Phytoremediation for reducing potential impacts of PFAS to human health and the environment

R.S. Zalesny Jr.[1], E.R. Rogers[1,2], R.A. Vinhal[1,2], C-H. Lin[2]

[1] USDA Forest Service, Rhinelander, Wisconsin, USA
[2] University of Missouri, Columbia, Missouri, USA

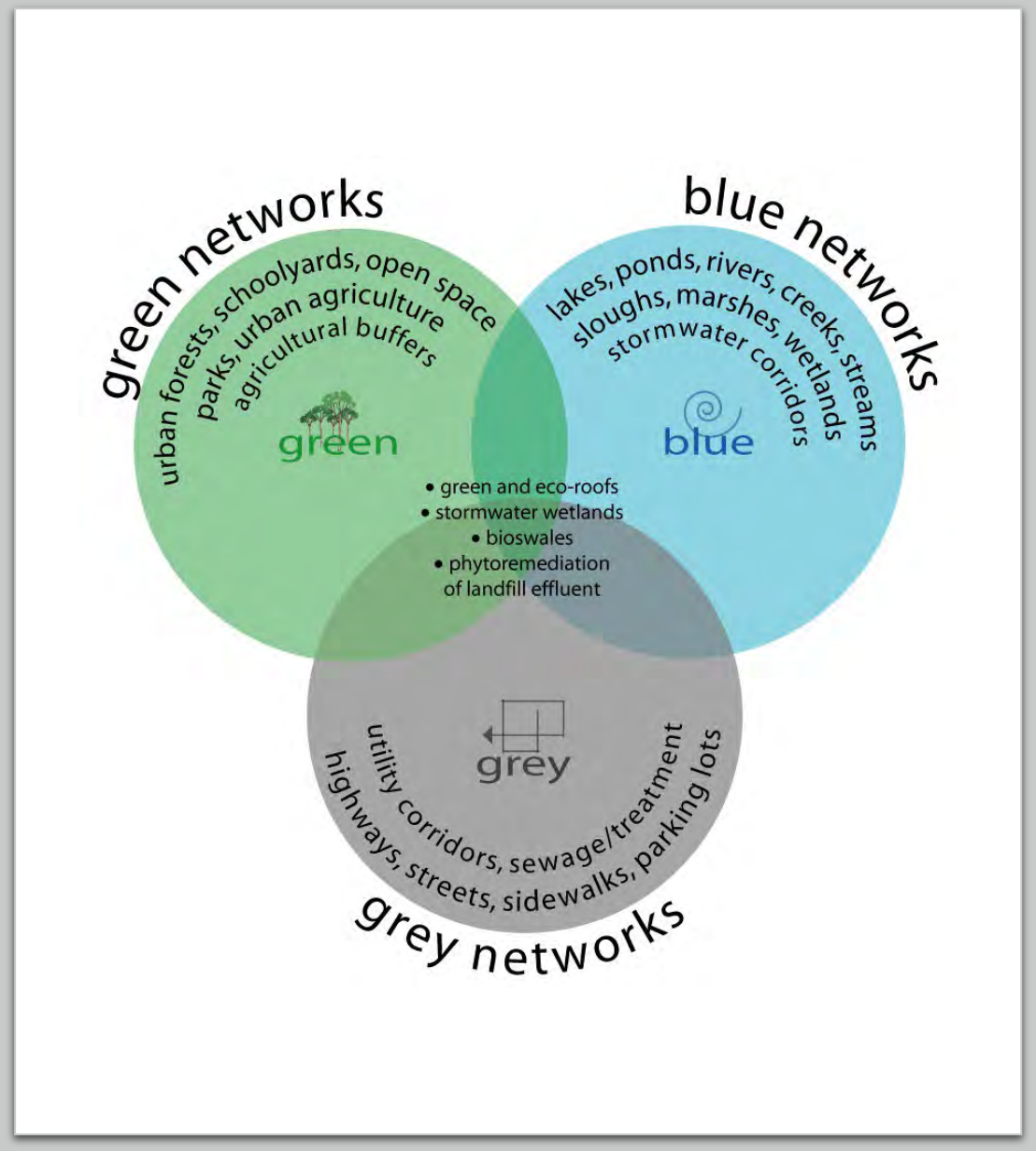
The Center for Agroforestry
University of Missouri

Marquette PFAS Workshop, 31 January – 1 February 2023

Phytotechnologies

"The **strategic use of plants** to **solve environmental problems** by remediating the qualities and quantities of our soil, water, and air resources and by **restoring ecosystem services** in managed landscapes."

-International Phytotechnology Society



Examples:

Green Roofs / Eco Roofs
Green Infrastructure
Stormwater Wetlands
Constructed Wetlands
Bioswales / Rain Gardens
Urban Tree Canopies
Vegetative Forest Buffers

Mine Reclamation
Phytoremediation

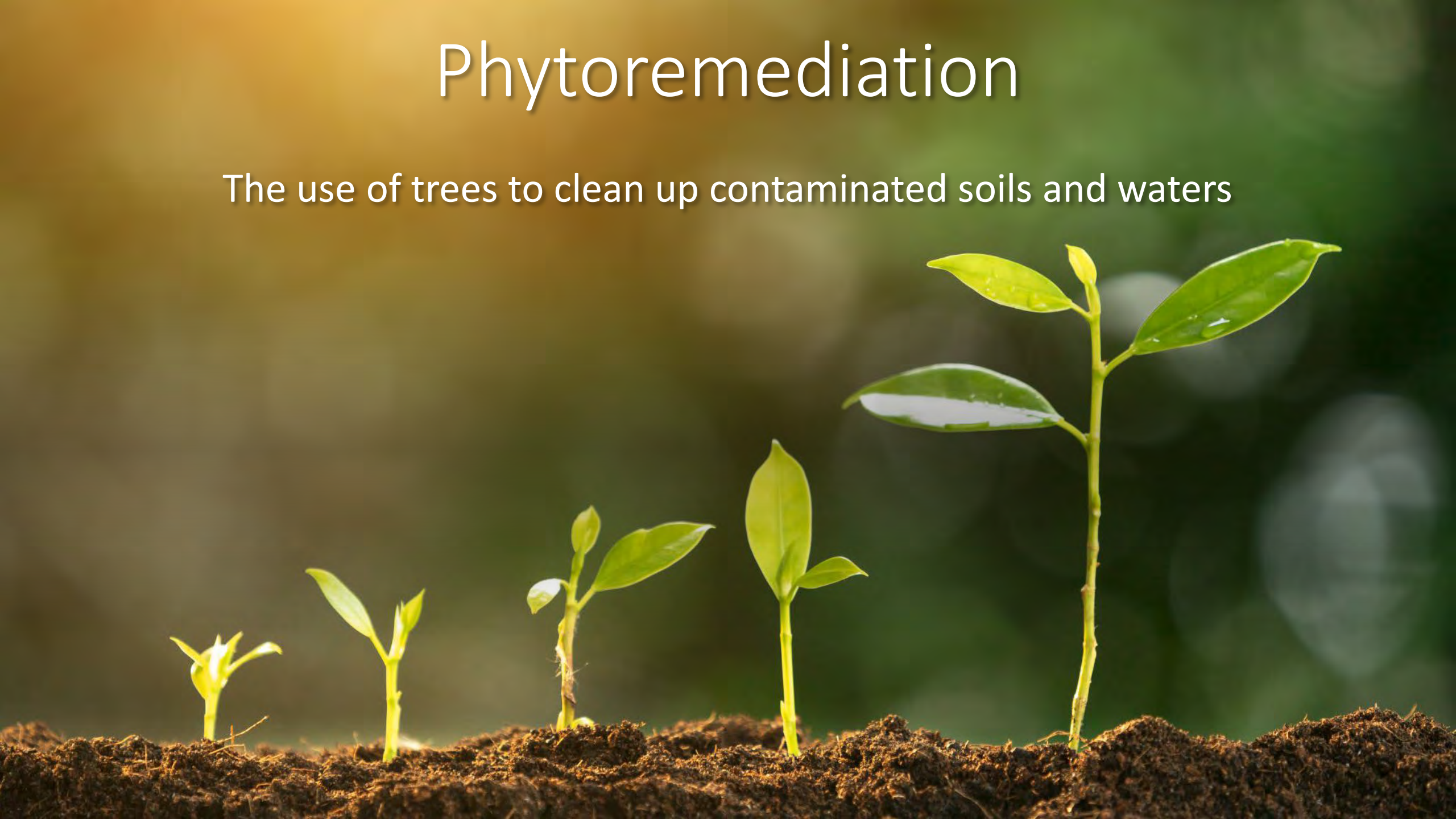

PC: greenroofs.org


PC: easterlake.org

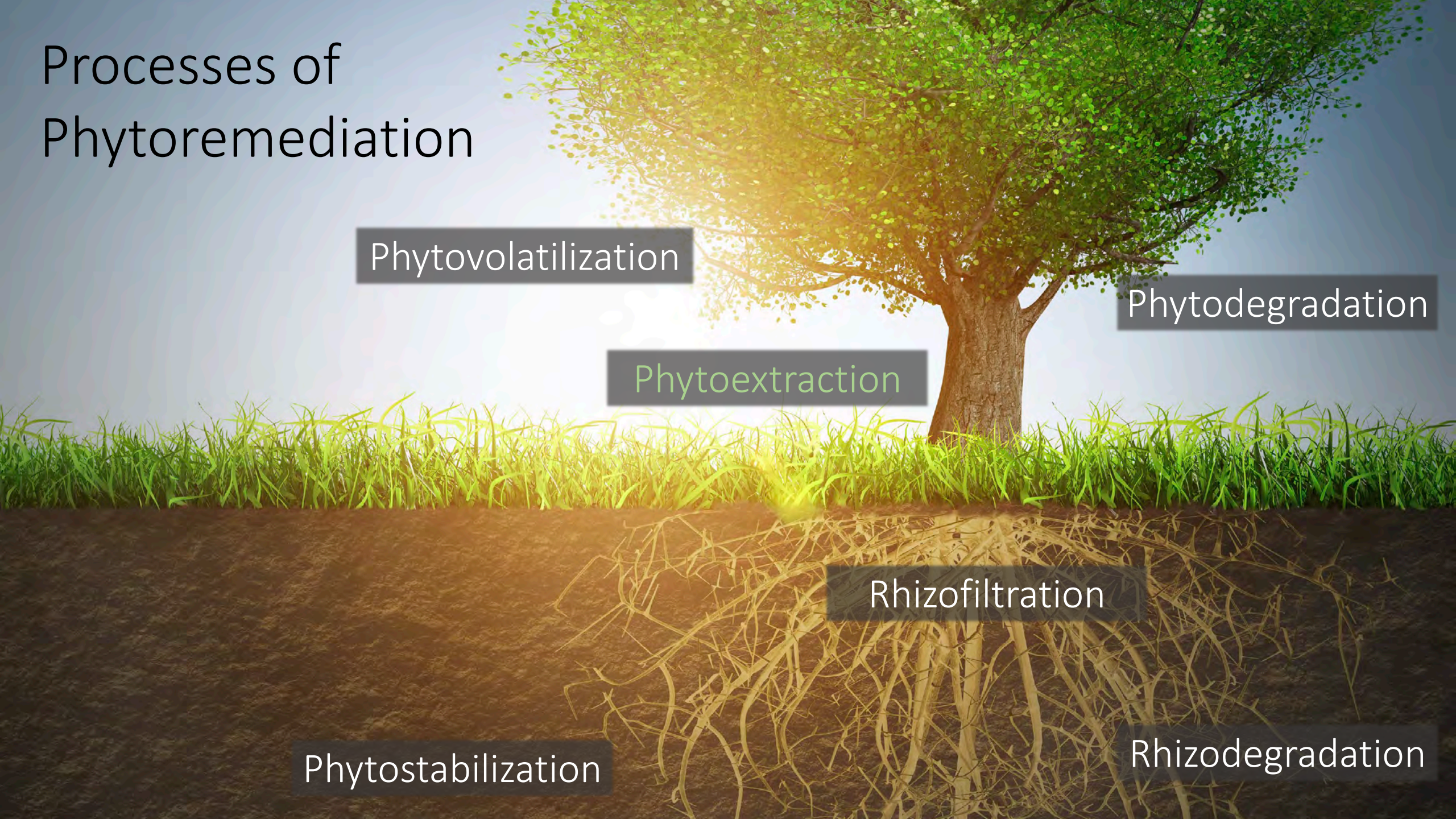

PC: American Society of Landscape Architects

Phytoremediation

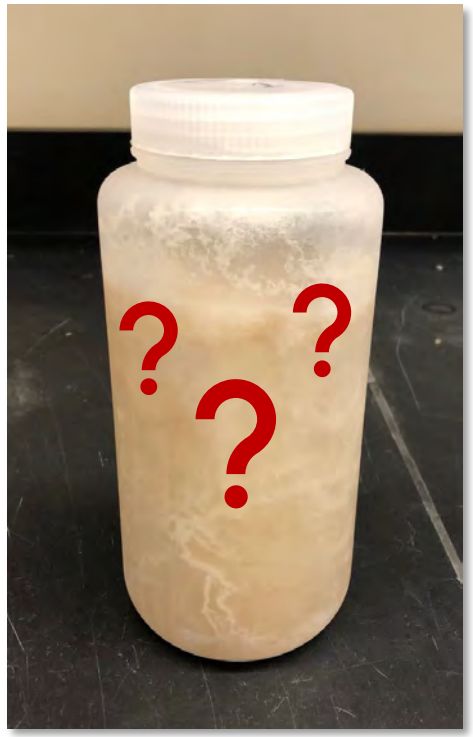
The use of trees to clean up contaminated soils and waters



Processes of Phytoremediation



New Approach: Prioritization Tool



Landfill Leachate

Toxicity Data

Community Priorities

Prioritized Contaminants

Rank	ToxPi Score	Name
1	0.5867	Atropine methyl bromide
2	0.5846	Fluorene
3	0.5546	Butylate
4	0.5527	Fluoxymesterone
5	0.5488	Pyrilamine
6	0.5449	Octylonium bromide
7	0.5201	3-Methyl-1,2-cyclohexanedione
8	0.5077	Benz[a]anthracene
9	0.4944	Dimethametryn
10	0.4943	DL-α-Lipoic Acid
11	0.4937	4-Biphenylamine
12	0.4928	Tulobuterol hydrochloride
13	0.4772	9-Hydroxyrisperidone
14	0.4771	Acarbose (Glucobay)
15	0.4714	Tropisetron
16	0.4708	raclopride
17	0.4680	Benzofuran
18	0.4646	Eletriptan
19	0.4616	Quinocide
20	0.4541	Felodipine

Design Phytoremediation Systems

Journal of Environmental Management 284 (2021) 112031

Contents lists available at ScienceDirect

Journal of Environmental Management

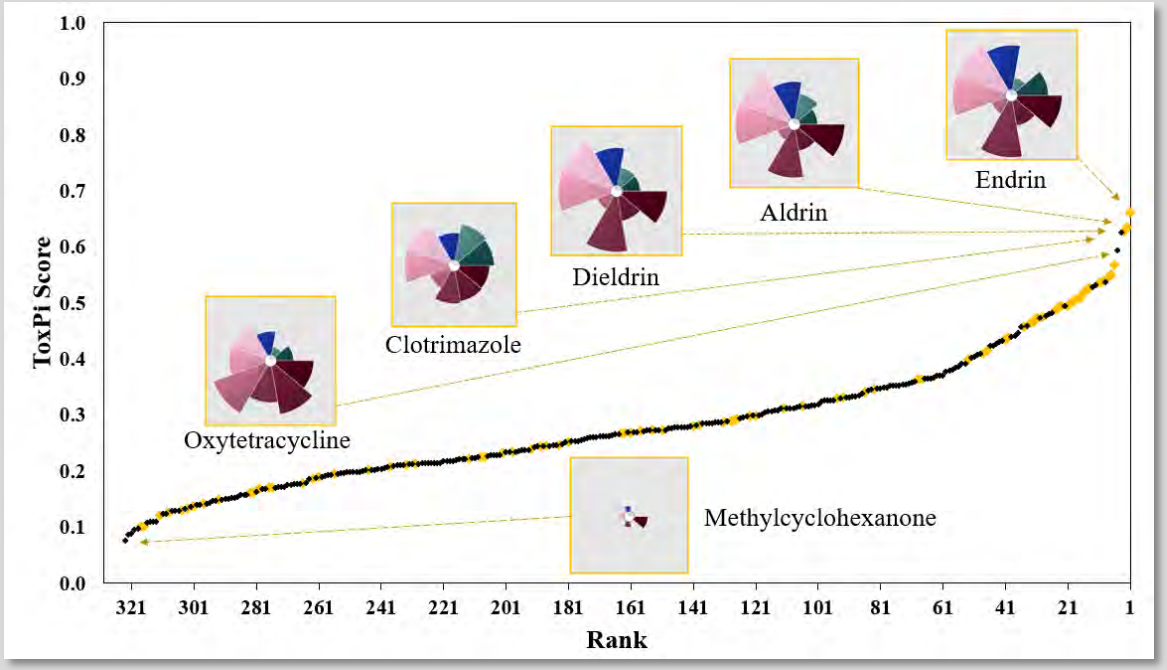
journal homepage: http://www.elsevier.com/locate/jenvman

A systematic approach for prioritizing landfill pollutants based on toxicity: Applications and opportunities

Elizabeth R. Rogers [a,b,c], Ronald S. Zalesny Jr. [c], Chung-Ho Lin [a,b,*]

Future Applications

- Integrate the tool with genotypic selection for **phytoremediation** activities
- Combine the tool with **metabolomics profiling** for comprehensive understanding



Landfill Leachate Contaminants Ranked By Toxicity

https://www.nrs.fs.fed.us/disturbance/pollution/prioritizing-contaminants/


CO2


Poplars


Willows


Eucalypts


Pines

Short Rotation Woody Crops (SRWCs)

Fast-growing trees such as poplars (*Populus* L.), willows (*Salix* L.), eucalypts (*Eucalyptus* L'Hér), pines (*Pinus* L.), and other species that are dedicated to the provision of biomass feedstocks for energy, pulp, and solid wood products, as well as ecosystem services associated with restoration, environmental remediation, and community livelihoods.

Zalesny et al. (2019) WIREs Energy Environ 8:e345

Phyto-Recurrent Selection

Test. Select. Deploy.

International Journal of Phytoremediation, 9:513–530, 2007

ISSN: 1522-6514 print / 1549-7879 online
DOI: 10.1080/15226510701709754

Taylor & Francis

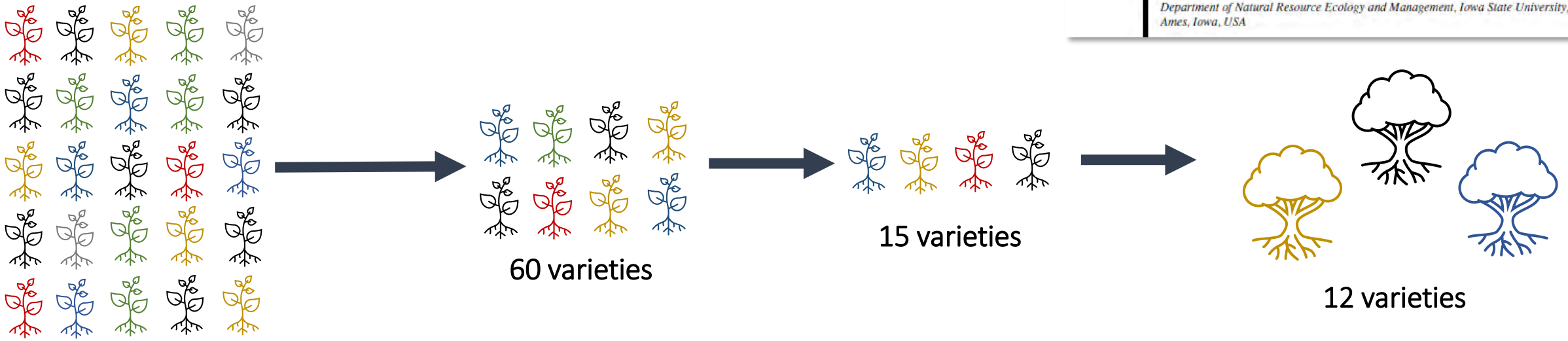
CHOOSING TREE GENOTYPES FOR PHYTOREMEDIATION OF LANDFILL LEACHATE USING PHYTO-RECURRENT SELECTION

Jill A. Zalesny
Department of Natural Resource Ecology and Management, Iowa State University, Ames, Iowa, USA

Ronald S. Zalesny Jr. and Adam H. Wiese
USDA Forest Service, Northern Research Station, Institute for Applied Ecosystem Studies, Rhinelander, Wisconsin, USA

Richard B. Hall
Department of Natural Resource Ecology and Management, Iowa State University, Ames, Iowa, USA

Stepwise selection process involving multiple selection cycles to identify and select clones with superior performance



Greenhouse Testing

Field Implementation and Testing

Phyto-Recurrent Selection

Cycle 1

Cycle 2

Cycle 3

Multiple growing seasons

Greenhouse Testing

Field Implementation and Testing

Long-Term Monitoring

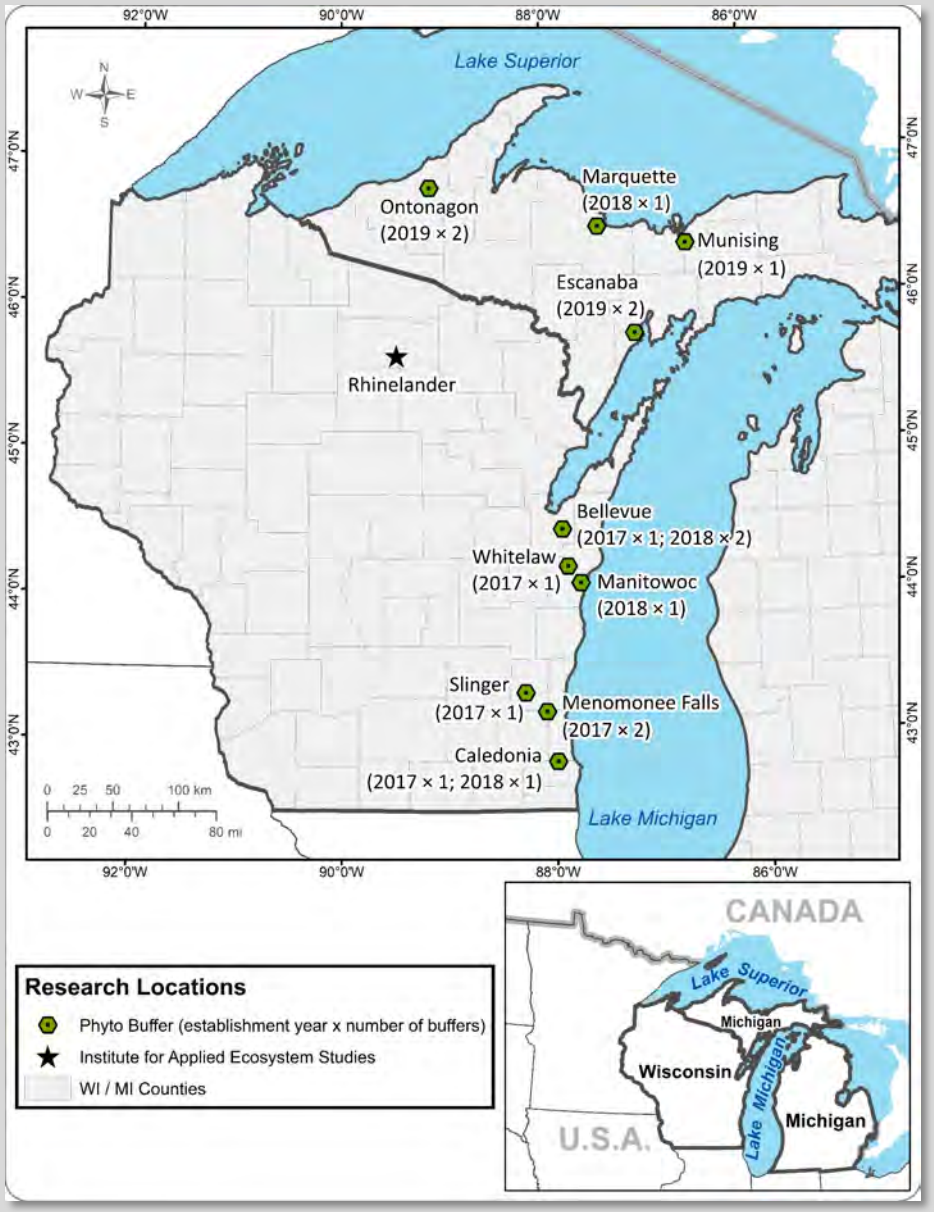

PC: Brent DeBauche

- Necessary to evaluate the performance of a system over time, and to better understand remediation mechanisms, clonal differences
- Long-term phyto projects that maintain the plantings and collect data are rare, but important

GREAT LAKES PHYTO

Enhancing Ecosystem Services

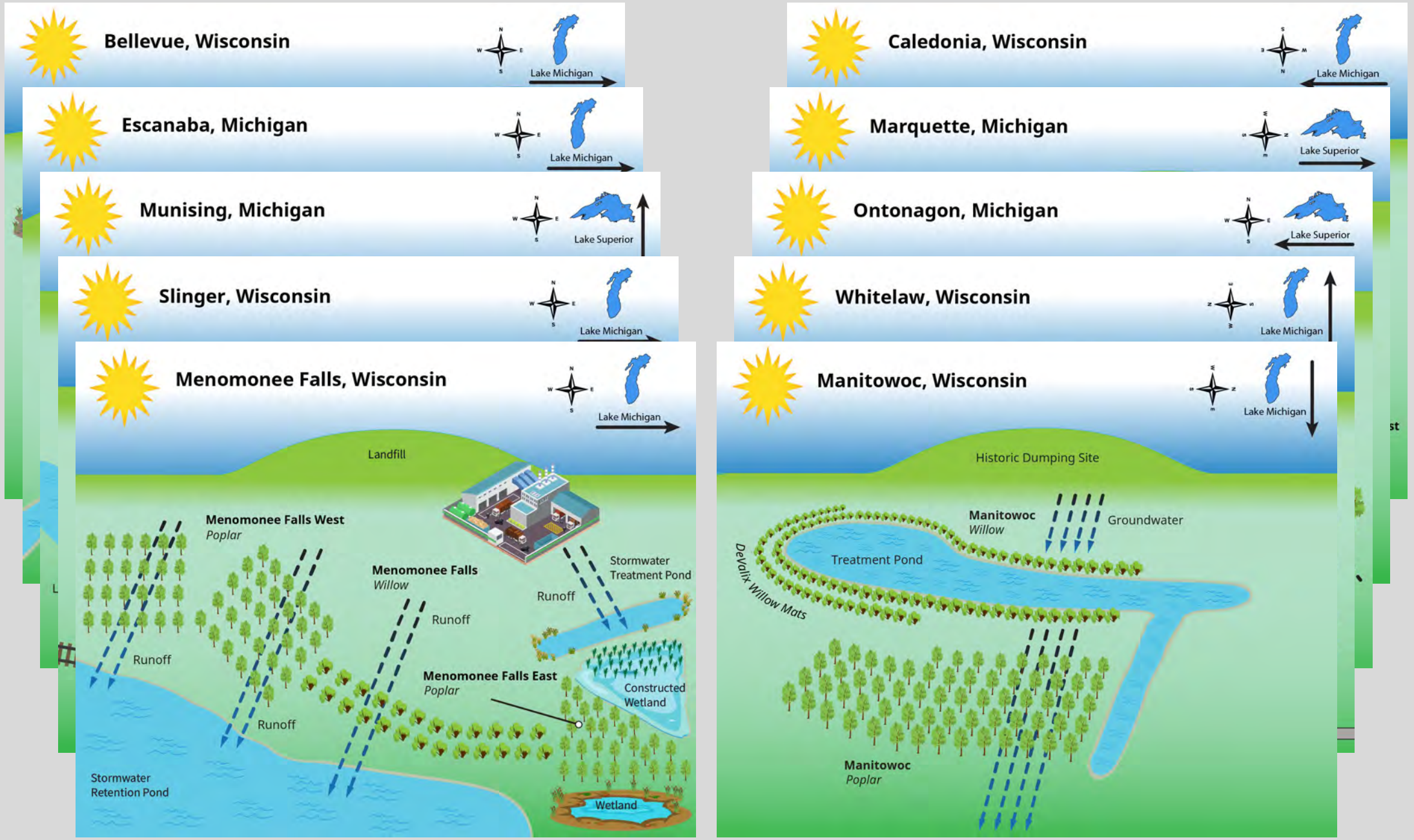
Agroforestry Phytoremediation Buffer Systems in the Great Lakes Basin



Great Lakes RESTORATION

GREAT LAKES PHYTO
Enhancing Ecosystem Services

https://www.nrs.fs.fed.us/disturbance/pollution/phytoremediation-buffers/


Bellevue, Wisconsin
Lake Michigan
Escanaba, Michigan
Lake Michigan
Munising, Michigan
Lake Superior
Slinger, Wisconsin
Lake Michigan
Menomonee Falls, Wisconsin
Lake Michigan
Landfill
Menomonee Falls West
Poplar
Menomonee Falls
Willow
Runoff
Runoff
Runoff
Runoff
Stormwater
Treatment Pond
Menomonee Falls East
Poplar
Constructed
Wetland
Stormwater
Retention Pond
Wetland
Caledonia, Wisconsin
Lake Michigan
Marquette, Michigan
Lake Superior
Ontonagon, Michigan
Lake Superior
Whitelaw, Wisconsin
Lake Michigan
Manitowoc, Wisconsin
Lake Michigan
Historic Dumping Site
Manitowoc
Willow
Groundwater
Treatment Pond
DeValix Willow Mats
Manitowoc
Poplar

Bellevue, Wisconsin, USA

PC: P.V. Manley, J.G. Burken, Missouri S&T

Applications: Runoff Reduction, Phytoremediation

Bellevue, Wisconsin, USA

June 2018

Professional photo courtesy of Brent Steven DeBauche, BS, AG, CMC.

Bellevue, Wisconsin, USA

July 2018

Professional photo courtesy of Brent Steven DeBauche, BS, AG, CMC.

Bellevue, Wisconsin, USA

July 2019

Whitelaw, Wisconsin, USA

PC: P.V. Manley, J.G. Burken, Missouri S&T

Applications: Groundwater Recycling, Phytoremediation

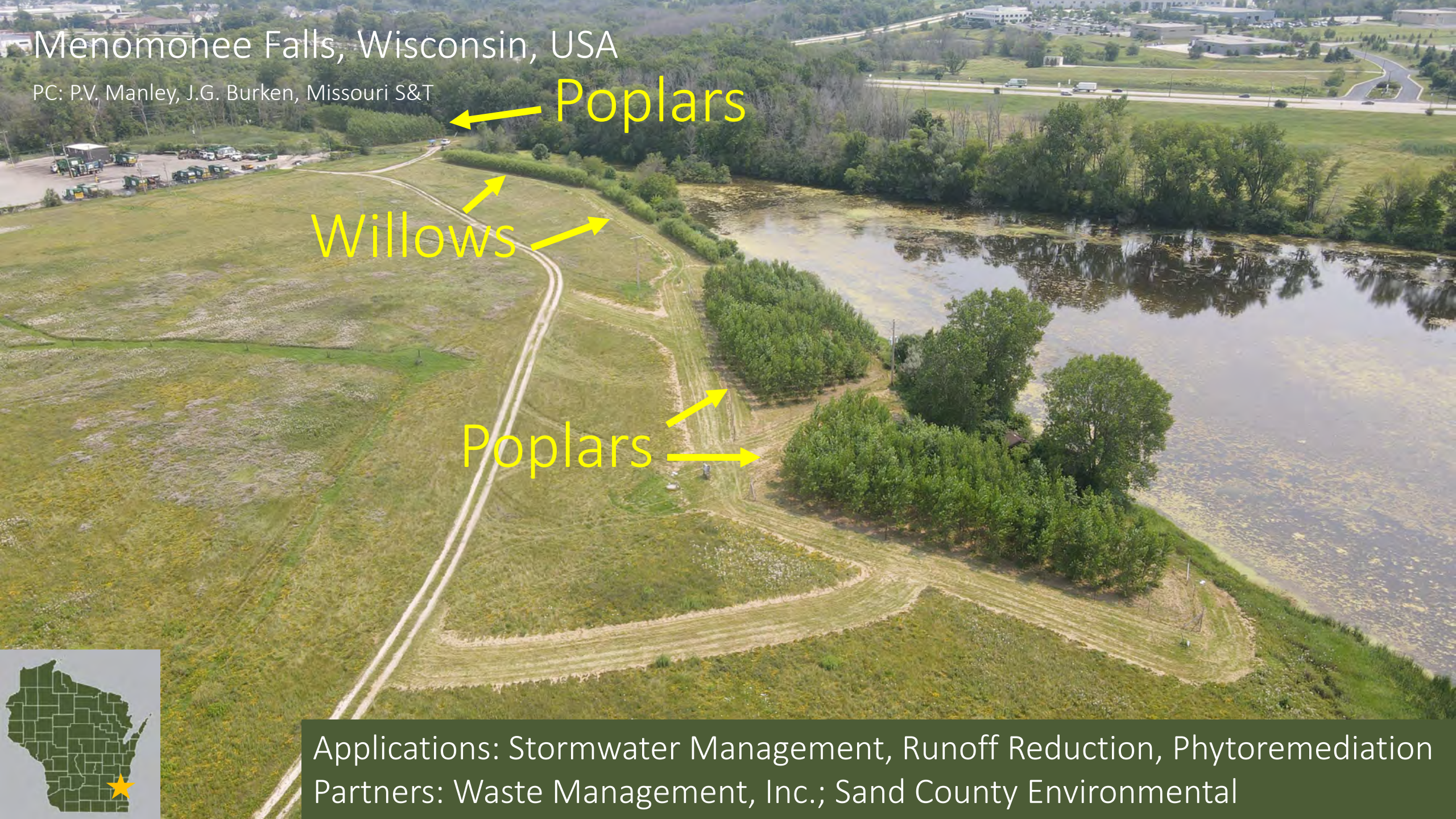
Partners: Waste Management, Inc.; Wisconsin DNR

Whitelaw, Wisconsin, USA

PC: P.V. Manley, J.G. Burken, Missouri S&T

Poplars | Willows

Applications: Groundwater Recycling, Phytoremediation


Menomonee Falls, Wisconsin, USA
PC: P.V. Manley, J.G. Burken, Missouri S&T
Poplars
Willows
Poplars
Applications: Stormwater Management, Runoff Reduction, Phytoremediation
Partners: Waste Management, Inc.; Sand County Environmental

USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Northern Research Station

Rooted in Research

ISSUE 10 | JUNE 2022

Pollution Solutions: Maximizing the Cleaning Power of Trees

It is hard to imagine the vast expanse of the Great Lakes being anything but pristine, yet trouble roils just beneath the surface. Along with an increase in the use of electronics, pharmaceuticals, and personal care products comes an increase in the pollutants that are pumped into the environment every day.

"In the Great Lakes region, we are used to having an abundance of fresh water," says Liz Rogers, a Pathways Intern at the U.S. Department of Agriculture, Forest Service's Northern Research Station (NRS). The Great Lakes contain roughly 90 percent of the surface freshwater supply in the United States—and 20 percent of the world's freshwater supply. "If pollution to the Great Lakes continues unchecked, the freshwater we drink, fish we eat, and recreation opportunities the lakes provide could all be affected, changing our ways of life as we know them."

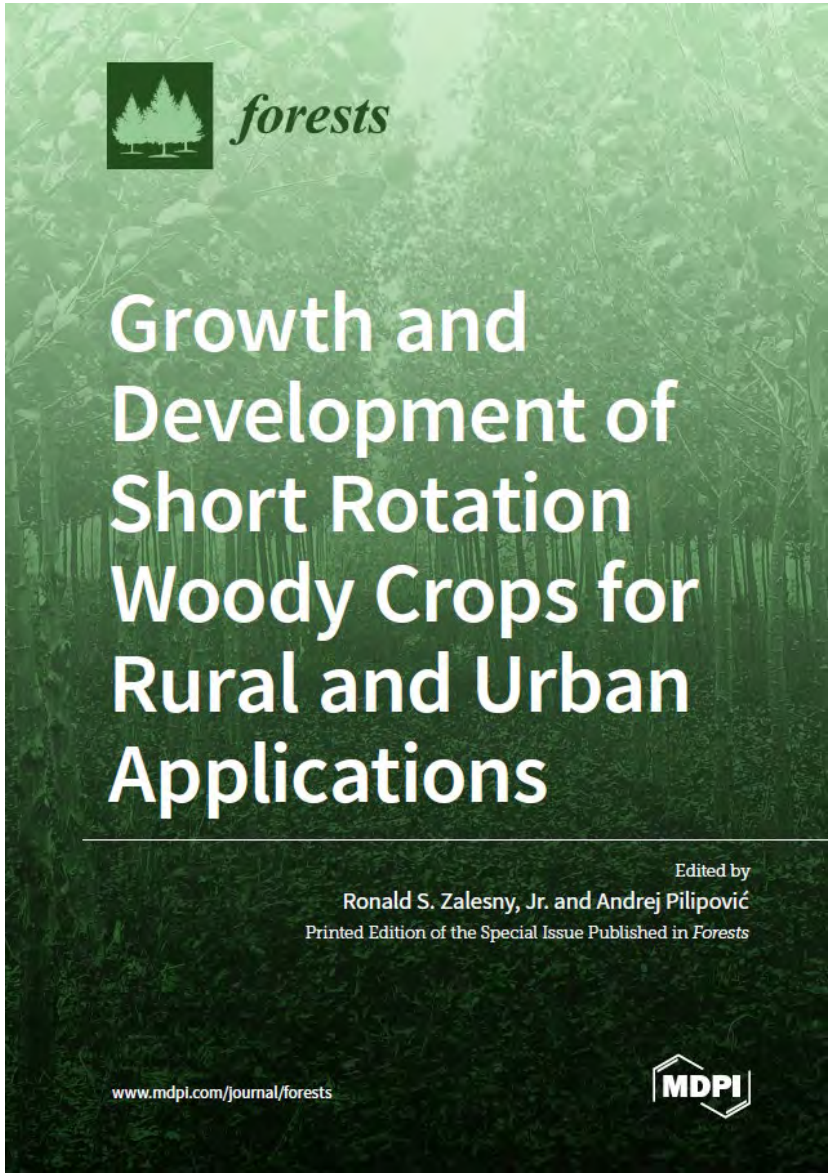
Rogers and Ryan Vinhal, another USDA Pathways Intern, both work in the lab of Chung-Ho Lin, an associate professor at the University of Missouri's Center for Agroforestry. Lin, Rogers, and Vinhal are working with Ron Zalesny, an NRS scientist based in Rhinelander, WI, who leads the Station's research on phytotechnologies—technologies that use trees to solve environmental problems—in urban and rural areas. The work of this team to establish standardized, customizable approaches is setting a new standard for tailoring the phytoremediation process to the needs of communities anywhere in the world.

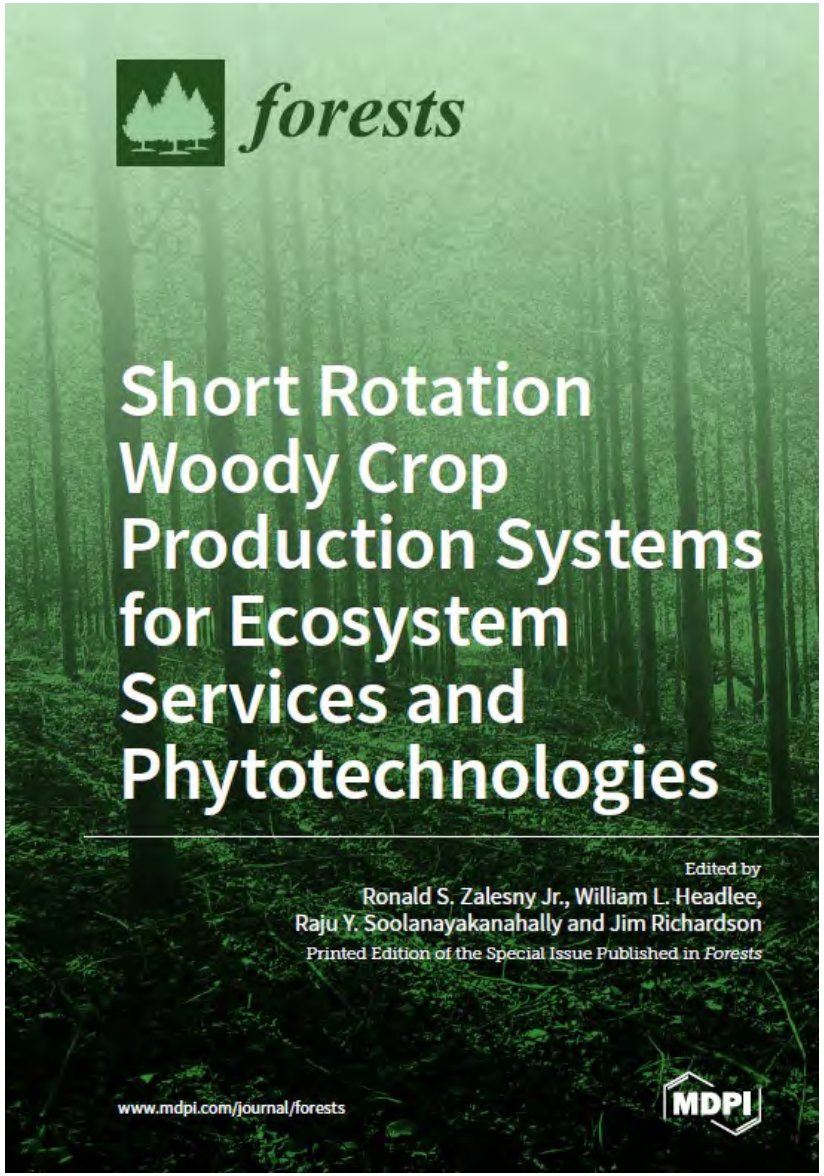
Zalesny with other NRS scientists in the Great Lakes region began studying and applying phytoremediation, a process that harnesses the power of trees to soak up and break down pollutants, back in 1995. Today, phytoremediation is among the most cost-effective approaches for capturing pollutants before they contaminate drinking water, disrupt recreation, or destroy essential wildlife habitat. In 2016, a team of NRS researchers established a 16-site system of trees for phytoremediation—the largest replicated field-scale phytoremediation network in the world. With funding from the Great Lakes Restoration Initiative, scientists are formalizing methods for identifying pollutants of greatest concern, selecting trees best suited for the specific job at each site, and measuring how the remediation process unfolds throughout the life cycle of the trees.

KEY MANAGEMENT CONSIDERATIONS

- The prioritization method developed by the team uses the most current pollutant toxicity information available to help site managers make important decisions about which pollutants to clean up.
- Poplar and willow trees have a longstanding history of successfully removing pollutants from soil and waterways. Trees chosen through a process called phyto-recurrent selection can help to optimize their effectiveness.
- Measuring how phytoremediation unfolds throughout the life cycle of the tree could help site managers make key tree selection and management decisions.
- Leading-edge planting methods developed by researchers could enhance the success of phytoremediation systems.

An agroforestry phytoremediation buffer system at a landfill in eastern Wisconsin. Courtesy photo by Paul Manley, Missouri University of Science and Technology, used with permission.


forests
Growth and Development of Short Rotation Woody Crops for Rural and Urban Applications
Edited by
Ronald S. Zalesny, Jr. and Andrej Pilipović
Printed Edition of the Special Issue Published in Forests
www.mdpi.com/journal/forests
MDPI


forests
Short Rotation Woody Crop Production Systems for Ecosystem Services and Phytotechnologies
Edited by
Ronald S. Zalesny Jr., William L. Headlee, Raju Y. Soolanayakanahally and Jim Richardson
Printed Edition of the Special Issue Published in Forests
www.mdpi.com/journal/forests
MDPI

Thank You!

Elizabeth R. Rogers
elizabeth.r.rogers@usda.gov

Ryan A. Vinhal
ryan.vinhal@usda.gov

Ronald S. Zalesny Jr.
ronald.zalesny@usda.gov

USDA Forest Service
Northern Research Station
Rhinelander, WI, USA

https://youtu.be/7e2bqtnU75g

https://www.nrs.fs.fed.us/disturbance/pollution/phytoremediation-buffers/
https://www.nrs.fs.fed.us/units/iaes/focus/woody-crop-systems/