

# Opportunities for Phytotechnologies in Urban Areas

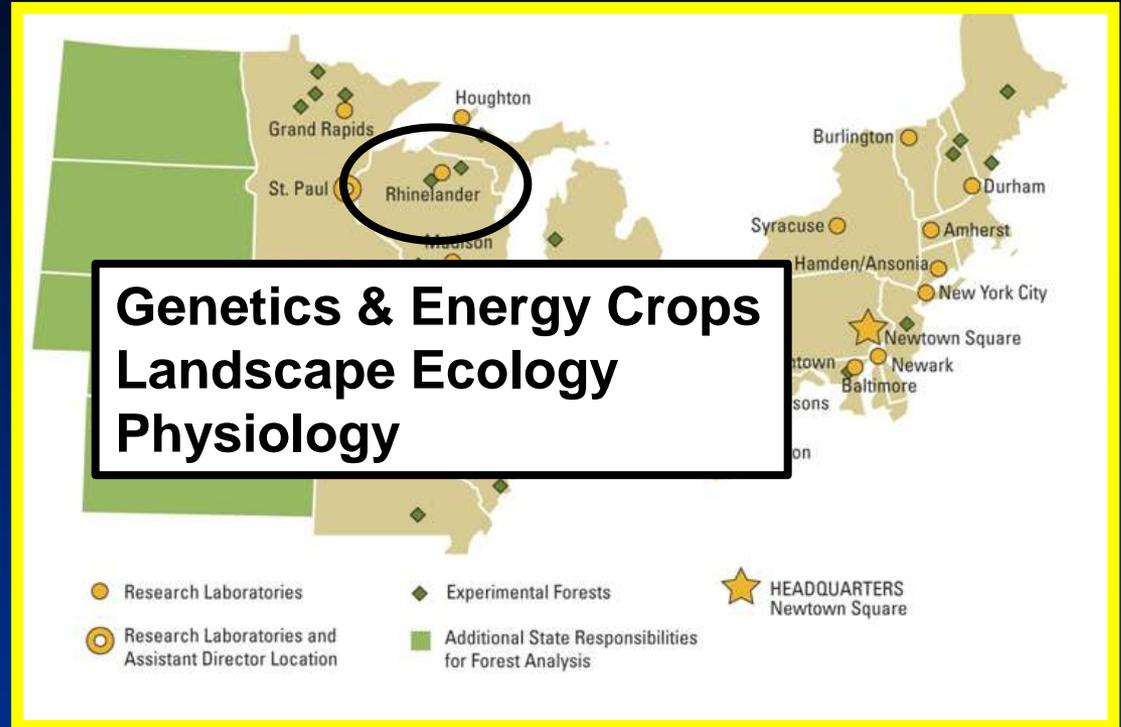
*Ronald S. Zalesny Jr.*

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# 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

## (NRS-13)

**Our objective is to use the link between energy, climate, & tree genetics to:**

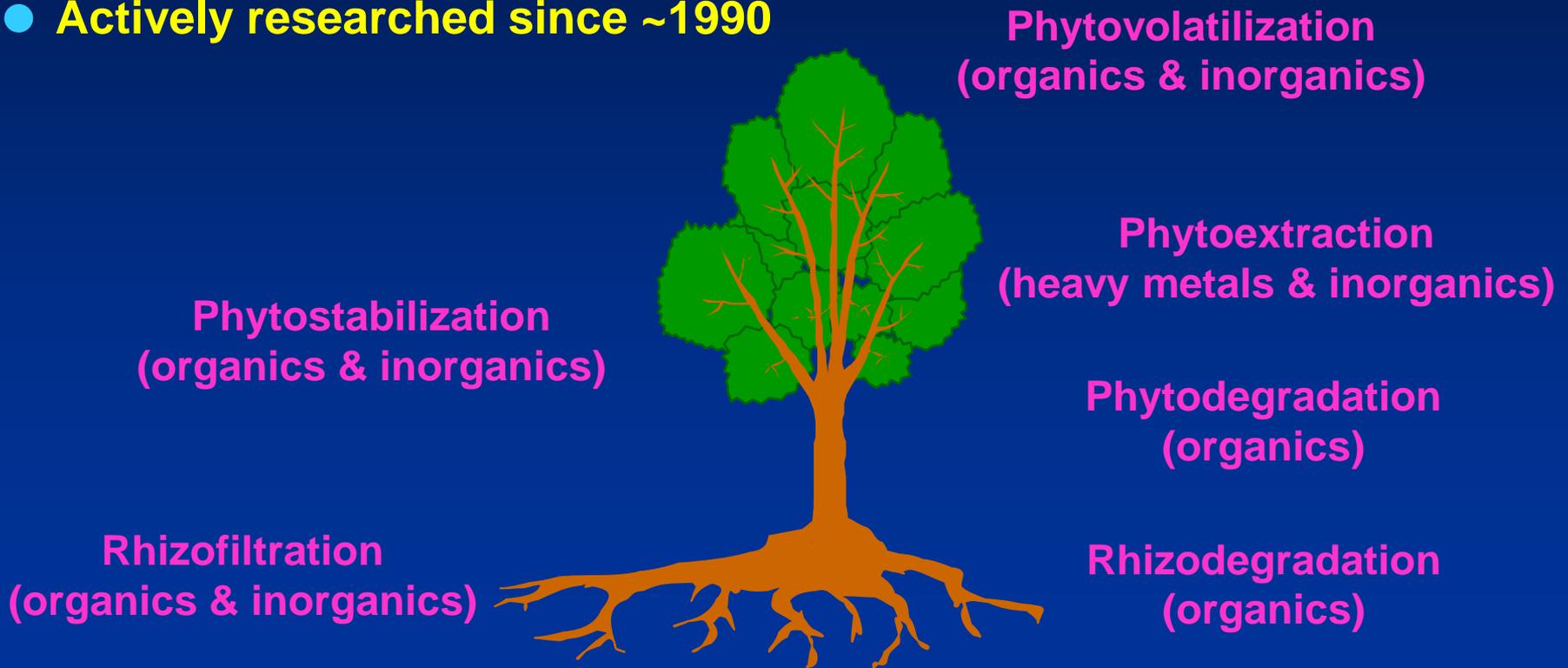
- 1) develop fast-growing tree crops as energy feedstocks;**
- 2) develop sustainable forest biomass removal strategies;**
- 3) understand climate change effects on natural & plantation forests;**
- 4) fill critical knowledge gaps in 1), 2), & 3).**



- **Short rotation woody crops for fiber, energy, & phytotechnologies**
- **Ecological sustainability of using forest residues for energy**
- **Carbon sequestration & climate change adaptation of conifers**

# Phytoremediation

- Derived from the Greek prefix “phyto” meaning “plant” & the Latin suffix “remedium” meaning “to restore or cure”
- A technology that utilizes plants to clean up contaminated soil, sludge, sediment, or groundwater
- Actively researched since ~1990



# What are Ecosystem Services?

- **The benefits people obtain from ecosystems**

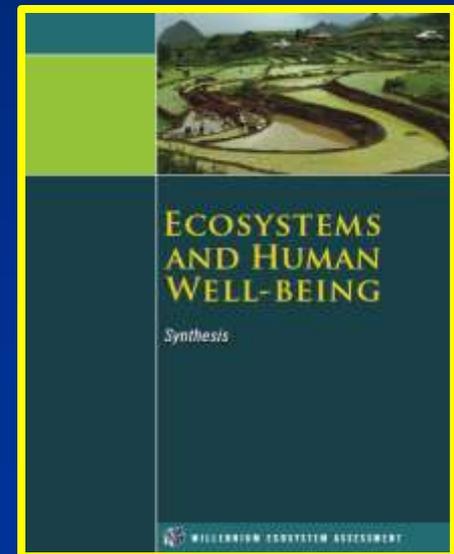
(Source: <http://www.greenfacts.org/glossary/def/ecosystem-services.htm>)

- **Became very popular in the 1940's**

1. Osborn, F. 1948. *Our Plundered Planet*. Little, Brown and Company: Boston. 217pp.
2. Vogt, W. 1948. *Road to Survival*. William Sloan: New York. 335pp.
3. Leopold, A. 1949. *A Sand County Almanac and Sketches from Here and There*. Oxford University Press, New York. 226pp.

- **Millennium Ecosystem Assessment**

1. Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington. 155pp.



# Categories of Ecosystem Services

## 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

## Supporting Services

The natural processes that maintain the other ecosystem services

# Provisioning Services

The goods or products obtained from ecosystems

Service	Definition	Example(s)
<p data-bbox="83 501 432 548"><b>Biomass Fuel</b></p> 	<p data-bbox="562 501 1228 872"><b>Biological material derived from living or recently living organisms – both plant and animal – that serves as a source of energy</b></p>	<ul data-bbox="1282 501 1740 808" style="list-style-type: none"><li><b>*Fuelwood and charcoal</b></li><li><b>*Grain for ethanol production</b></li><li><b>*Dung</b></li></ul>
<p data-bbox="83 965 369 1012"><b>Freshwater</b></p> 	<p data-bbox="562 965 1234 1272"><b>Inland bodies of water, groundwater, rainwater, and surface waters for household, industrial, and agricultural uses</b></p>	<p data-bbox="1282 965 1837 1329"><b>*Freshwater for drinking, cleaning, cooling, industrial processes, electricity generation, or mode of transportation</b></p>

# Regulating Services

The benefits obtained from an ecosystem's control of natural processes

Service	Definition	Example(s)
<b>Erosion Control</b> 	Role ecosystems play in retaining and replenishing soil and sand deposits	*Vegetation such as grass and trees prevents soil loss due to wind and rain and prevents siltation of water ways
<b>Maintenance of Soil Quality</b> 	Role ecosystems play in sustaining soil's biological activity, diversity, and productivity; storing and recycling nutrients and gases	*Some organisms aid in decomposition of organic matter, increasing soil nutrient levels *Some organisms aerate soil, improve soil chemistry, and increase moisture retention

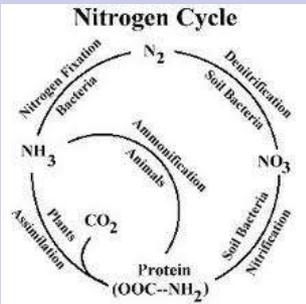
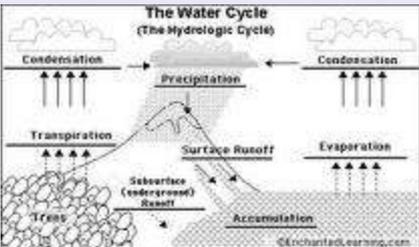
# Cultural Services

The nonmaterial benefits obtained from ecosystems

Service	Definition	Example(s)
<p data-bbox="83 344 484 458"><b>Ethical and Spiritual Values</b></p> 	<p data-bbox="562 344 1213 715"><b>Spiritual, religious, aesthetic, intrinsic, “existence”, or similar values people attach to ecosystems, landscapes, or species</b></p>	<p data-bbox="1282 344 1798 772"><b>*Spiritual fulfillment derived from sacred lands and rivers</b> <b>*People’s desire to protect endangered species and rare habitats</b></p>
<p data-bbox="83 808 498 979"><b>Educational and Inspirational Values</b></p> 	<p data-bbox="562 808 1213 1108"><b>Information derived from ecosystems used for intellectual development, culture, art, design, and innovation</b></p>	<p data-bbox="1282 808 1831 1365"><b>*The structure of tree leaves has inspired technological improvements in solar power cells</b> <b>*School fieldtrips to nature preserves aid in teaching scientific concepts</b></p>

# Supporting Services

The natural processes that maintain the other ecosystem services

Service	Definition	Example(s)
<p data-bbox="81 501 498 554"><b>Nutrient Cycling</b></p>  <p>The diagram illustrates the Nitrogen Cycle. It shows atmospheric nitrogen (<math>N_2</math>) being fixed by bacteria into ammonia (<math>NH_3</math>). This ammonia is then taken up by plants through assimilation. Plants release carbon dioxide (<math>CO_2</math>) through respiration. Animals consume plants and release nitrogen through excretion and decomposition, which is then processed by soil bacteria through nitrification into nitrate (<math>NO_3</math>). Finally, soil bacteria perform denitrification, returning nitrogen to the atmosphere as <math>N_2</math>.</p>	<p data-bbox="562 501 1136 743"><b>Flow of nutrients (e.g., nitrogen, sulfur, phosphorus, carbon) through ecosystems</b></p>	<p data-bbox="1282 501 1818 929"><b>*Transfer of nitrogen from plants to soil, from soil to oceans, from oceans to atmosphere, and from the atmosphere to plants</b></p>
<p data-bbox="81 966 440 1019"><b>Water Cycling</b></p>  <p>The diagram shows the Water Cycle. Water evaporates from the ocean and transpires from trees into the atmosphere, where it condenses into clouds. Precipitation falls as rain or snow. On land, water can run off the surface into rivers and oceans, or infiltrate the ground as subsurface (underground) runoff. In the ground, water can be stored as accumulation. The cycle is continuous and maintains the distribution of water on Earth.</p>	<p data-bbox="562 966 1190 1143"><b>Flow of water through ecosystems in its solid, liquid, or gaseous forms</b></p>	<p data-bbox="1282 966 1792 1200"><b>*Transfer of water from soil to plants, plants to air, and air to rain</b></p>

# Genetics & Energy Crop Production Unit

Our objective is to use the link between energy, climate, & tree genetics to:

1) develop

2) develop

3) understand climate change effects on natural & plantation forests:

## Provisioning Services

The goods or products obtained from ecosystems

## Regulating Services

The benefits obtained from an ecosystem's control of natural processes

## Supporting Services

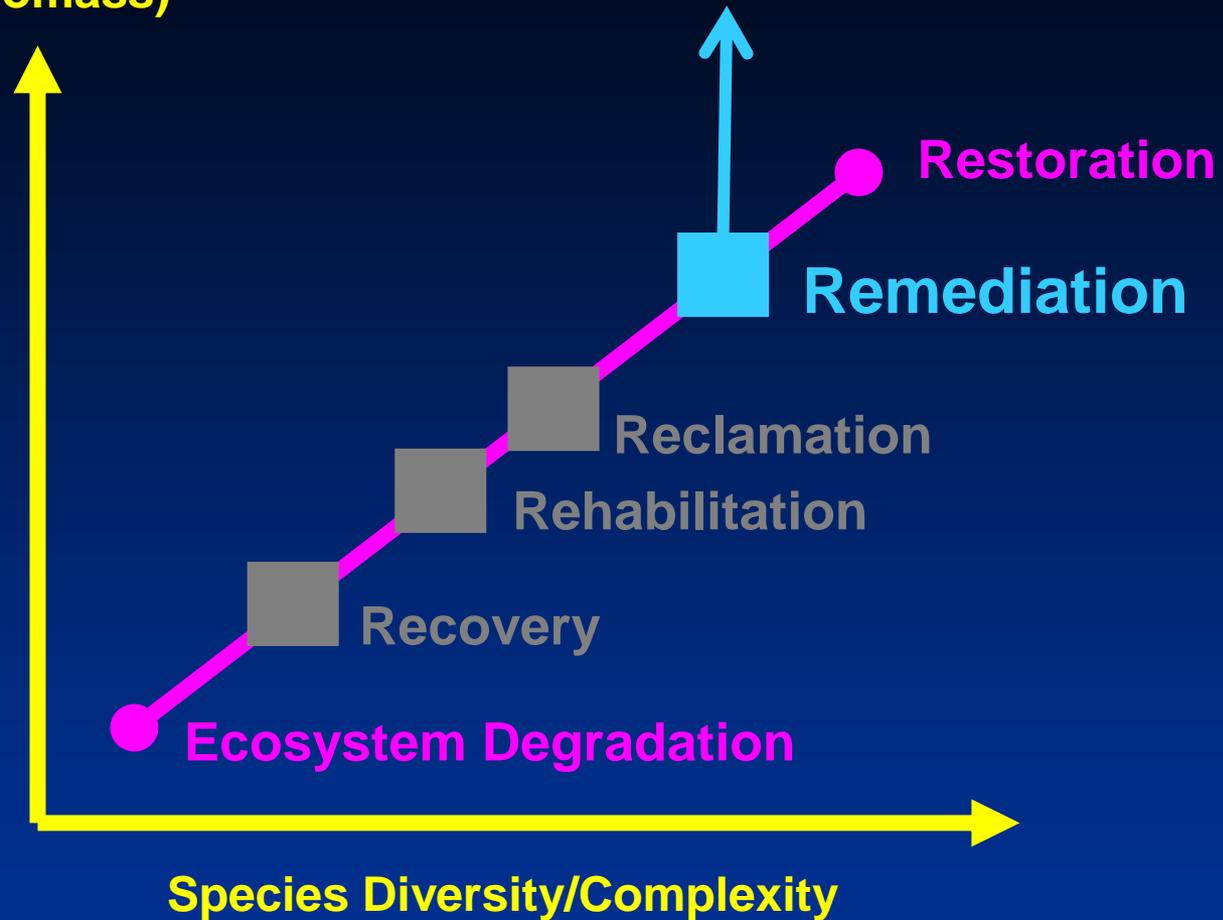
The natural processes that maintain the other ecosystem services



- Short rotation woody crops for fiber, energy, & **phytotechnologies**
- Ecological sustainability of using forest residues for energy
- Carbon sequestration & climate change adaptation of conifers

**Positive Ecosystem Function  
(e.g., Plant Biomass)**

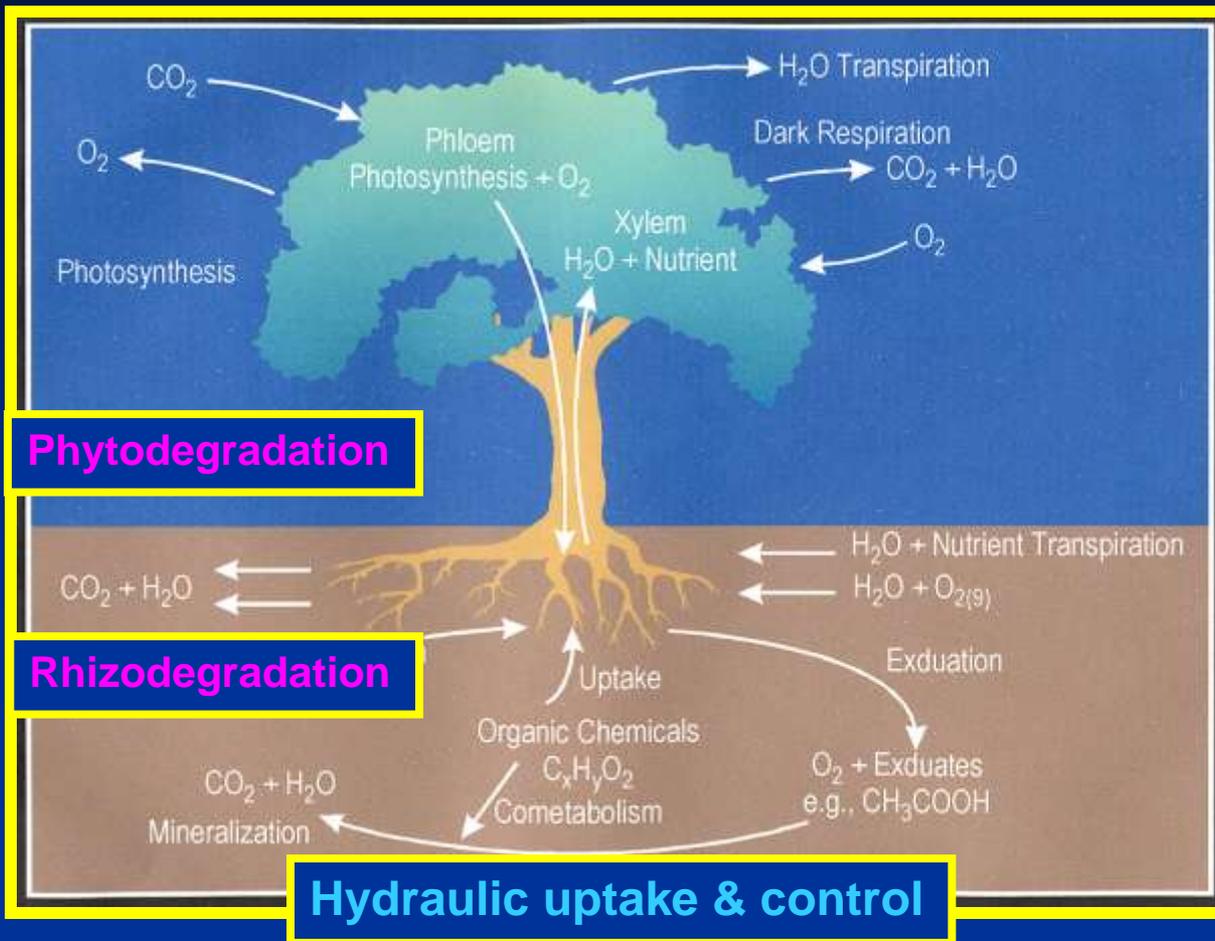
**Need plants that are workhorses**



**Continuum between complete ecosystem degradation & pre-disturbance condition (restoration) for positive ecosystem function & species diversity/complexity.**

# Hybrid Poplars as Phreatophytes

(Latin for “tree well”)



**High water usage**

**Fast growth**

**Deep root systems**

# Phytotechnologies Research (Rhineland)

- Began in mid-1990's
- Emphasis on *Populus* (i.e., poplars) & *Salix* (i.e., willows) as biological filters atop or adjacent to closed landfills
  - Recycle & reuse municipal solid waste (MSW) landfill leachate on-site to reduce economic & ecological costs associated with treating the waste waters
  - Maintain regional environmental integrity of groundwater aquifers & nearby water bodies



# Environmental Applications

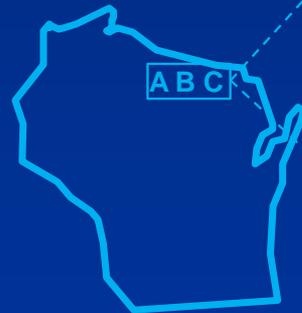
- **Incorporating intensive forestry with waste management for the application of phytotechnologies**

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



# Phytoremediation Projects

- Municipal wastewater
- Ammonia
- Petroleum hydrocarbons
- Polychlorinated biphenyls (PCB's)
- Nitrates / fertilizer residues
- Heavy metals
- Salts
- Landfill leachate



## A: Oneida County Landfill

Zalesny et al. (2007a, 2008a, 2008b, 2009a)

## B: Institute for Applied Ecosystem Studies

Zalesny and Bauer (2007a)

Zalesny and Zalesny (2009)

Zalesny et al. (2007b, 2009c)

## C: Former Rhinelander City Landfill

Zalesny and Bauer (2007b, 2007c)

Zalesny et al. (2006)

# Environmental Applications

- 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**

# Testing & Selection

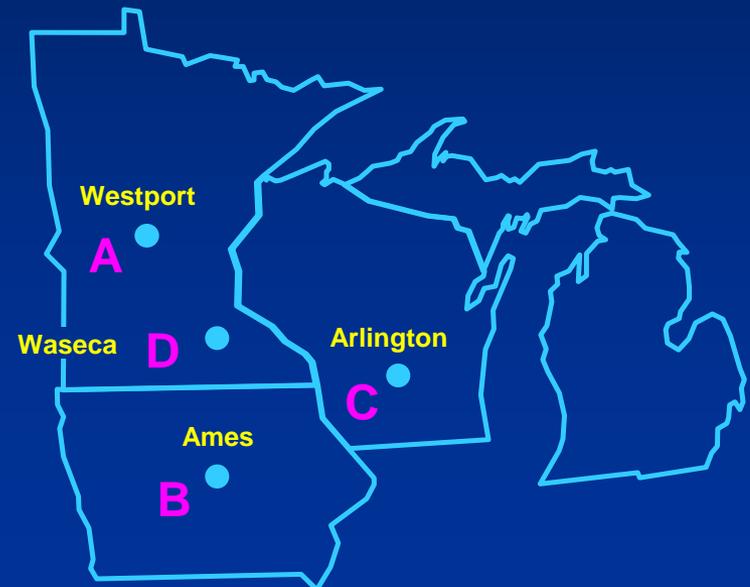
## Field Trials



**Generalist** clones that perform well over a broad geographic range.



**Specialist** clones that perform well within designated breeding zones.



# Limits to Clone Transfer

## Clone Stability and G × E Interaction

If variation due to the clone main effect is strong, then clone performance is stable.

Generalist genotypes that perform well over a broad range of contaminants (most readily-available genotypes are generalists).

If variation due to the clone × contaminant interaction is strong, then clone performance is contaminant-dependent.

Specific genotypes that perform well when irrigated & fertilized with designated contaminants.

Heavy Metals

A

B

C

Salts

A

B

D

Pesticides

A

B

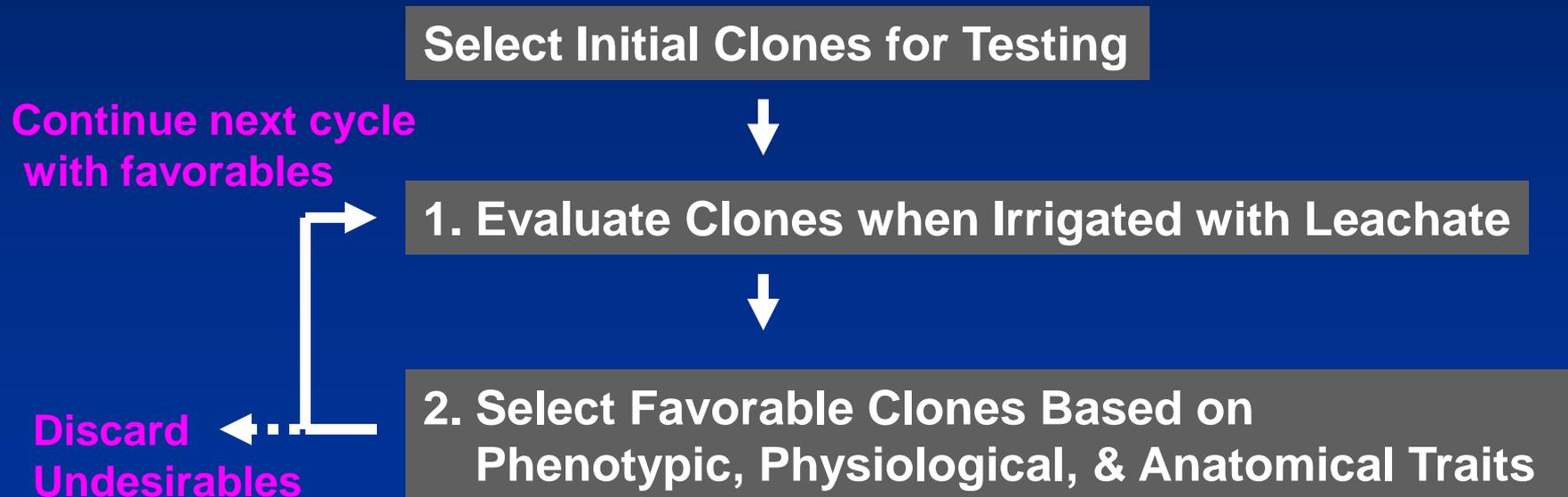
E

# Phyto-Recurrent Selection in Phytotechnologies

## Primary Objectives

*Choose clones for field deployment that have:*

1. Improved phytoremediation potential over original set of clones
2. Adequate genetic variation to guard against insect/disease outbreaks, changes in soil conditions (e.g., flood/drought), & unfavorable genotype environment interactions

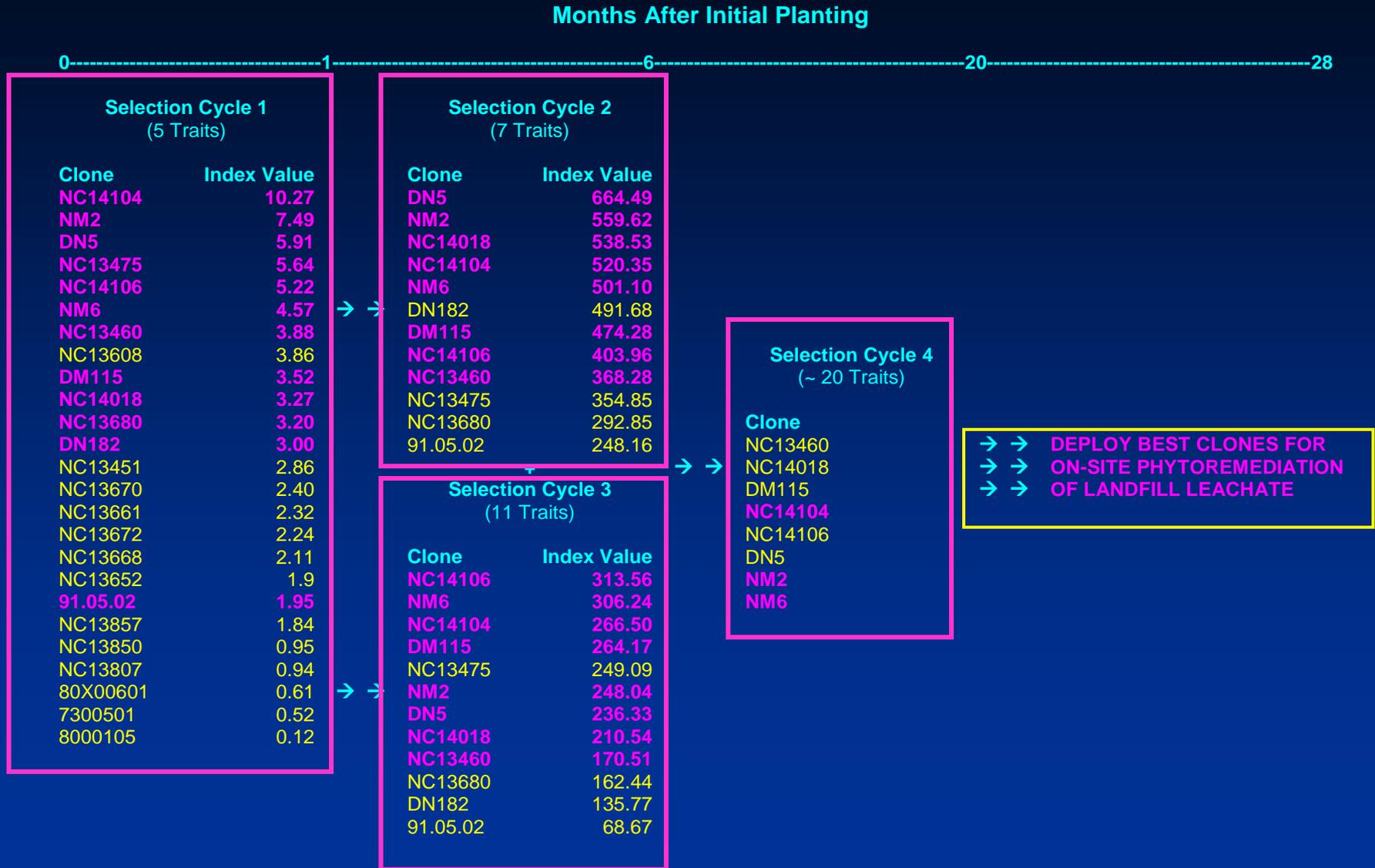


# Phyto-Recurrent Selection

- Consists of revising & combining crop & tree improvement protocols to utilize superior *Populus* & *Salix* clones for phytotechnologies.
- Such information is lacking for environmental clean-up technologies, but centuries of plant selection success in agronomy, horticulture, & forestry validate the need for similar approaches for environmental applications.



# Phyto-Recurrent Selection



Tree Tissue

Genus / Genotype

Leaf

Woody

Root

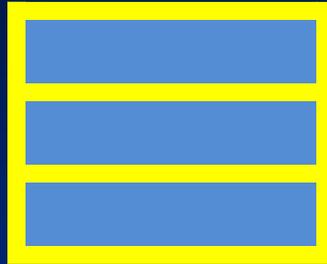
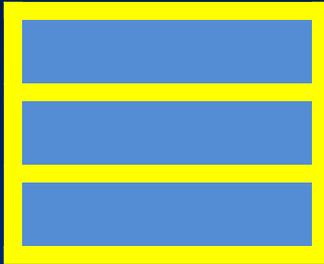
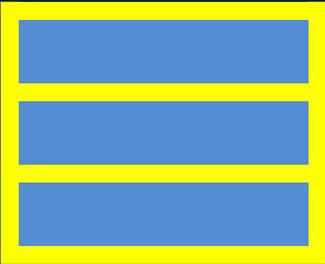
Inorganic Contaminant

*Populus*

A

B

C



*Salix*

A

B

C



**Table 4** Mean concentration ( $\text{mg kg}^{-1} \pm$  standard error,  $n = 30$ ) of elements in leaves, stems, and roots of trees used in an experiment testing clone-specific phytoremediation capabilities of *Populus* and *Salix*.

Element	Leaves		Stems		Roots	
	<i>Populus</i>	<i>Salix</i>	<i>Populus</i>	<i>Salix</i>	<i>Populus</i>	<i>Salix</i>
P	0.24 ± 0.01	0.11 ± 0.01	0.151 ± 0.003	0.099 ± 0.003	0.26 ± 0.01	0.18 ± 0.01
K	ns	ns	0.66 ± 0.01	0.36 ± 0.01	0.89 ± 0.01	0.57 ± 0.01
Ca	1.40 ± 0.04	2.43 ± 0.04	0.47 ± 0.01	0.38 ± 0.01	0.82 ± 0.01	0.49 ± 0.01
Mg	0.26 ± 0.01	0.34 ± 0.01	0.158 ± 0.004	0.072 ± 0.004	0.140 ± 0.003	0.112 ± 0.003
S	0.42 ± 0.02	0.35 ± 0.02	0.073 ± 0.002	0.053 ± 0.002	ns	ns
Zn	ns	ns	ns	ns	50.06 ± 1.41	69.68 ± 1.42
B	72.44 ± 2.53	94.10 ± 2.61	ns	ns	ns	ns
Mn	194.58 ± 5.43	151.67 ± 5.59	58.40 ± 2.01	37.81 ± 2.03	73.66 ± 5.69	103.41 ± 5.75
Fe	ns	ns	ns	ns	521.60 ± 123.39	877.21 ± 124.82
Cu	6.49 ± 0.16	5.44 ± 0.17	ns	ns	ns	ns
Al	52.61 ± 2.66	81.40 ± 2.74	ns	ns	647.71 ± 148.45	1086.75 ± 150.16
Na	171.71 ± 17.21	70.64 ± 17.21	92.66 ± 2.42	58.64 ± 2.45	251.58 ± 17.11	349.20 ± 17.31
Cl	1496.70 ± 89.09	945.91 ± 91.83	95.53 ± 5.78	43.72 ± 5.85	ns	Ns

ns = pairwise comparisons not significantly different at  $\alpha = 0.05$ .

**Chloride**

**Leaves**

**Stems**

**Roots**

**Populus**

**Salix**

**1497**

**946**

**96**

**44**

**ns**

**ns**

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Na	171.58 ± 17.21	29.04 ± 17.74	93.66 ± 2.42	58.64 ± 2.45	251.58 ± 17.11	349.20 ± 17.51
Cl	1496.70 ± 89.09	945.91 ± 91.83	95.53 ± 5.78	43.72 ± 5.85	ns	Ns

ns = pairwise comparisons not significantly different at  $\alpha = 0.05$ .

# Aluminum

Leaves

53

81

Stems

ns

ns

Roots

648

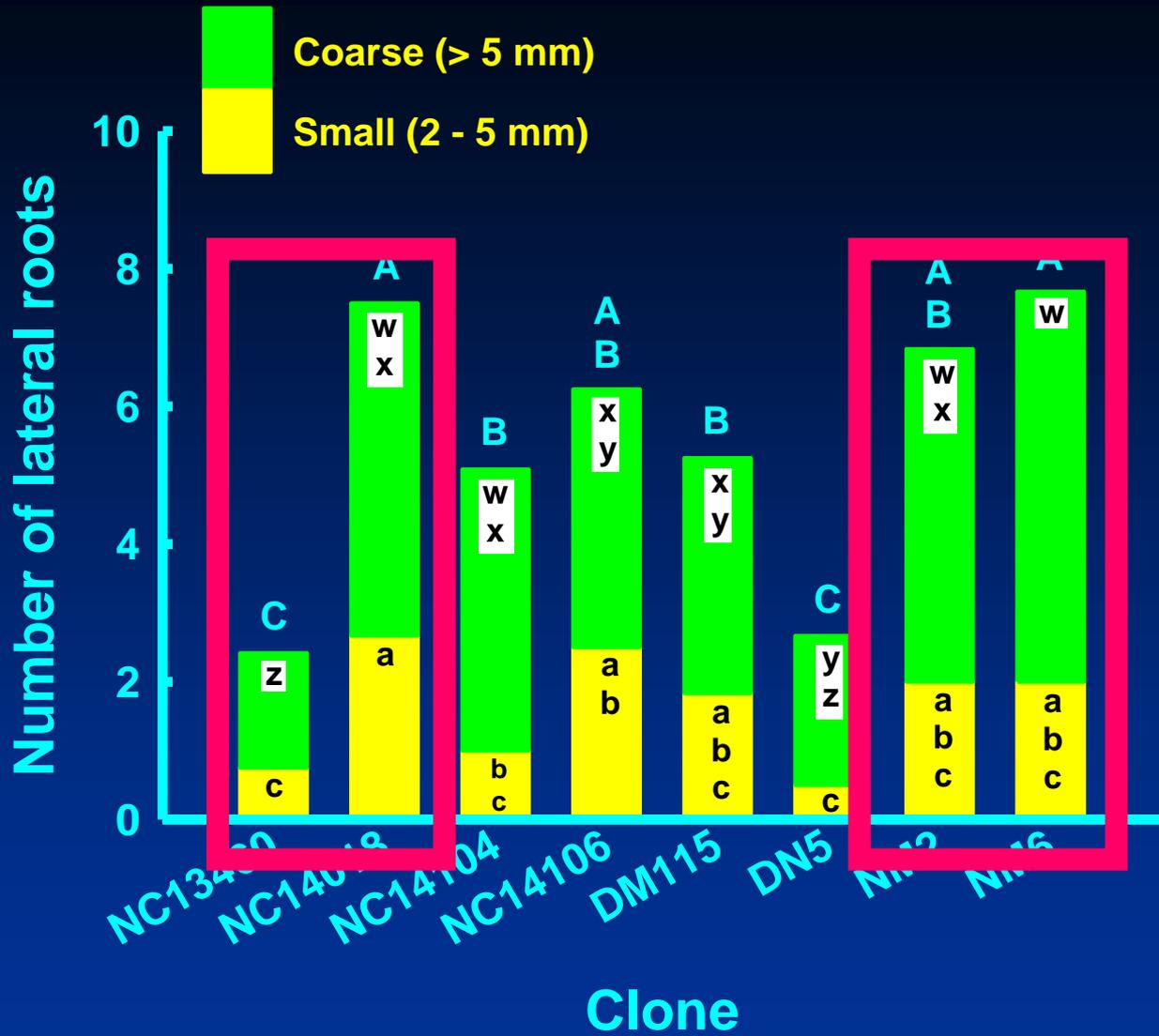
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**Populus**

**Salix**

Height, diameter, volume, and biomass components ( $\pm$  standard error,  $n = 60$ ) of trees during an experiment testing clone-specific phytoremediation capabilities of *Populus* and *Salix*. All pairwise comparisons are different at  $\alpha = 0.05$ .

	<i>Populus</i>		<i>Salix</i>	
Height (cm)	100	2	117	2
Diameter (cm)	1.0	0	0.8	0
Volume (cm <sup>3</sup> )	113	6	85	6
Leaf dry mass (g)	6.8	0.8	1.1	0.8
Stem dry mass (g)	17	1	26	1
Root dry mass (g)	4	0	8	0



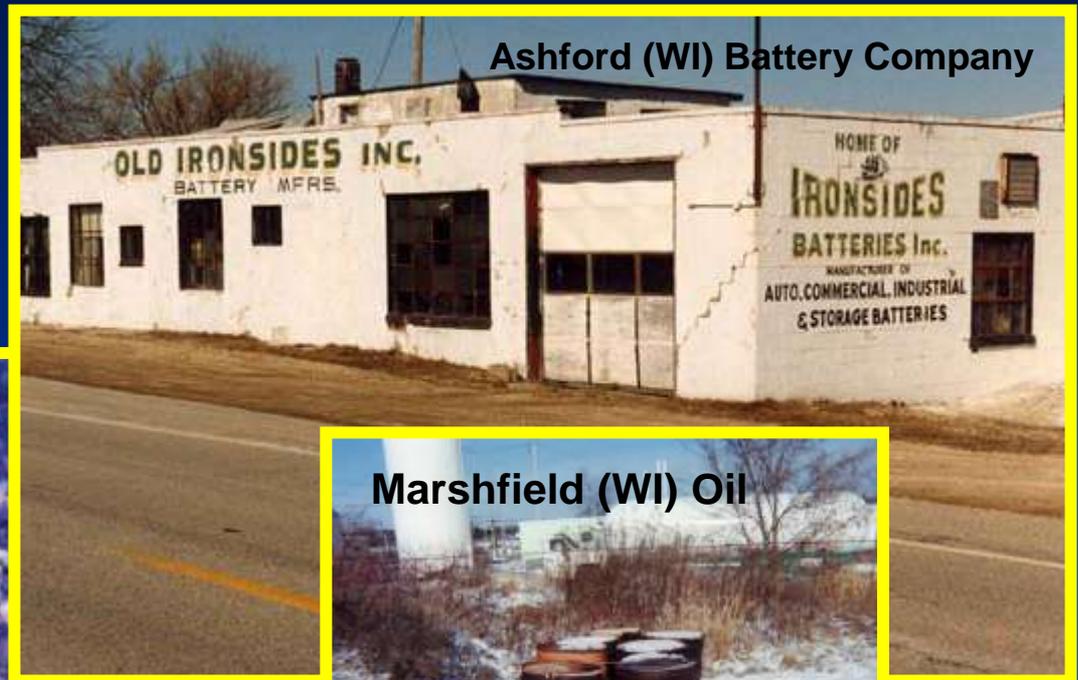
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NM6

# Brownfields

- Abandoned or underused industrial & commercial facilities available for re-use, where expansion or redevelopment may be complicated by real or perceived environmental contaminations



# Phytoremediation of a PCE Contaminated Site in LaSalle, IL USA with *Populus* Clones Through Hydraulic Uptake & Enhanced Microbial Activity

*J.G. Isebrands<sup>1</sup>, D.L. Rockwood<sup>2</sup>, R.B. Hall<sup>3</sup>  
A. Lindner<sup>2</sup>, A. Pacheco<sup>2</sup>, N. Brown<sup>4</sup>, R.M. Lange<sup>5</sup>*



geology.com

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- <sup>4</sup> Ecology & Environment, Inc., Chicago, IL, USA
- <sup>5</sup> Illinois Environmental Protection Agency, LaSalle, IL, USA

# PCE Case Study

## PCE – perchloroethylene

A colorless nonflammable toxic liquid  $C_2Cl_4$  used often as a solvent in dry cleaning & for removal of grease from metals (Merriam Webster)



Clone	Genomic Group
7300501	<i>P. deltoides</i>
119.16	<i>P. deltoides</i>
220-5	<i>P. deltoides</i>
252-4	<i>P. deltoides</i>
42-7	<i>P. deltoides</i>
51-5	<i>P. deltoides</i>
80x00601	<i>P. deltoides</i>
80x01015	<i>P. deltoides</i>
80x01107	<i>P. deltoides</i>
ISU 25-21	<i>P. deltoides</i>
ISU 25-35	<i>P. deltoides</i>
ISU 25-R4	<i>P. deltoides</i>
ISU 25-R5	<i>P. deltoides</i>
Eugenei	<i>P. deltoides</i> <i>P. nigra</i>
I45-51	<i>P. deltoides</i> <i>P. nigra</i>
Belgian 25	<i>P. nigra</i> <i>P. maximowiczii</i>
NM2	<i>P. nigra</i> <i>P. maximowiczii</i>
Crandon	<i>P. nigra</i> <i>P. maximowiczii</i>

# PCE Case Study

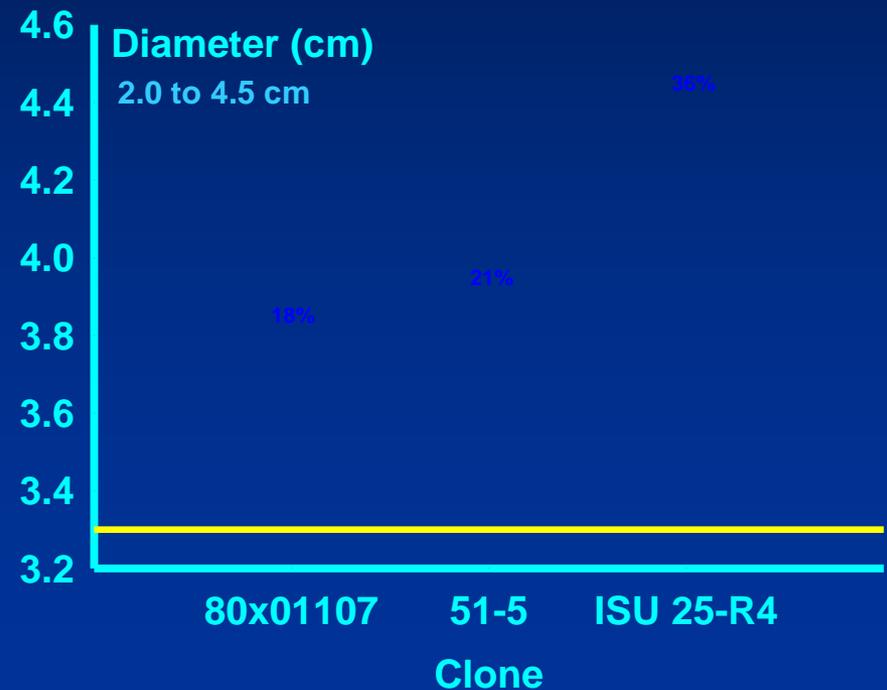
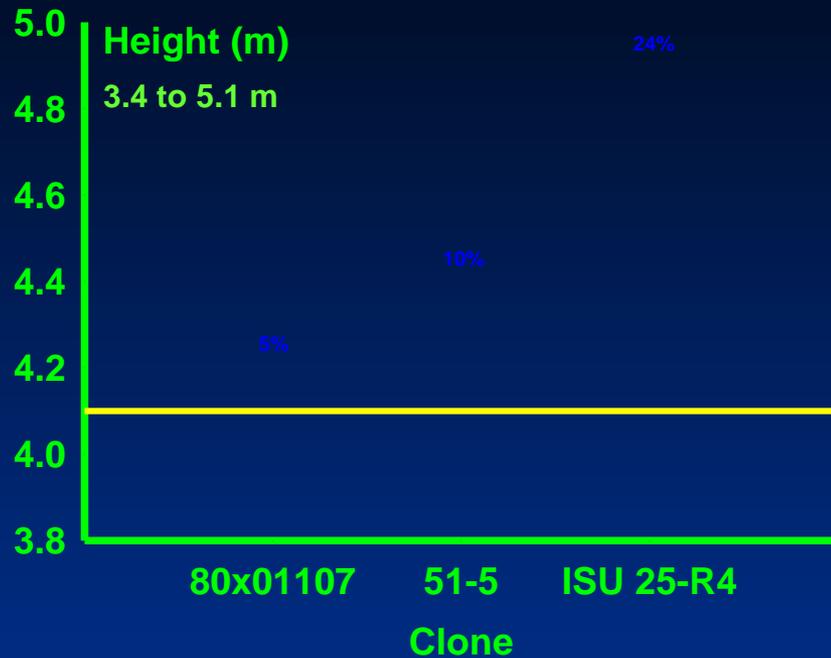
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ISU 25-21	<i>P. deltoides</i>
ISU 25-35	<i>P. deltoides</i>
<b>ISU 25-R4</b>	<b><i>P. deltoides</i></b>
ISU 25-R5	<i>P. deltoides</i>
Eugenei	<i>P. deltoides</i> <i>P. nigra</i>
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# Growth Performance (age 2 years)



# Other Urban Areas

**Osceola (WI) Creek**



**Ashland (WI) Railyard**



**Sheboygan (WI) Harbor**



**Indiana Harbors Canal  
Gary, IN**

SCC Photo



## CLONAL VARIATION IN SURVIVAL AND GROWTH OF HYBRID POPLAR AND WILLOW IN AN *IN SITU* TRIAL ON SOILS HEAVILY CONTAMINATED WITH PETROLEUM HYDROCARBONS

**Ronald S. Zalesny Jr. and Edmund O. Bauer**

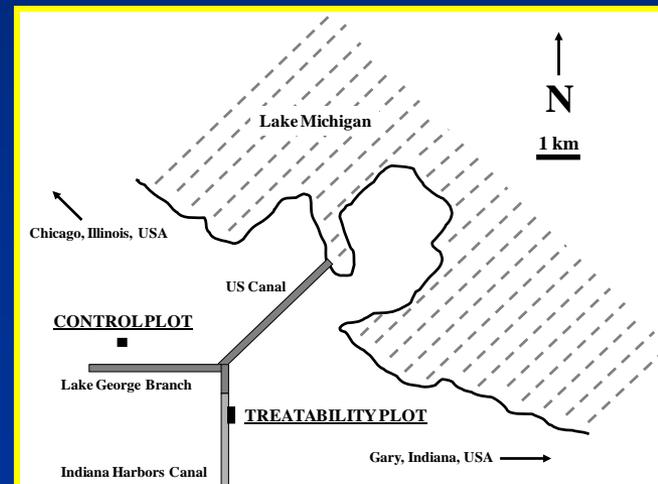
*USDA Forest Service, North Central Research Station, Forestry Sciences Laboratory, Rhinelander, Wisconsin, USA*

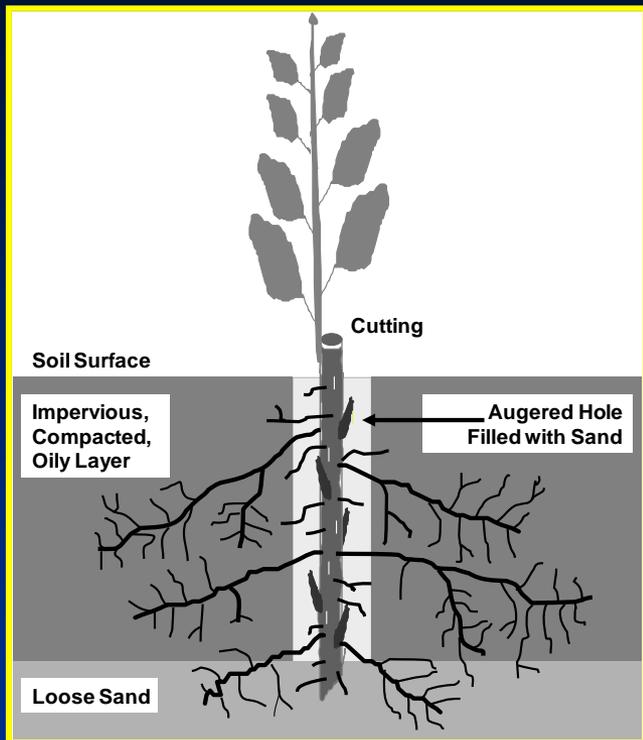
**Richard B. Hall and Jill A. Zalesny**

*Department of Natural Resource Ecology and Management, Iowa State University, Ames, Iowa, USA*

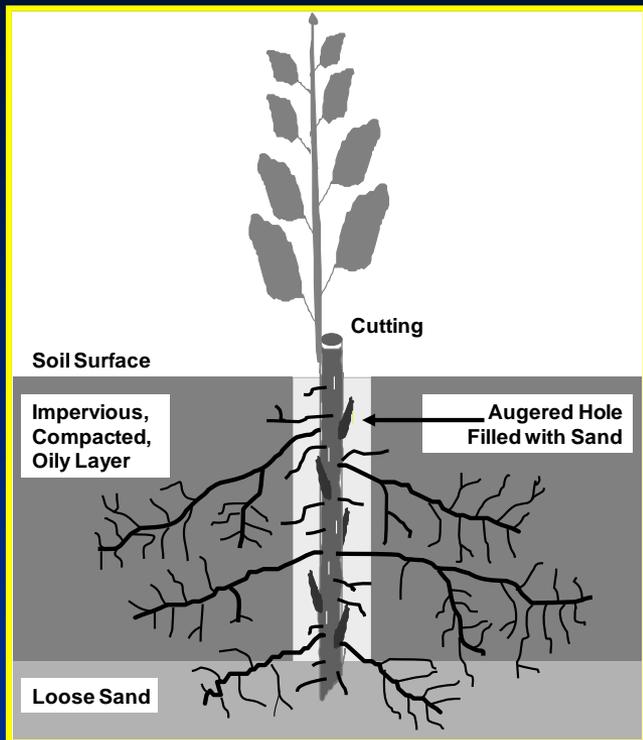
**Joshua Kunzman and Chris J. Rog**

*Sand Creek Consultants, Inc., Rhinelander, Wisconsin, USA*



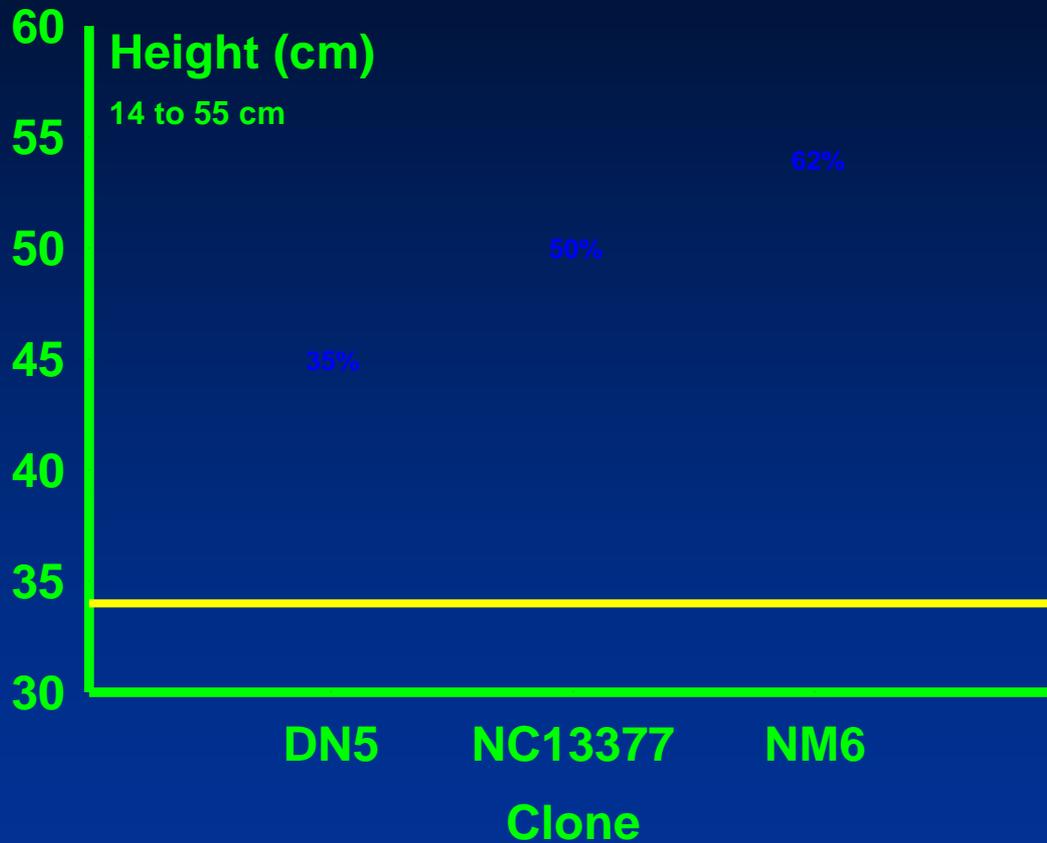


Clone	Genomic Group		
NC14002	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
NC13469	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
NC13624	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
NC13570	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
NC13377	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
80x00601	<i>P. deltoides</i>	<i>P. deltoides</i>	
119.16	<i>P. deltoides</i>	<i>P. deltoides</i>	
NC14107	<i>P. deltoides</i>	<i>P. maximowiczii</i>	
NC14105	<i>P. deltoides</i>	<i>P. maximowiczii</i>	
NC14104	<i>P. deltoides</i>	<i>P. maximowiczii</i>	
NM6	<i>P. nigra</i>	<i>P. maximowiczii</i>	
DN5	<i>P. deltoides</i>	<i>P. nigra</i>	
DN34	<i>P. deltoides</i>	<i>P. nigra</i>	
DN182	<i>P. deltoides</i>	<i>P. nigra</i>	
NAT	<i>P. deltoides</i>		
D125	<i>P. deltoides</i>		
D124	<i>P. deltoides</i>		
91.05.02	<i>P. deltoides</i>		
8000105	<i>P. deltoides</i>		
7300501	<i>P. deltoides</i>		
SV1	<i>S. dasyclados</i>		
SX61	<i>S. sachalinensis</i>		



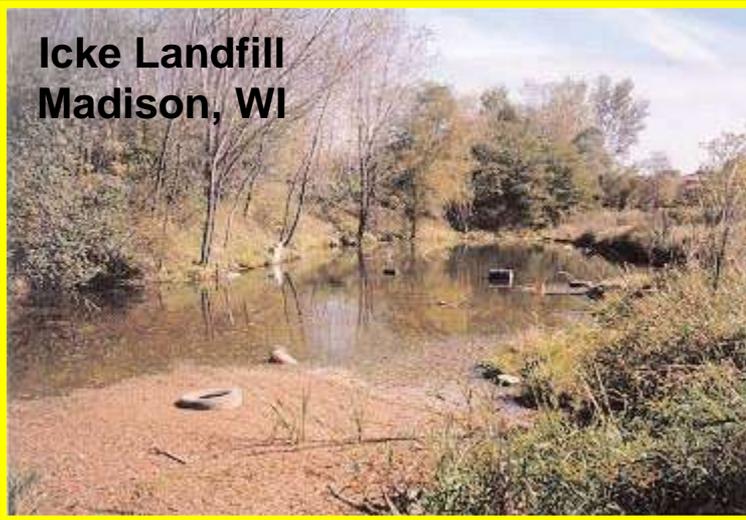
Clone	Genomic Group		
NC14002	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
NC13469	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
NC13624	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
NC13570	<i>(P. trichocarpa</i>	<i>P. deltoides)</i>	<i>P. deltoides</i>
<b>NC13377</b>	<b><i>(P. trichocarpa</i></b>	<b><i>P. deltoides)</i></b>	<b><i>P. deltoides</i></b>
80x00601	<i>P. deltoides</i>	<i>P. deltoides</i>	
119.16	<i>P. deltoides</i>	<i>P. deltoides</i>	
NC14107	<i>P. deltoides</i>	<i>P. maximowiczii</i>	
NC14105	<i>P. deltoides</i>	<i>P. maximowiczii</i>	
NC14104	<i>P. deltoides</i>	<i>P. maximowiczii</i>	
<b>NM6</b>	<b><i>P. nigra</i></b>	<b><i>P. maximowiczii</i></b>	
<b>DN5</b>	<b><i>P. deltoides</i></b>	<b><i>P. nigra</i></b>	
DN34	<i>P. deltoides</i>	<i>P. nigra</i>	
DN182	<i>P. deltoides</i>	<i>P. nigra</i>	
NAT	<i>P. deltoides</i>		
D125	<i>P. deltoides</i>		
D124	<i>P. deltoides</i>		
91.05.02	<i>P. deltoides</i>		
8000105	<i>P. deltoides</i>		
7300501	<i>P. deltoides</i>		
SV1	<i>S. dasyclados</i>		
SX61	<i>S. sachalinensis</i>		

# Growth Performance (age 4 months)



# Landfills

Icke Landfill  
Madison, WI



Ragnsells Avfallsbehandling AB  
Upplands-Bro, Sweden



Oneida County Landfill  
Rhineland, WI



# Using Trees & Grasses to Improve Ecosystem Health & Functioning at Freshkills Park

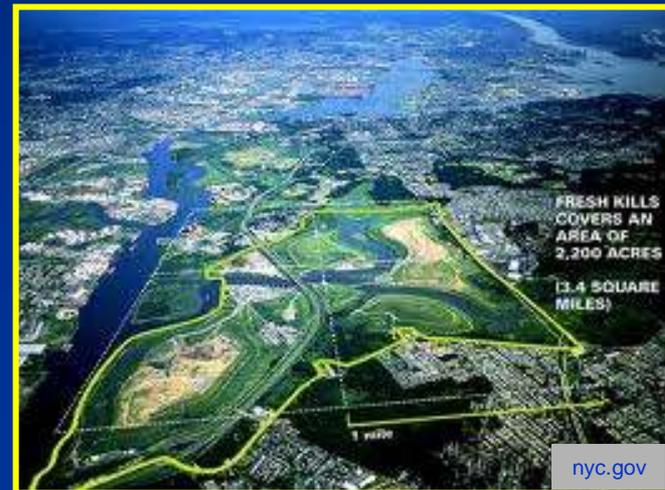
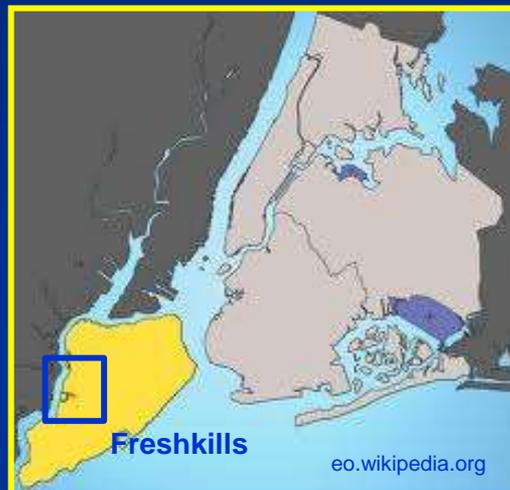
*Ronald S. Zalesny Jr.<sup>1</sup>, Richard A. Hallett<sup>2</sup>,  
Nancy Falxa-Raymond<sup>3</sup>, Carrie Grassi<sup>4</sup>*

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<sup>2</sup> Center for Research on Ecosystem Change, Durham, NH, USA

<sup>3</sup> NYC Urban Field Station, New York, NY, USA

<sup>4</sup> New York City Department of Parks and Recreation, New York, NY, USA



# Opportunities at Freshkills

- **Improving ecosystem health & functioning at Freshkills Park through phytotechnologies**
  - Improve the usage classification of imported soils from “Restricted Residential” to a higher classification such as “Residential” or “Ecological”
  - Enhance the physical, chemical, biological, & agronomic characteristics of imported soils
  - Prevent the establishment of invasive plant species
  - Encourage the establishment of native vegetation & invertebrates

# Project Work Plan

Phase 1  
**Site selection & characterization  
Plant material collection/propagation**

Phase 2  
**Greenhouse testing**

Phase 3  
**Field testing**

Phase 4  
**Phyto buffer establishment**

Phase 5  
**Transition to native vegetation**



***Phase 1: Site Selection; Initial Water, Sediment, and Soil Sampling; Plant Collection***

Objective 1: Select sites, gather baseline data for site characterization, and collect plant material for propagation

***Phase 2: Phyto-Recurrent Selection Cycles 1 and 2 at IAES Greenhouses***

Objective 1: Select genotypes for advancement to phyto-recurrent selection cycle 3 at Freshkills Park

***Phase 3: Phyto-Recurrent Selection Cycle 3 at Freshkills Park***

Objective 1: Select genotypes for integrated phyto buffers at Freshkills Park  
Objective 2: Test the changes in ecosystem health within phyto buffers  
Objective 3: Use phytoforensic methods to detect and delineate potential contamination  
Objective 4: Test the efficacy of phyto buffers for site remediation

***Phase 4: Phyto-Recurrent Selection Cycle 4 at Freshkills Park***

Objective 1: Establish and maintain integrated phytoremediation buffer systems (i.e., phyto buffers)

***Phase 5: Transition from Phyto Buffers to Native Species Restoration at Freshkills Park***

Objective 1: Restore ecosystems at Freshkills Park with native vegetation

# Experimental Design

**16 Blocks Available**

**4 Blocks**

**2 Soil Sources**

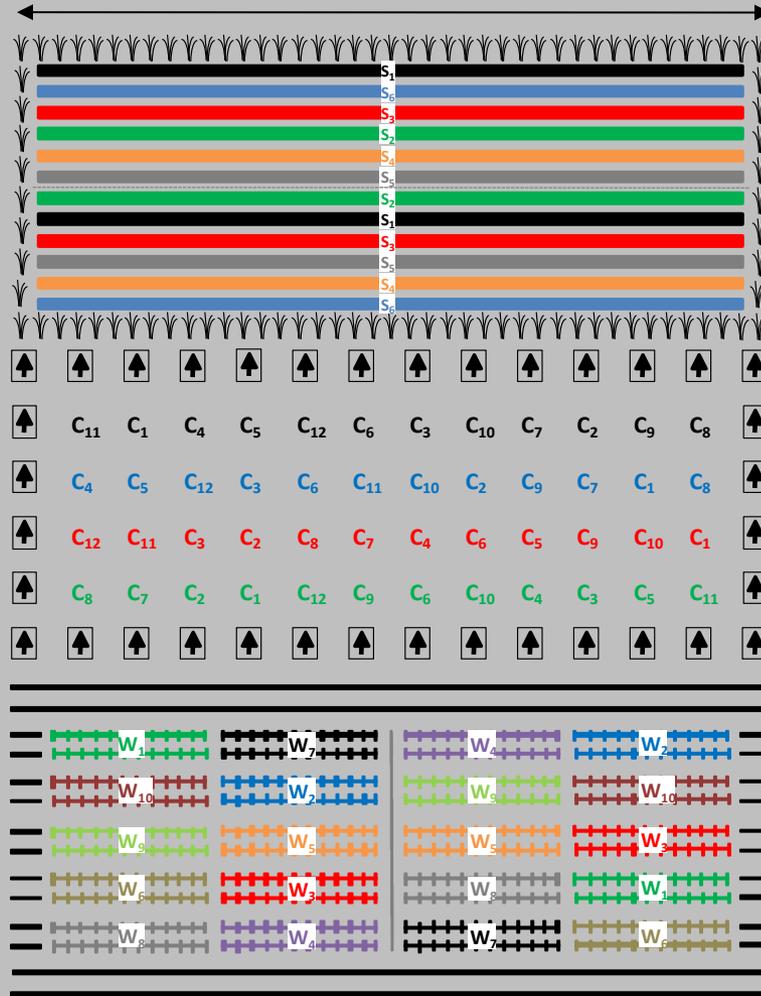
**2 Vegetation Trts  
(w/ plants, control)**



**Total Area:**  
0.13 ha  
(0.31 ac)

31.2 m (102.4 ft)

40.8 m  
(133.9 ft)



**Switchgrass**

- 6 genotypes
- 0.25 m row width
- 30 m row length
- 2 rows per block
- ↕ border plants

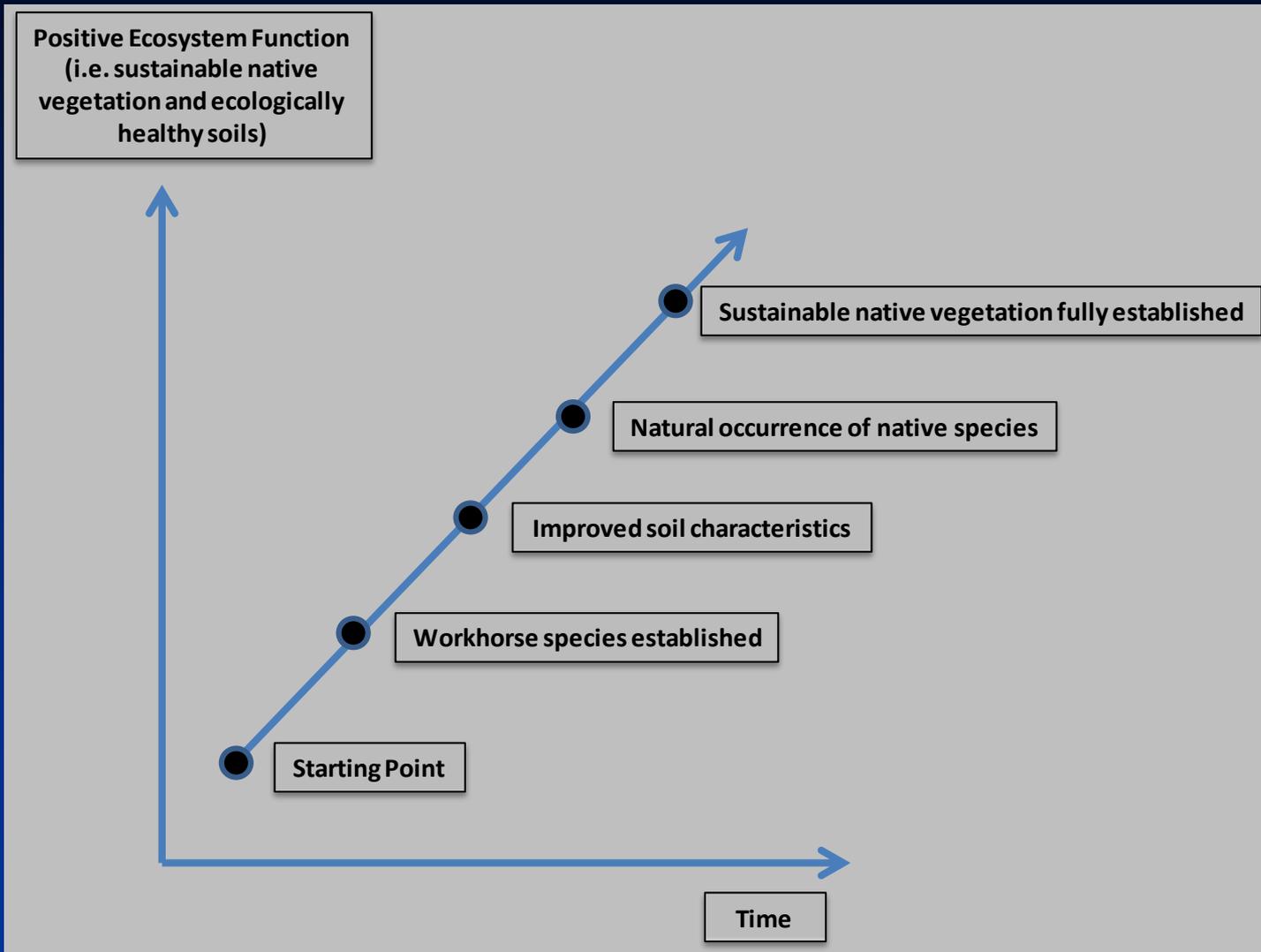
**Cottonwood**

- 12 genotypes
- 2.4 x 2.4 m spacing
- 4 trees per block
- ▲ border trees

**Willow**

- 10 genotypes
- 0.75 m within double rows
- 1.5 m between sets of double rows
- 60 cm among trees within rows
- 6.6 m row length
- 24 trees per double row
- 48 trees per block
- border rows

# End Goal



# Practical Implications

- **Cost-effective phytotechnologies are available to assist researchers, resource managers, regulators, etc. to improve environmental conditions while protecting human health**
- **We have reached an all-time threshold of collaboration between researchers & regulators, making phyto-related projects increasingly more ecologically, economically, & socially acceptable**

# SUSTAINABILITY

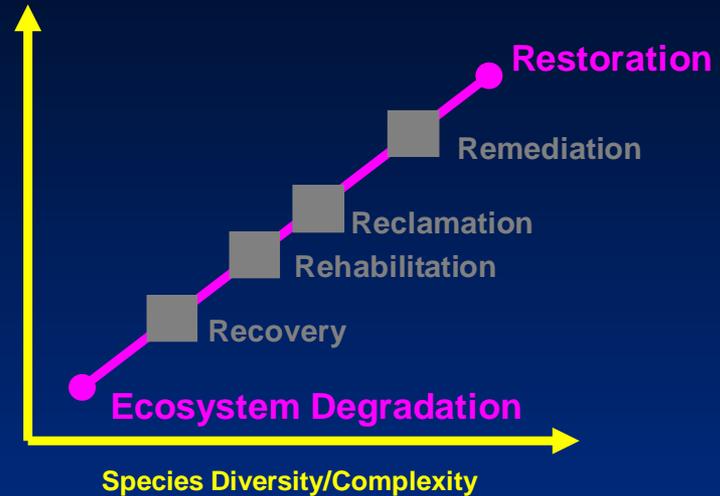
**Ecosystem Services  
&  
Pillars of Sustainability**



# Brownfields & Other Urban Areas

## Tree Planting is Strategic

Positive Ecosystem Function  
(e.g., Plant Biomass)



## Redevelopment

- Create green space (livability)
- Urban amenity plantings
- Direct contact issues
- Economic value of trees

## Ecology

- Buffer Great Lakes (TMDLs)
- Redirect surface water
- Increase tree canopy
- Carbon sequestration

# Thank you!

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## Contact Information

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[http://www.nrs.fs.fed.us/units/iaes/focus/energy\\_climate\\_genetics/](http://www.nrs.fs.fed.us/units/iaes/focus/energy_climate_genetics/)

## Acknowledgements

I thank Dave Bloniarz and Donna Murphy for the invitation to speak today.