Integrating Phytotechnologies with Energy Crop Production for Biofuels, Bioenergy, & Bioproducts

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Research Themes:
1) Forest Disturbance Processes
2) Providing Clean Air & Water
3) Sustaining Forests
4) Urban Natural Resource Stewardship
5) Natural Resources Inventory & Monitoring

Genetics & Energy Crops
Landscape Ecology
Physiology
Our objective is to use the link between energy, climate, & tree genetics to:
1) develop fast-growing tree crops as energy feedstocks;
2) develop sustainable forest biomass removal strategies;
3) understand climate change effects on natural & plantation forests;
4) fill critical knowledge gaps in 1), 2), & 3).

- Short rotation woody crops for energy, fiber, &
  PHYTOTECNOLOGIES
- Ecological sustainability of using forest residues for energy
- Carbon sequestration & climate change adaptation of conifers
Lake States Genetics Research

- Forest Service studies began in 1927
- All major conifer species
  - Range-wide & regional collections
  - Common garden tests
  - Community approach (states, universities)
- Short rotation crops began ~1970,
  with emphasis on limits to productivity
  - Focus on species & varieties
  - Focus on agricultural-type inputs
  - Advantage of hybrid poplars proven
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
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) (R. Zalesny)
Urbana-Champaign, IL (UI UC) (J. Jokela)

~40,000 + ~48,000 + Previous

~88,000 Genotypes

>100,000 Genotypes
### Crop Development Strategy

**Energy & Fiber**

<table>
<thead>
<tr>
<th>Species</th>
<th>Rooting</th>
<th>Pest &amp; Disease</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. deltoides</em></td>
<td>E</td>
<td>G</td>
<td>G</td>
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<tr>
<td><em>P. trichocarpa</em></td>
<td>VG</td>
<td>VB</td>
<td>G</td>
</tr>
<tr>
<td><em>P. nigra</em></td>
<td>G</td>
<td>B</td>
<td>G</td>
</tr>
<tr>
<td><em>P. suaveolens</em></td>
<td>VG</td>
<td>B</td>
<td>G</td>
</tr>
<tr>
<td>Hybrids</td>
<td>G</td>
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</table>
Traits of Interest

Rooting Ability

* Composition
* Degradability

Pest / Disease Resistance

Yield

m³ ha⁻¹ yr⁻¹

Aspen  Com. Poplar  Exp. Poplar

0 10 20 30 40 50 60 70

cd (dt) ac⁻¹ yr⁻¹

0 1 2 3 4 5 6 7 8
Energy

- Biofuels
- Bioenergy
- Bioproducts
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


Applications: Energy

Forest bioenergy & bioproducts supply chain
Why Poplars?

- 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 Poplars?

<table>
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<tr>
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<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

\[ >10.0 \text{ dt ac}^{-1} \text{ yr}^{-1} \]

Depends on genotype × environment interactions
Why Poplars?

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

Regional 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

Energy Crops ↔ Phytotechnologies

- Incorporating intensive forestry with waste management for the application of phytotechnologies

Utilizing sustainable recycling of waste waters as irrigation & fertilization for alternative biomass feedstock production systems
Phytotechnologies

- A common protocol has been to utilize a limited number of readily-available genotypes with decades of deployment in other applications (e.g. fiber, windbreaks)

- It is possible to increase the success of phytotechnologies with proper genotypic screening & selection, followed by field establishment of favorable clones

Phyto-Recurrent Selection
# Crop Development Strategy

## Phytotechnologies

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<td><em>P. maximowiczii</em></td>
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<td>B</td>
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Practical Implications

- Short rotation woody crops are a viable option for helping to meet our nation’s energy needs.
- Proper genotypic selection is necessary for successful deployment of ecologically-sustainable phytotechnologies.
- It is possible to combine intensive forestry with waste management to achieve dual goals of energy production & environmental benefits.
Ecological & Social Implications

- Soil health
- Water quality
- Carbon
- Land use shifts
Energy Crop Deployment & Environmental Sustainability

- Merge our knowledge of poplar biology with large-scale spatial analysis to predefined zones of potential plant adaptation that are ecologically sustainable & economically feasible across the landscape.

- Develop a GIS-based spatial analysis protocol to identify candidate core areas for potential establishment, based on key climatic & soil properties, as well as land ownership & use constraints.
Energy Crop Deployment & Environmental Sustainability

1. Develop coarse & fine resolution digital maps of environmental & sociopolitical constraints to identify candidate core areas

2. Construct database of poplar growth & development, apply information within areas

3. Evaluate land-use, soil health, & water quality changes within areas

4. Synthesize results to assess potential impacts of deploying poplars across region

Carbon sequestration potential

Energy from Native Forests

Assessing the environmental sustainability & capacity of forest-based biofuel feedstocks within the Lake States region  J. Bradford, S. Fraver, R. Kolka, B. Palik + (Univ. WI, MN, MO)

Impacts of woody biomass harvesting on saproxylic communities, nutrient availability, & productivity in aspen ecosystems  J. Bradford, S. Fraver, R. Kolka, B. Palik + (Univ. MN)

Wood energy developments in the Northeast  J. Wiedenbeck, B. Adams + (PSU)

Developing biofuels in the Appalachians: what are the limits of sustainability?  B. Adams, J. Wiedenbeck + (WVU)

Guidelines for integrating biomass marketing opportunities into restoration of degraded stands  S. Stout + (PSU)

A full life-cycle carbon calculator for forest landowners & policy makers in the Northeast  M. Twery

NED decision support systems for forest management for multiple values  M. Twery

Characterizing lessons learned from federal biomass removal projects  P. Jakes

Forest biomass & carbon estimation, information, & data delivery  L. Heath

Changes in the Lake States pellet industry from 2005 to 2008  B. Luppold

Impacts of harvesting forest residues for bioenergy on nutrient cycling & community assemblages in northern hardwood forests  D. Donner, R. Zalesny + (UW, USGS, R9)

Soil carbon & nutrient cycling in northern hardwood forests  R. Zalesny, D. Donner + (UW, USGS, R9)
Energy from Tree Plantations

Influence of alternative biomass cropping systems on short-term ecosystem processes  R. Kolka + (ISU)

Breeding & selecting poplar for biofuels, bioenergy, & bioproducts  
R. Zalesny + (ISU, MSU, Univ. WI, MN)

Biofuels, bioenergy, & bioproducts from short rotation woody crops  
R. Zalesny + (ISU, MSU, Univ. WI, MN)

Land-use, soil health, & water quality changes with woody energy crop production in Wisconsin & Minnesota  R. Zalesny, D. Donner

Ecological assessments of bioenergy feedstocks from plantations & forests in the Midwest  
R. Zalesny + (ISU, MSU)

Carbon sequestration potential of poplar energy crops at regional scales  R. Zalesny + (ISU, MSU)

High productivity & low recalcitrance poplar for biochemical conversion  R. Zalesny + (FPL, ISU, MSU)

Sustainable production of woody energy crops with associated environmental benefits  R. Zalesny

Development of technical innovations to reduce impacts of invasive species & enhance energy crop production  
R. Zalesny
“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 (retired)
Chief Scientist, USDA
Under Secretary for Research, Education, and Economics
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
1. Joined all county SSURGO soil data into state coverage.
2. Ran zonal statistics based off an unique soil id & the National Land Cover Dataset (NLCD) grid for WI.
4. Erased out State Lands, Federal Lands, Tribal Lands, & County Lands using the GAP land cover classification map.
5. Joined Land Capability Class (LCC) data to the attribute table based off the soil map unit key. Identified Prime (classes 1-3) & Marginal (classes 4-7) lands.
6. Joined Soil Rental Rate (SRR) information into the attribute table, based on SSURGO data.