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

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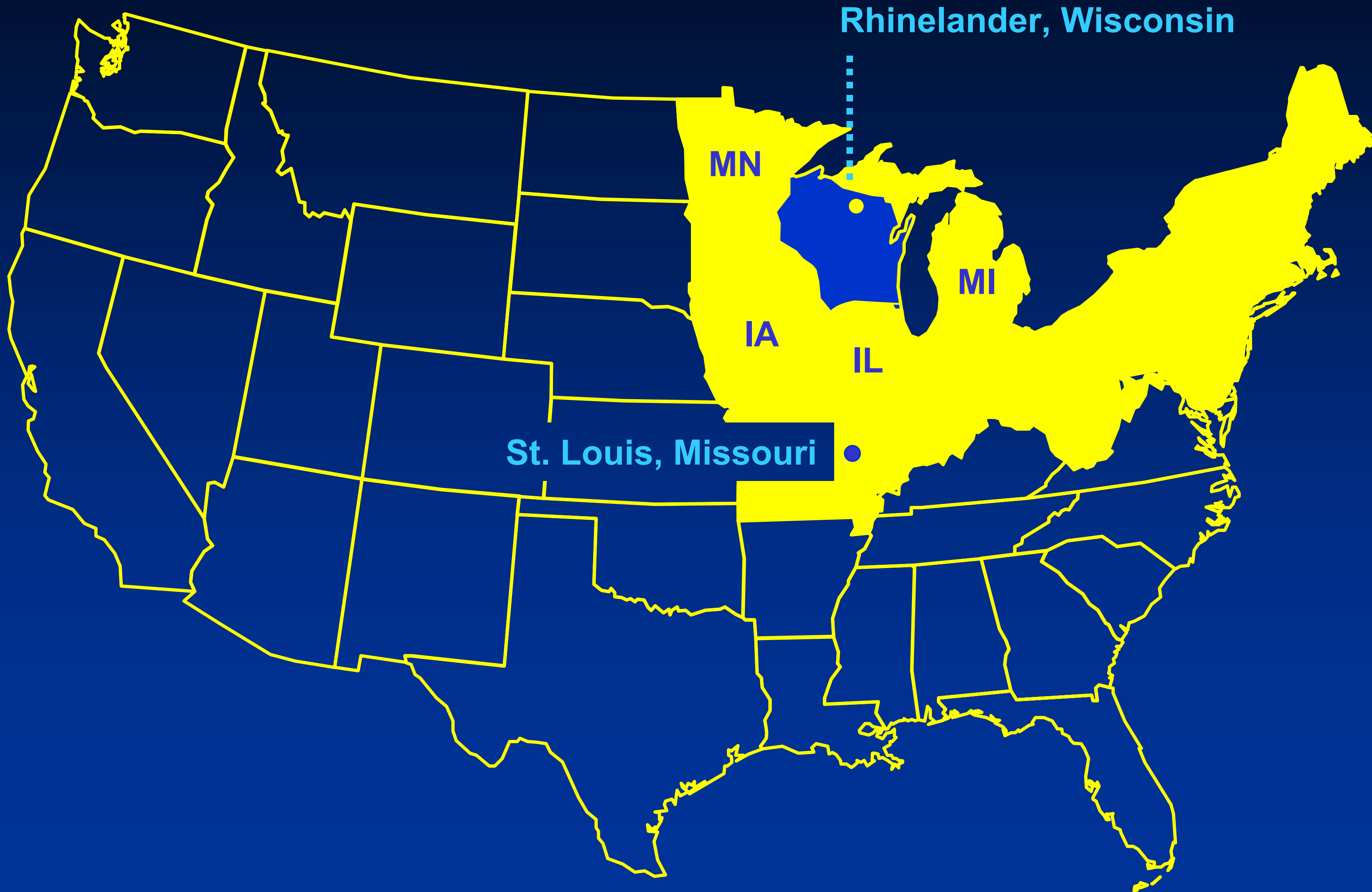
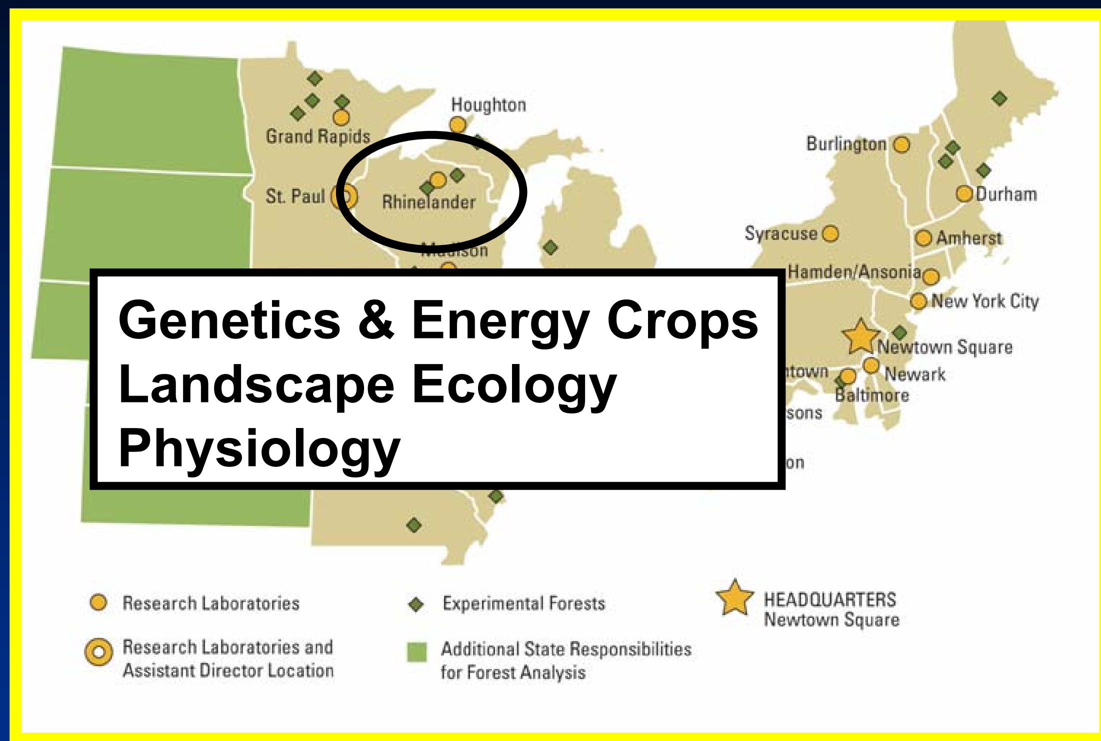
Northern Research Station



Northern Research Station



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 Crop Production Unit

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, & **PHYTOTECHNOLOGIES**
- 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**

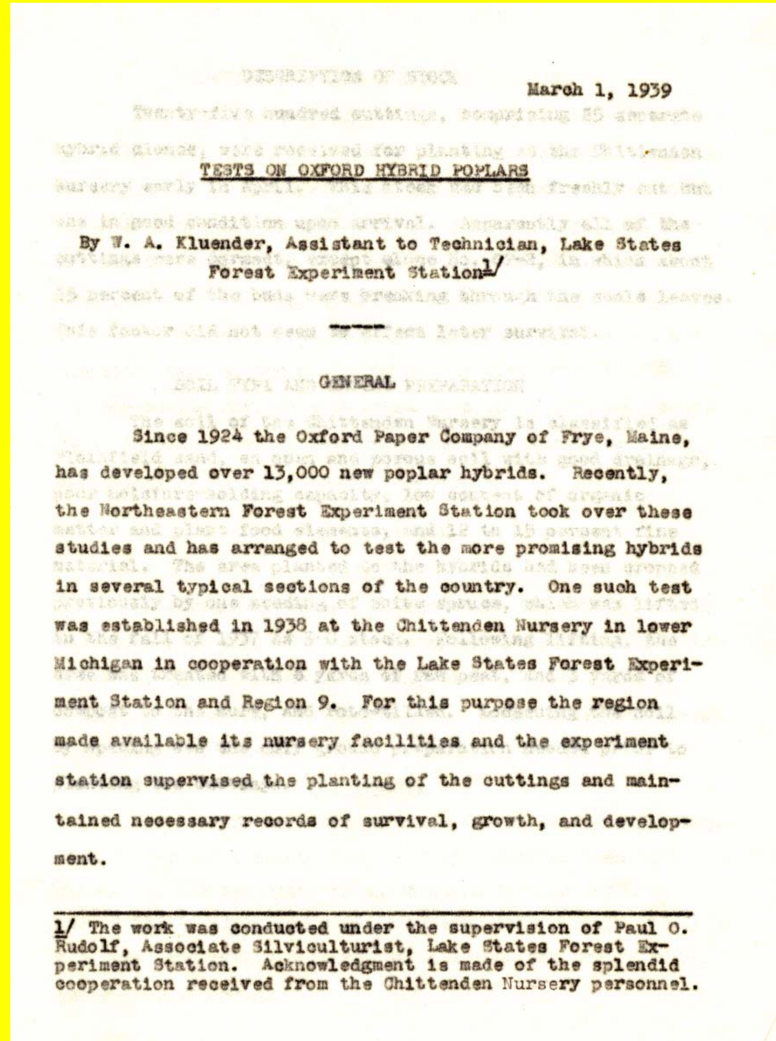
  1924 to 1939: 13,000 hybrids

- **North Central (IL) - 1950's**
- **North Central (MN) - 1960's**
- **Pacific Northwest - 1960's**
- **USFS Lake States**

  1937 - 1940: 25 Oxford Paper Company clones planted in lower Michigan

  1950: LSFES rejected Schreiner's idea for collaborative study

  1983: Poplar genetics research began



March 1, 1939

TESTS ON OXFORD HYBRID POPLARS

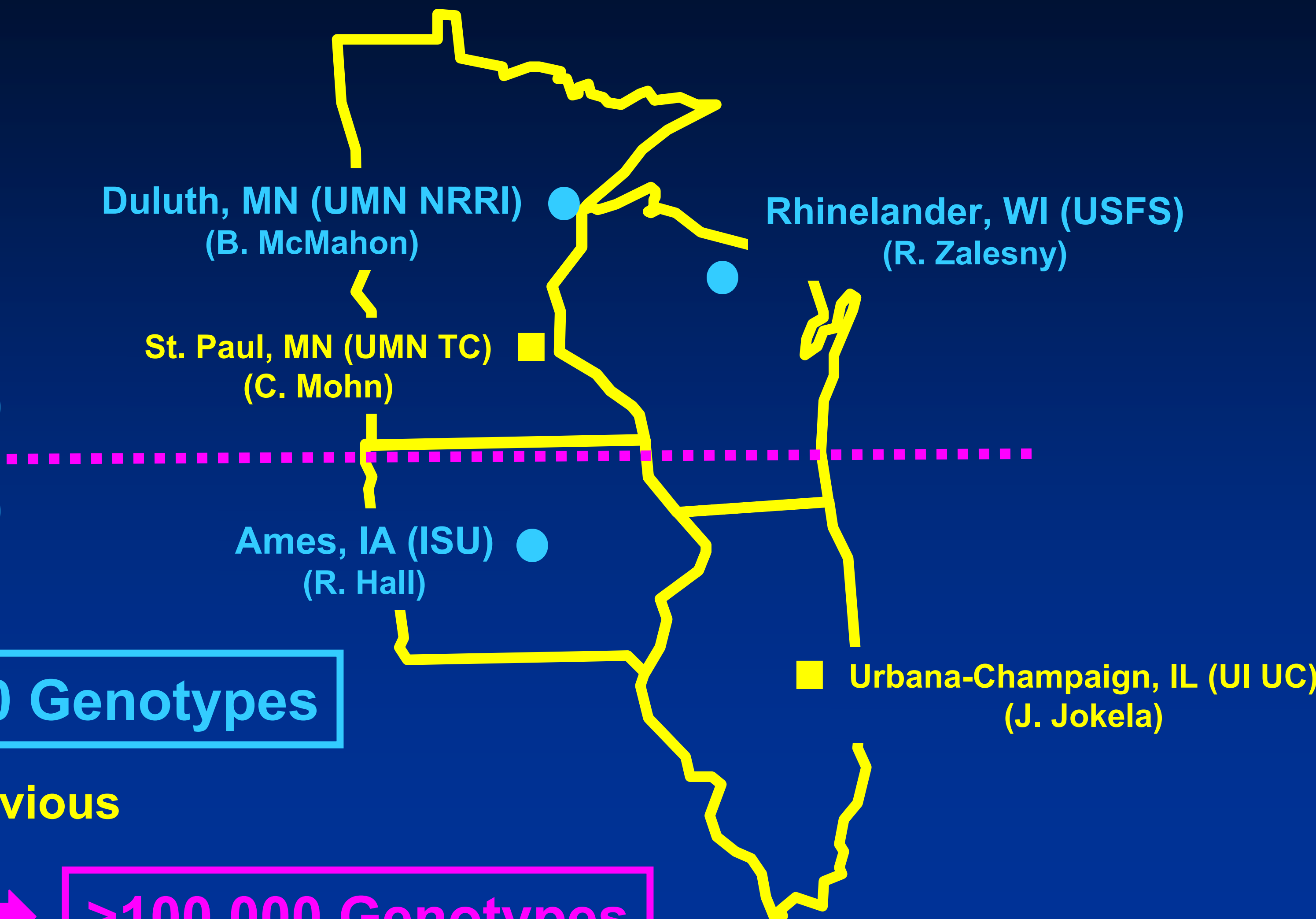
By W. A. Kluender, Assistant to Technician, Lake States Forest Experiment Station 1/

GENERAL

Since 1924 the Oxford Paper Company of Frye, Maine, has developed over 13,000 new poplar hybrids. Recently, the Northeastern Forest Experiment Station took over these studies and has arranged to test the more promising hybrids in several typical sections of the country. One such test was established in 1938 at the Chittenden Nursery in lower Michigan in cooperation with the Lake States Forest Experiment Station and Region 9. For this purpose the region made available its nursery facilities and the experiment station supervised the planting of the cuttings and maintained necessary records of survival, growth, and development.

1/ The work was conducted under the supervision of Paul O. Rudolf, Associate Silviculturist, Lake States Forest Experiment Station. Acknowledgment is made of the splendid cooperation received from the Chittenden Nursery personnel.

North Central Poplar Breeding



~40,000
+
~48,000

~88,000 Genotypes

+ Previous

>100,000 Genotypes

Crop Development Strategy

Energy & Fiber

	Rooting	Pest & Disease	Yield
P. deltoides	E	G	G
P. trichocarpa	VG	VB	G
P. nigra	G	B	G
P. suaveolens	VG	B	G
Hybrids	G	E	VG
Adv. Generation	G?	G?	G?

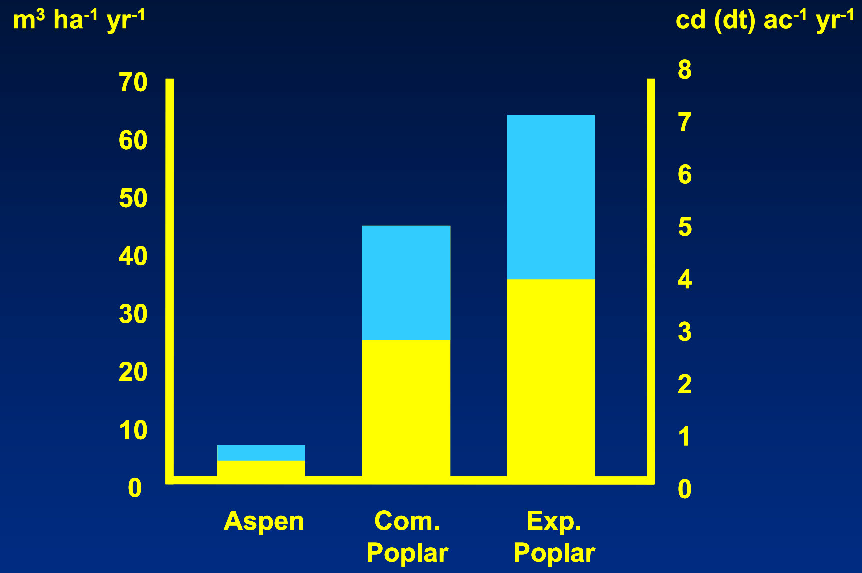
Traits of Interest

Rooting Ability

* Composition
* Degradability

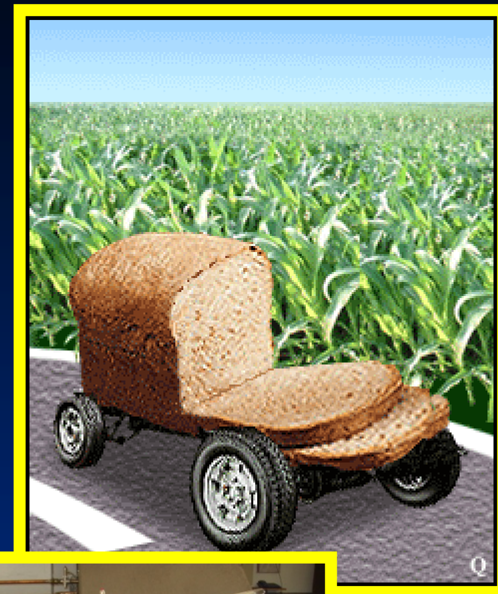
Pest / Disease Resistance

Yield



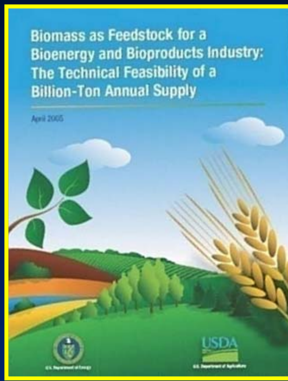
Energy

- **Biofuels**
- **Bioenergy**
- **Bioproducts**

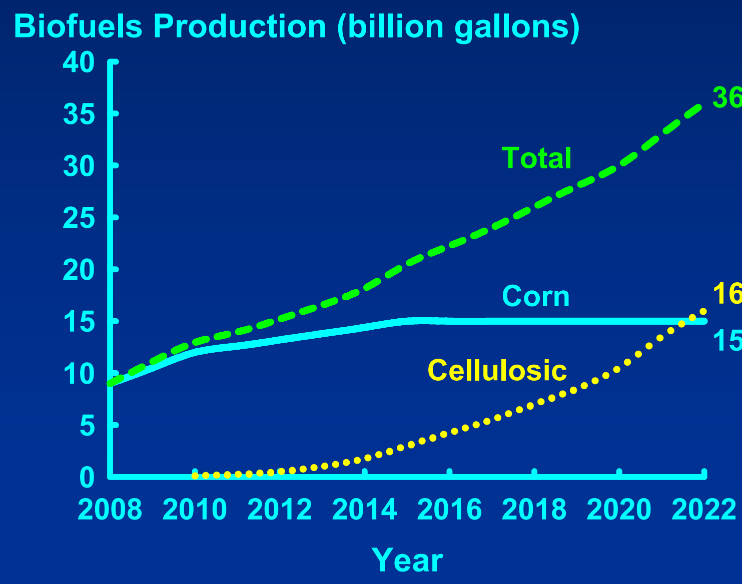


Renewable Fuel Standard

Energy Independence & Security Act of 2007



- 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

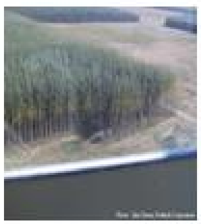


Source: Perlack, R.D. 2005. Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply. DOE-USDA. DOE/GO-102995-2135. ORNL/TM-2005/66

Source: Renewable Fuels Association. http://www.ethanolrfa.org/resource/standard

Applications: Energy

Feedstock Production → Feedstock Logistics → Biofuels & Bioproducts Production → Biofuels & Bioproducts Distribution → Biofuels & Bioproducts End Use



Short Rotation Woody Crops

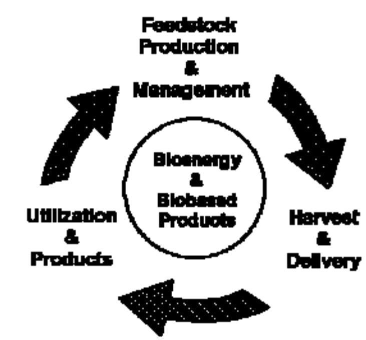
Harvesting
Collecting
Transportation

Manufacturing
Co-firing
Combustion
Gasification
Hydrolysis
Digestion
Pyrolysis
Extraction
Separation

Ethanol
Other Liquid Fuels
Hydrogen
Electricity and Heat
Composites
Specialty Products
New Products
Chemicals
Traditional Products

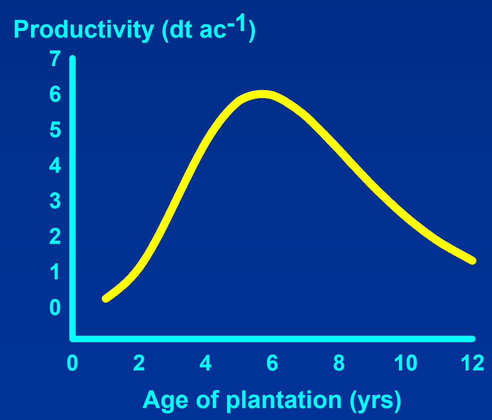
Transportation Fuels
Chemicals
Other Products

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?

	Realized Productivity
Switchgrass	9.0 dt ac^{-1} yr^{-1}
Willow	8.0 dt ac^{-1} yr^{-1}
Poplar	7.0 dt ac^{-1} yr^{-1}

Potential Productivity
>10.0 dt ac^{-1} 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

Cellulose	2 to 36
Willow	13
Poplar	12
Sugar Cane	8
Switchgrass	5.4
Soybean	2.5
Corn	1.34

Sources: 1.) http://ngm.nationalgeographic.com/2007/10/biofuels/biofuels-interactive.
2.) Schmer et al. 2008. Net energy of cellulosic ethanol from switchgrass. PNAS 105(2):464-469.

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**

1990

1994

1996

*Uniformity within
*Diversity among

Source: Hall, R.B. 2008. Woody bioenergy systems in the United States. NRS-GTR-P-31.

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

	Rooting	Pest & Disease	Yield	Other
P. deltoides	E	G	G	?
P. trichocarpa	VG	VB	G	?
P. nigra	G	B	G	?
P. maximowiczii	VG	B	G	?
Hybrids	G	E	VG	?
Adv. Generation	G?	G?	G?	?

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 predefine 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.

Zalesny, R.S. Jr., et al. 2009. Land-use, soil health, & water quality changes w/ woody energy crop production in Wisconsin & Minnesota. WI FOE EERD Proposal.

Energy Crop Deployment & Environmental Sustainability

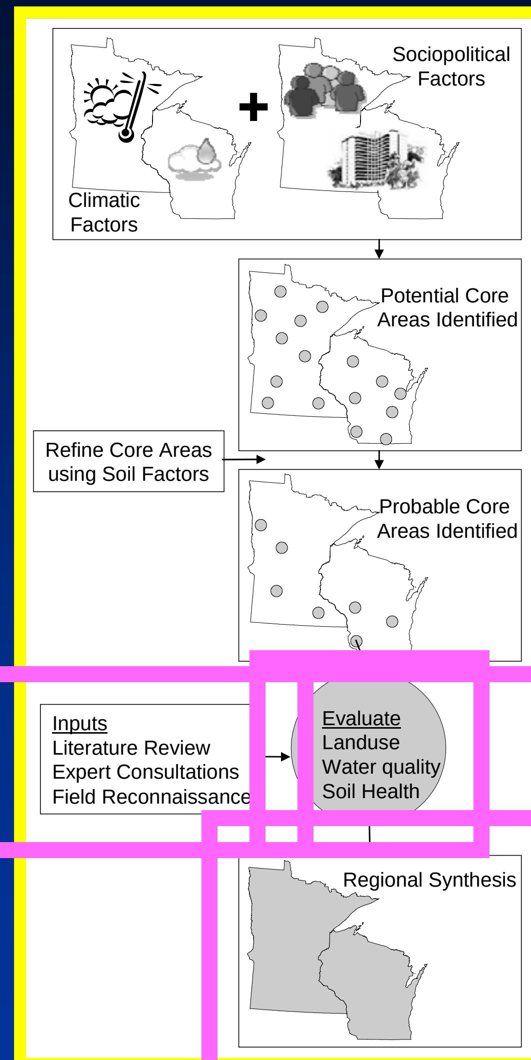
1. **Develop coarse & fine resolution digital maps of environmental & sociopolitical constraints to identify candidate core areas**

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



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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)

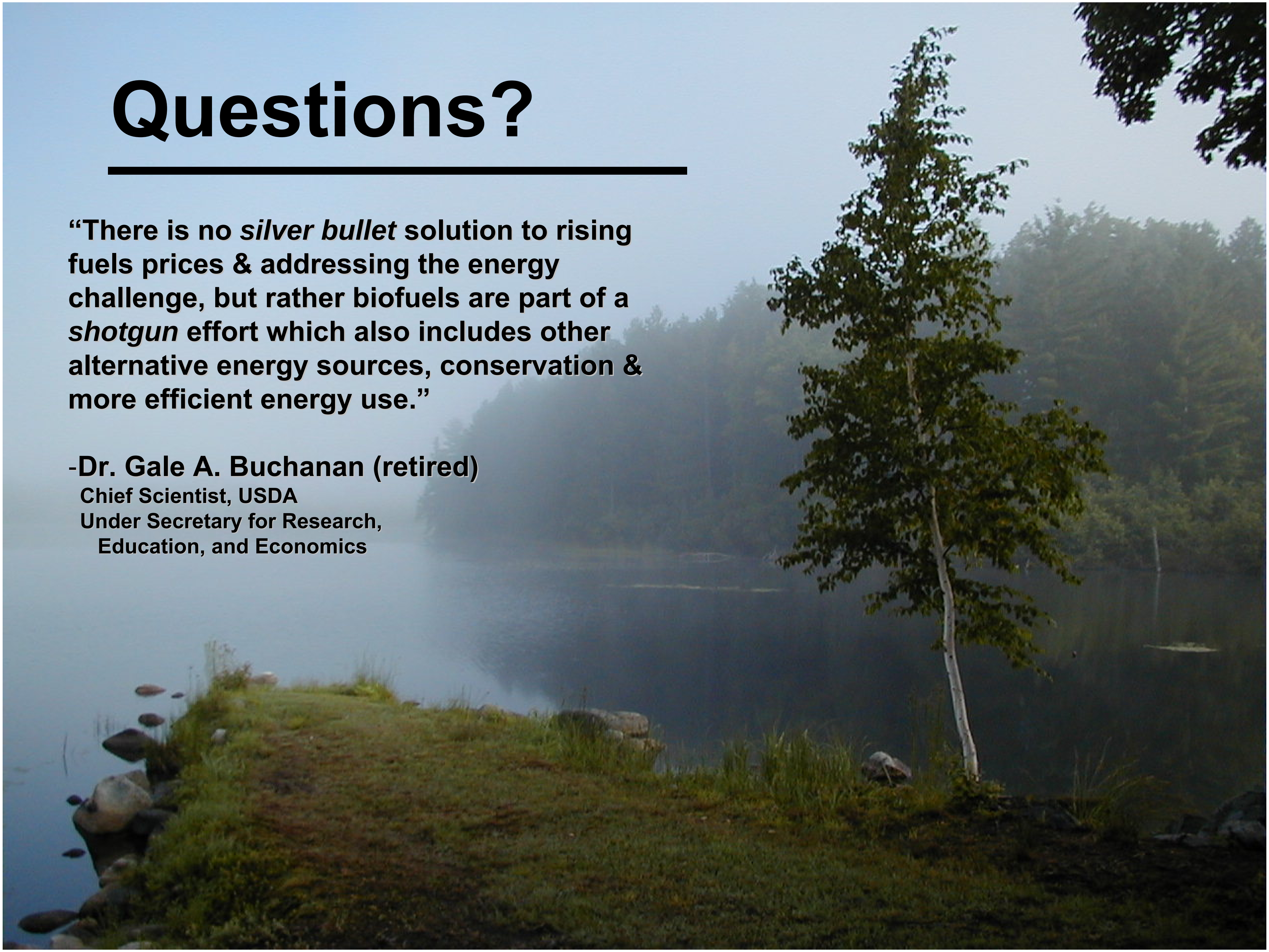
Carbon sequestration potential of poplar energy crops at regional scales R. Zalesny + (ISU, MSU)

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

Questions?



"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

Energy Crop Deployment & Environmental Sustainability

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.
3. Extracted out three NLCD classes: grassland/herbaceous, pasture hay, & cultivated crops.
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. Identfied Prime (classes 1-3) & Marginal (classes 4-7) lands.
6. Joined Soil Rental Rate (SRR) information into the attribute table, based on SSURGO data.

Zalesny, R.S. Jr., et al. 2009. Land-use, soil health, & water quality changes w/ woody energy crop production in Wisconsin & Minnesota. WI FOE EERD Proposal.