn capped at 15 billion gal\(^{-1}\) yr\(^{-1}\)
- Remaining 21 billion gallons from advanced biofuels
- 16 billion gallons from cellulosic biofuels
- Seven-fold increase in current biomass production from 190 million dry tons to 1.36 billion dry tons
- DOE / USDA goal of replacing 30% petroleum consumption with biofuels by 2030


Source: Renewable Fuels Association.
http://www.ethanolrfa.org/resource/standard
Why Short Rotation Woody Crops?

- Broad economic & environmental benefits
- Well-studied (silviculture, physiology, & genetics)
- Base populations exhibit tremendous diversity
- Grown on marginal lands not suitable for agriculture
- Very productive
## Why Short Rotation Woody Crops?

<table>
<thead>
<tr>
<th>Crop</th>
<th>Realized Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switchgrass</td>
<td>9.0 dt ac(^{-1}) yr(^{-1})</td>
</tr>
<tr>
<td>Willow</td>
<td>8.0 dt ac(^{-1}) yr(^{-1})</td>
</tr>
<tr>
<td>Poplar</td>
<td>7.0 dt ac(^{-1}) yr(^{-1})</td>
</tr>
</tbody>
</table>

### Potential Productivity

> 10.0 dt ac\(^{-1}\) yr\(^{-1}\)

Depends on genotype × environment interactions
Why Short Rotation Woody Crops?

Additional Advantages

- **Energy per biomass unit**: 16.5 to 17.2 MBtu dt^{-1}
- **Energy returned on energy invested (EROEI)**
- **Can be stored on the stump until harvest**
- **Harvest throughout the year**
- **Minimal fertilization**
- **Extended haul distances**
- **Used in crop rotations to improve soil tilth**
- **Elevated rates of soil carbon storage**
- **Superior genotypes replace existing clones**

North Central Poplar Breeding

Duluth, MN (UMN NRRI) (B. McMahon)
St. Paul, MN (UMN TC) (C. Mohn)
Ames, IA (ISU) (R. Hall)
Rhinelander, WI (USFS) (D. Riemenschneider)
Urbana-Champaign, IL (UI UC) (J. Jokela)

~40,000
+ ~48,000
~88,000 Genotypes

+ Previous
>100,000 Genotypes
Why Short Rotation Woody Crops?

Sustainability

Short rotation woody crops are one of the most sustainable sources of biomass, provided we strategically place them in the landscape & use cultural practices that...

- Conserve soil & water
- Recycle nutrients
- Maintain genetic diversity

*Uniformity within
*Diversity among

Potential Limitations to Success

- Intensive management & high costs during establishment
- Elevated water usage
- Failure to match clones with sites
- History of land use (i.e., social resistance to monocultures)
- Competition for land & price of land
- Competition among end uses
- Harvest efficiencies
- Difficulties in drying the wood
- Loss of research funding
Poplar Genetics Research

- **Northeastern - 1920’s**
  1924 to 1939: 13,000 hybrids

- **North Central (IL) - 1950’s**

- **North Central (MN) - 1960’s**

- **Pacific Northwest - 1960’s**

- **USFS Lake States**
  1950: LSFES rejected Schreiner’s idea for collaborative study
  1983: Poplar genetics research began
Traits of Interest

- Rooting Ability
- Composition
- Degradability
- Pest / Disease Resistance

Biomass

![Graph showing biomass comparison between Aspen, Common Poplar, and Exhibition Poplar](Image)

- m³ ha⁻¹ yr⁻¹
- cd (dt) ac⁻¹ yr⁻¹
Short Rotation Woody Crops

<table>
<thead>
<tr>
<th>Region</th>
<th>Rotation (yrs)</th>
<th>Productivity (dt ac⁻¹ yr⁻¹)</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Northwest</td>
<td>7 to 15</td>
<td>4 to 6</td>
<td>Solid</td>
</tr>
<tr>
<td>North Central</td>
<td>10 to 12</td>
<td>3 to 5</td>
<td>Pulp</td>
</tr>
<tr>
<td>Mississippi Valley</td>
<td>8 to 10</td>
<td>2 to 3</td>
<td>Pulp</td>
</tr>
<tr>
<td>Canada</td>
<td>12 to 18</td>
<td>1 to 4</td>
<td>Pulp</td>
</tr>
</tbody>
</table>

Poplar Energy Crops

Model Output

- Product quantity
- Consumed resources
- Costs
- Emissions
- Carbon

Own: $1,000 to $2,500 ac\(^{-1}\)

Rent: $70 to $200 ac\(^{-1}\)

Own: $400 to $3,000 ac\(^{-1}\)
Poplar Energy Crops

Model Output

- Product quantity
- **Consumed resources**
- Costs
- Emissions
- Carbon

![Map of the United States with highlighted states for poplar energy crops]

![Image of poplar trees]
Consumed Resources / Costs

- Site preparation
- Stand establishment
- Stand management
- Timber harvest

Equipment (leveling, diskng, tilling, etc.) $60 to $100 ac\textsuperscript{-1}
Pre-emergent herbicide $30 to $40 ac\textsuperscript{-1}
Consumed Resources / Costs

- Site preparation
- Stand establishment
- Stand management
- Timber harvest

**Planting Stock**

Evaluate trade-offs
* Cutting cost
* Trees planted
* Need for machine
* Survival

**Unrooted**

**Rooted**
Consumed Resources / Costs

- Site preparation
- Stand establishment
- Stand management
- Timber harvest

- **Unrooted planting stock**
  - $0.10 to $0.12 ctg\(^{-1}\) (internal production)
  - $0.20 to $0.30 ctg\(^{-1}\) (wholesale purchase)

- **Spacing / density varies**
  - NC fiber: 10’ × 10’ (436 trees ac\(^{-1}\))
  - PNW bioenergy: 10’ × 3’ (1452 trees ac\(^{-1}\))

- **Hand planting with dibble bar**
  - 4,000 to 5,000 trees d\(^{-1}\)  $40.00 ac\(^{-1}\)
Consumed Resources / Costs

- Site preparation
- Stand establishment
- **Stand management**
- Timber harvest

- **Field cultivation**
  - NC & PNW: > $40 ac⁻¹

- **Fertilizer**
  - PNW bioenergy: N, 3 yr × 30 lb ac⁻¹ yr⁻¹ ($120 ac⁻¹)
  - P, 1 yr × 10 lb ac⁻¹ ($30 ac⁻¹)

- **Herbicide**
  - PNW bioenergy – total rotation: $80.00 ac⁻¹

- **Insecticide**
  - PNW bioenergy – total rotation: $150.00 ac⁻¹

- **Irrigation**
  - PNW bioenergy – total rotation: $300.00 ac⁻¹

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Highly variable in North Central region
Consumed Resources / Costs

- **Site preparation**
- **Stand establishment**
- **Stand management**
- **Timber harvest**

**Methods**
- Mechanized – fell, bunch, skid, chip, load, transport: $1000 ac⁻¹
- Some hand felling

**Haul distance**
- NC fiber: maximum 75 miles one way
- PNW bioenergy: average 30 miles round trip

**Rotation age**
- NC fiber: 10 to 12 years
- PNW bioenergy: 3 years coppice cycle for 5 rotations

**Material**
- NC fiber: winter harvest, leaves left on ground
- PNW bioenergy: harvest all aboveground material
## Poplar Biomass Production Costs

<table>
<thead>
<tr>
<th>Region</th>
<th>Farm (NPV)</th>
<th>Harvest (NPV)</th>
<th>Total (NPV)</th>
</tr>
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<tbody>
<tr>
<td>Pacific Northwest</td>
<td>$32</td>
<td>$32</td>
<td>$64</td>
</tr>
<tr>
<td>North Central</td>
<td>$30</td>
<td>$31</td>
<td>$61</td>
</tr>
<tr>
<td>Mississippi Valley</td>
<td>$24</td>
<td>$29</td>
<td>$53</td>
</tr>
</tbody>
</table>

*Growing costs reported at NPV (6.5% discount rate) per dry metric ton, inclusive of the cost of land rent, site preparation, planting stock, planting, & crop care through rotation.

“There is no silver bullet solution to rising fuels prices & addressing the energy challenge, but rather biofuels are part of a shotgun effort which also includes other alternative energy sources, conservation & more efficient energy use.”

-Dr. Gale A. Buchanan
Chief Scientist, USDA
Under Secretary for Research, Education, and Economics