An Approach for Siting Poplar Energy Production Systems to Increase Productivity & Associated Ecosystem Services

Ronald S. Zalesny Jr.\(^1\), William L. Headlee\(^2\)
Deahn M. Donner\(^1\), David R. Coyle\(^3\)

\(^1\) US Forest Service, Northern Research Station, Institute for Applied Ecosystem Studies, Rhinelander, WI, 54501, USA

\(^2\) University of Georgia, D.B. Warnell School of Forestry & Natural Resources, Athens, GA, 30602, USA

\(^3\) Iowa State University, Department of Natural Resource Ecology & Management, Ames, IA, 50011, USA
Multiple Uses of Poplars

- **Traditional products**
  Pulpwood, chips (oriented strand board), engineered lumber products, etc.

- **Energy**
  Biofuels, bioenergy, bioproducts

- **Phytotechnologies**
  Phytoremediation, phytovolatization, rhizodegradation, etc.
Ecosystem Services
The benefits people obtain from ecosystems
(Source: http://www.greenfacts.org/glossary/def/ecosystem-services.htm)

**Provisioning Services**
The goods or products obtained from ecosystems

**Regulating Services**
The benefits obtained from an ecosystem’s control of natural processes

**Cultural Services**
The nonmaterial benefits obtained from ecosystems (e.g., values)

**Supporting Services**
The natural processes that maintain the other ecosystem services
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
*4 ha clone⁻¹

Ecosystem Services & Pillars of Sustainability

- Provisioning Services
- Regulating Services
- Supporting Services
- Cultural Services

SUSTAINABILITY

Eco (Ecological) Economic Social Eco (Ecological) Eco (Ecological)
Long-Range Goal

Develop a protocol for identifying suitable testing & deployment sites of poplar energy production systems in the Midwest, USA (& beyond...)
Objectives

1. Identify eligible lands suitable for poplar deployment based on current land use, land ownership, & local soil characteristics
2. Determine temperature-precipitation gradients important to poplar growth
3. Establish sites for field reconnaissance within the suitable lands
4. Assess the validity of the outcomes from 1) & 2) by comparing available databases with field soils data (i.e., QA/QC)
5. Apply a process-based growth model (3-PG) to predict & map poplar productivity within the identified suitable lands
6. Assess the regional sustainability of potential poplar deployment within the eligible lands (current studies)
7. Develop a database of information to guide protocol development & sustainability assessment

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
Objectives

1. Identify eligible lands suitable for poplar deployment
2. Determine temperature-precipitation gradients
3. Conduct field reconnaissance
4. Assess the validity of the outcomes from 1) & 2)
5. Predict & map poplar productivity
6. Assess the regional sustainability of poplar deployment
7. Develop a database of information

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
Map Development

Constraints Considered

- Land cover class
- Land ownership
- Available water storage capacity
- Water deficit (P – PET)
- Soil texture
- Precipitation / temperature
- Flood frequency
- Depth to bedrock
- Patch size

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
## Primary Constraints

<table>
<thead>
<tr>
<th>CONSTRAINTS</th>
<th>DEFINITION OF CONSTRAINTS USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Land Cover Dataset (NLCD 2001)</td>
<td>Grassland/Herbaceous, Pasture Hay, Cultivated Crops</td>
</tr>
<tr>
<td>GAP Stewardship 2008 (Land Ownership)</td>
<td>Federal, Tribal, State, County (excluded)</td>
</tr>
<tr>
<td>Available Water Storage Capacity (SSURGO)</td>
<td>≥7 cm (assuming 0 to 50 cm depth, 0.15 fraction available water)</td>
</tr>
<tr>
<td>Soil Texture (SSURGO)</td>
<td>Clay Loam, Coarse Sandy Loam, Coarse Silty, Fine Sandy Loam, Gravelly Loam, Gravelly Sandy Loam, Loam, Loamy Coarse Sand, Loamy Sand, Mixed, Sandy Clay Loam, Sandy Loam, Sandy Over Loam, Silt Loam, Silty, Silty Clay Loam, Very Fine Sandy Loam</td>
</tr>
</tbody>
</table>
Obj. 1: Eligible Lands
- 11.2 million ha
  MN = 7.5 million ha
  WI = 3.7 million ha
- 30.8% of study area
- Land cover
  79.1% cultivated crops
  17.8% pasture/hay
  3.1% grassland
Obj. 3: Field Reconnaissance

- 143 sites
  - MN = 84
  - WI = 59
- Most slopes 5% or less
- Acceptable drainage
  - MN = 70%
  - WI = 98%
- Acceptable erosion
  - MN = 81%
  - WI = 85%
- Negligible stoniness

<table>
<thead>
<tr>
<th>Crop</th>
<th>MN</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>19%</td>
<td>49%</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>8%</td>
<td>17%</td>
</tr>
<tr>
<td>Soybean</td>
<td>13%</td>
<td>19%</td>
</tr>
<tr>
<td>Poplar</td>
<td>40%</td>
<td>8%</td>
</tr>
<tr>
<td>Other</td>
<td>20%</td>
<td>7%</td>
</tr>
</tbody>
</table>
Soil Evaluations

Field

- Soil structure
- Presence of horizons / gleying

Laboratory

- Soil texture*
- pH*
- Nitrogen, Carbon
- Base Cations (Ca, Mg, K, Na)
- CEC*, ECEC

*Used for comparison with SSURGO data (QA/QC)

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
3-PG Productivity Modeling

**SSURGO Soils Data** *(Headlee et al. 2012 – STATSGO)*
- Soil texture
- Available soil water in top 100 cm
- Minimum depth to water table

**NARR Climate Data** *(Headlee et al. 2012 – Weather Station)*
- Surface precipitation
- Temperature (2-m; surface)
- Downward shortwave radiation
3-PG Productivity Scenarios

1. Generalist clones
   - Default settings from Headlee et al. (2012)
   - SSURGO soils data

2. Specialist clones (SITE)
   - Default settings from Headlee et al. (2012)
   - Optimum temperature for growth set equal to each site’s mean maximum growing season temperature (June – August)
   - Field soils data

3. Specialist clones (SSURGO)
   - Default settings from Headlee et al. (2012)
   - Optimum temperature for growth set equal to each site’s mean maximum growing season temperature (June – August)
   - SSURGO soils data

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
3-PG Productivity Scenarios

1. Generalist clones
   - Default settings from Headlee et al. (2012)
   - SSURGO soils data

2. Specialist clones (SITE)
   - Default settings from Headlee et al. (2012)
   - Optimum temperature for growth set equal to each site’s mean maximum growing season temperature (June – August)
   - Field soils data

3. Specialist clones (SSURGO)
   - Default settings from Headlee et al. (2012)
   - Optimum temperature for growth set equal to each site’s mean maximum growing season temperature (June – August)
   - SSURGO soils data

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
Poplar Productivity Across Study Area

Across states & scenarios
Range: 9.5 – 11.9 dry Mg ha\(^{-1}\) yr\(^{-1}\)
Mean: 10 dry Mg ha\(^{-1}\) yr\(^{-1}\)

Within states
WI: 11.2 dry Mg ha\(^{-1}\) yr\(^{-1}\)
MN: 10.6 dry Mg ha\(^{-1}\) yr\(^{-1}\)

Within scenarios
Specialist (SITE): 11.6 dry Mg ha\(^{-1}\) yr\(^{-1}\)
Specialist (SSURGO): 11.4 dry Mg ha\(^{-1}\) yr\(^{-1}\)
Generalist: 9.7 dry Mg ha\(^{-1}\) yr\(^{-1}\)
Poplar Productivity Within Eligible Lands

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
Poplar Productivity Within Eligible Lands

Specialist (SSURGO)
30 × 30 m resolution

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.
Contribution of Poplar Biomass?

Table 5
Total standing aboveground dry biomass (Tg) of natural forests on private lands in Minnesota and Wisconsin, USA (2007 to 2011; DBH > 2.54 cm) (data from Woudenberg et al., 2011) (A.) and potential of poplar on suitable lands at the end of a 10-year rotation as predicted using three yield scenarios with 3-PG (B.).

(A.)

<table>
<thead>
<tr>
<th>Tree Species Group</th>
<th>Minnesota</th>
<th>Wisconsin</th>
<th>Minnesota + Wisconsin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottonwood and Aspen</td>
<td>44.0</td>
<td>33.4</td>
<td>77.5</td>
</tr>
<tr>
<td>Noncommercial Hardwoods</td>
<td>3.0</td>
<td>4.8</td>
<td>7.9</td>
</tr>
<tr>
<td>Commercial Hardwoods</td>
<td>130.7</td>
<td>295.5</td>
<td>426.2</td>
</tr>
<tr>
<td>Softwoods</td>
<td>34.4</td>
<td>68.1</td>
<td>102.5</td>
</tr>
<tr>
<td>Total</td>
<td>212.2</td>
<td>401.8</td>
<td>614.0</td>
</tr>
</tbody>
</table>

(B.)

<table>
<thead>
<tr>
<th>Yield Scenario</th>
<th>Minnesota</th>
<th>Wisconsin</th>
<th>Minnesota + Wisconsin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generalist (SSURGO)</td>
<td>712.5</td>
<td>363.5</td>
<td>1,087.3</td>
</tr>
<tr>
<td>Specialist (Site)</td>
<td>847.5</td>
<td>441.4</td>
<td>1,300.2</td>
</tr>
<tr>
<td>Specialist (SSURGO)</td>
<td>825.0</td>
<td>441.4</td>
<td>1,277.8</td>
</tr>
</tbody>
</table>

\(^{a}\)Commercial hardwood species include: ash, basswood, beech, black walnut, hard maple, hickory, red oaks, soft maple, white oaks, and yellow birch (Woudenberg et al., 2011).

\(^{b}\)Softwood species include: balsam fir, eastern hemlock, eastern white and red pines, jack pine, and spruces (Woudenberg et al., 2011).

\(^{c}\)See Materials and Methods for details about the three yield scenarios tested with 3-PG.
Integrated Studies: Regional Sustainability

Productivity Modeling

Enterprise Budgets

Landowner Preferences

Carbon Implications

County Productivity Groups

- 12 Counties
- Low, Medium, High

Genotype Groups

- Specialist, Generalist

Crop Histories

- Corn, CRP, Poplar

Productivity Levels

- Low, Medium, High

Genotype Groups

- Specialist, Generalist
Integrated Studies: Regional Sustainability

Productivity Modeling

Enterprise Budgets

Landowner Preferences

Carbon Implications

- Soil carbon sequestration & greenhouse gas emissions
- Aboveground carbon stocks
- Biochemical conversion to liquid fuels
Short Rotation *Populus*:
A Database of North American Literature,
1989 - 2011

Home

The first poplar database reported literature published from 1854 to 1963 (Farmer and McNight 1967), the second from 1964 to 1974 (Hart 1976), and the last from 1975 to 1980 (Ostry and Henderson 1990). Given that these databases are outdated, and the number of forestry/bioenergy related journals has increased dramatically (along with subsequent publications), it was important to develop the current database to include literature from 1989 to 2011. In addition to compiling the information into this database, our objectives are to encourage publication in peer-reviewed journals and to enhance collaborations with partners outside the poplar community.


The constraints of the database include: only peer-reviewed manuscripts that are focused on poplars, cottonwoods, aspens, and their hybrids grown as short rotation woody crops, research conducted in North America, and at least one topic area.

The database contains 864 unique citations that are cross-listed among up to three topic areas, resulting in 1,395 total entries.

Funding for database development came from the Wisconsin Focus on Energy Environmental and Economic Research and Development Program, as well as the U.S. Forest Service, Northern Research Station and The Poplar Council of the United States.

www.poplardatabase.com
Short Rotation *Populus*:
A Database of North American Literature, 1989 - 2011

**Topic Area Descriptions**

**Cell & Tissue Culture**
Proliferation of tissues from callus, axiles, nodules, buds, etc.

**Conservation**
Sustainability of water, soil, and wildlife resources.

**Diseases**
Major stem and leaf diseases impacting health and productivity.

**Economics & Social Science**
Financial feasibility of growing and harvesting poplars; public perception.

**General**
Advantages and disadvantages of short rotation poplar crops; technological innovations.

**Genetics**
Quantitative, molecular, and population genetics of pure species and hybrids.

**Global Change**
Climate change effects on tree establishment and growth.

**Growth & Productivity**
Below- and above-ground growth of individual trees and plantations, including yield predictions.

**Insects & Mites**
Major insects and mites impacting health and productivity.

**Physiology**
Internal processes regulating plant growth and development.

**Phytotechnologies**
Use of the trees for remediation of contaminated soil, water, and sediment.

**Silviculture**
Production management systems, including irrigation and fertilization.

**Wood Science & Wood Products**
Wood properties and conversion technologies; consumer products.
New publication in press

- Worldwide overview
- Latest knowledge and technology
- Research and implementation
- Characteristics, cultivation & use
- Issues, problems and trends
- 13 chapters
- 70 contributing authors
- from 15 countries in 5 continents
- >500 pages
- Nearly 2500 references
- Fully illustrated (b/w & color)
- Co-publication of CABI & FAO
- Available early 2013

PICK UP A FLYER
Thank you!

Acknowledgements
I thank the conference organizing committee for the opportunity to speak.

Contact Information
Dr. Ronald S. Zalesny Jr.
Team Leader, Genetics and Energy Crop Production
Research Plant Geneticist
U.S. Forest Service
Northern Research Station
Institute for Applied Ecosystem Studies
5985 Highway K
Rhineland, WI 54501, USA

Phone: +1 715 362 1132
Cell: +1 715 490 1997
Fax: +1 715 362 1166
rzalesny@fs.fed.us
http://www.nrs.fs.fed.us/people/Zalesny
http://www.nrs.fs.fed.us/units/iaes/focus/energy_climate_genetics/
Table 1
Classification scheme for assigning soils to default 3-PG soil classes. The SSURGO soil textures were used for base map development, while the site textures were those sampled from the 143 field plots and used for QA/QC analyses.

<table>
<thead>
<tr>
<th>3-PG Soil Class</th>
<th>SSURGO Texture</th>
<th>Site Texture</th>
<th>Approximate Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay (C)</td>
<td>None</td>
<td>Silty clay</td>
<td>&gt;40% clay</td>
</tr>
<tr>
<td>Clay Loam (CL)</td>
<td>Clay loam, fine loam, sandy clay loam, silty clay loam</td>
<td>Clay loam, sandy clay loam, silty clay loam</td>
<td>20-40% clay</td>
</tr>
<tr>
<td>Sandy Loam (SL)</td>
<td>Coarse loam, coarse sandy loam, coarse silt, fine sandy loam, fine silt, gravelly loam, gravelly sandy loam, gravelly coarse sandy loam, gravelly fine sandy loam, gravelly silt loam, loam, sandy loam, sandy over loam, silt loam, silt, very fine sandy loam, very gravelly loam, very gravelly sandy loam</td>
<td>Loam, sandy loam, silt, silt loam</td>
<td>&lt;20% clay, &lt;80% sand</td>
</tr>
<tr>
<td>Sand (S)</td>
<td>Loamy coarse sand, loamy fine sand, loamy very fine sand, loamy sand</td>
<td>Loamy sand, sand</td>
<td>&lt;20% clay, &gt;80% sand</td>
</tr>
</tbody>
</table>

*aSuitable soil textures for base map development were based on those deemed highly suitable and suitable by Schroeder et al. (2003); those classified as marginally suitable (e.g., with >40% clay content) were not considered in the current study.*
Table 2
Descriptions of soil drainage and erosion risk classes (from Schroeder et al., 2003).

<table>
<thead>
<tr>
<th>Drainage Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapidly drained</td>
<td>The soil moisture content seldom exceeds field capacity in any horizon except immediately after water additions (soils are free from gleying throughout the profile)</td>
</tr>
<tr>
<td>Well drained</td>
<td>The soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year (soils are free from mottling in the upper 1 m)</td>
</tr>
<tr>
<td>Moderately well drained</td>
<td>The soil moisture in excess of field capacity remains for a small but significant period of the year (soils are mottled in the bottom of the B and C horizons)</td>
</tr>
<tr>
<td>Imperfectly drained</td>
<td>The soil moisture in excess of field capacity remains in subsurface layers for moderately long periods of the year (soils are mottled in the B and C horizons)</td>
</tr>
<tr>
<td>Poorly drained</td>
<td>The soil moisture in excess of field capacity remains in all horizons for a large part of the year (soils are usually very strongly gleyed)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Erosion Class</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low</td>
<td>Good soil management and average growing conditions will produce a crop with sufficient residue to protect these soils from erosion</td>
</tr>
<tr>
<td>Low</td>
<td>Good soil management and average growing conditions may produce a crop with sufficient residue to protect these soils against erosion</td>
</tr>
<tr>
<td>Medium</td>
<td>Average growing conditions may not supply adequate residue to protect these soils against wind erosion, and enhanced soil management practices are necessary to control erosion</td>
</tr>
<tr>
<td>High</td>
<td>Average growing conditions will not provide sufficient residue to protect these soils against erosion</td>
</tr>
<tr>
<td>Very high</td>
<td>These soils should not be used for annual cropping, but rather for pasture and forage crops which will protect the surface from severe degradation</td>
</tr>
</tbody>
</table>

Zalesny, R.S. Jr., et al. 2012. An approach for siting poplar energy production systems to increase productivity and associated ecosystem services. For Ecol Manage 284:45-58.