Using Phytotechnologies to Remediate Brownfields, Landfills, & Other Urban Areas

Zalesny and Zalesny: Phytotechnologies for Remediation in the Urban Environment

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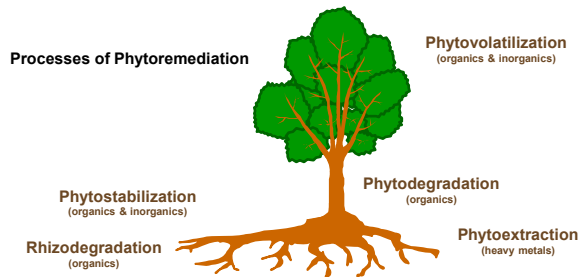**MillionTreesNYC, Green Infrastructure & Urban Ecology: A Research Symposium, March 5-6, 2010**

RATIONALE

Urban areas requiring remedial work has prompted the use of phytotechnologies to improve water quality, soil health, & biodiversity, as well as to achieve sustainable social & economic goals. Phytotechnologies directly use plants to clean up contaminated groundwater, soil, & sediment. An example of such technologies is phytoremediation, which is comprised of many processes.

Processes of Phytoremediation

Phytovolatilization (organics & inorganics)
Phytostabilization (organics & inorganics)
Phytodegradation (organics)
Rhizodegradation (organics)
Phytoextraction (heavy metals)

While woody & herbaceous crops are candidates for such remediation systems, trees within the genera *Populus* (poplars, cottonwoods, aspens) & *Salix* (willows) are ideal given their elevated rates of photosynthesis and transpiration (A), fast growth (B), & extensive root systems (C). These trees are often known as "workhorses" towards remediation of contaminated areas. The genetic diversity within these genera substantially increases the establishment & growth potential across heterogeneous sites.
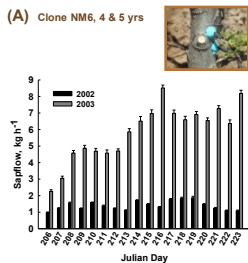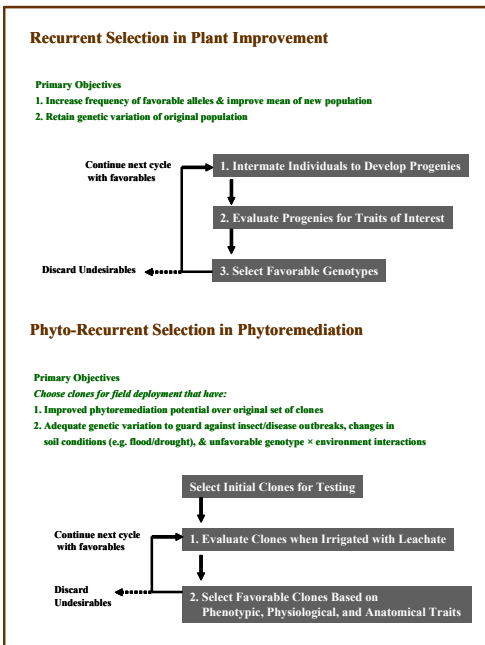
Examples of phytoremediation projects conducted at the Institute for Applied Ecosystem Studies include:

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

(A) Clone NM6, 4 & 5 yrs

2002 / 2003
y-axis: Sapflow, kg h^{-1}
x-axis: Julian Day

(B) Clone NC14104, 14 months after planting.

(C) Clone NM6, 14 months after planting

OBJECTIVES

We have tested these trees for more than a decade across various sites & contaminants, which has resulted in developing **phyto-recurrent selection**, a method utilizing multiple testing cycles to evaluate, identify, & select favorable varieties with adequate genetic variation to guard against insect/disease outbreaks & changing edaphic conditions (especially those induced by contaminated soil & water) in the field. The figure below is an example for phytoremediation of landfill leachate.

Recurrent Selection in Plant Improvement

Primary Objectives
1. Increase frequency of favorable alleles & improve mean of new population
2. Retain genetic variation of original population

Continue next cycle with favorables
1. Intermate Individuals to Develop Progenies
2. Evaluate Progenies for Traits of Interest
3. Select Favorable Genotypes
Discard Undesirables

Phyto-Recurrent Selection in Phytoremediation

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

Select Initial Clones for Testing
Continue next cycle with favorables
1. Evaluate Clones when Irrigated with Leachate
2. Select Favorable Clones Based on Phenotypic, Physiological, and Anatomical Traits
Discard Undesirables

REMEDIATION & RESTORATION

When moving towards remediation of contaminated sites, workhorse species are needed to achieve positive ecosystem function (i.e., plant biomass) while maintaining species diversity & complexity. Once remediation is successful, restoration is more likely to be attainable. These basic principles of the continuum between complete ecosystem degradation & pre-disturbance condition (i.e., restoration) are depicted below, with brownfields & landfills shown as examples that follow.

y-axis: Positive Ecosystem Function (i.e. Plant Biomass)
x-axis: Species Diversity/Complexity

Restoration
Remediation
Reclamation
Rehabilitation
Recovery
Ecosystem Degradation
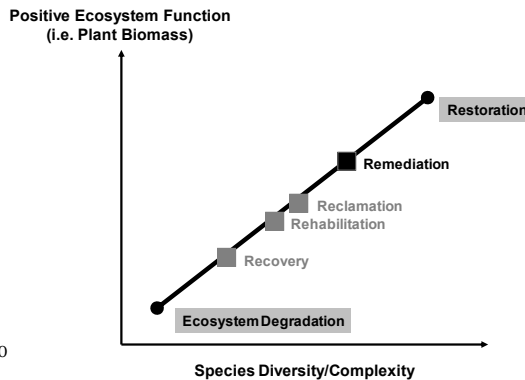
BROWNFIELDS

Abandoned or underused industrial & commercial facilities available for re-use, where expansion or redevelopment may be complicated by real or perceived environmental contaminations. Typically these sites are limited to reclamation, but remediation may be possible in some instances.

Ashford (WI) Battery Company
Neillsville (WI) Foundry
Marshfield (WI) Oil

LANDFILLS

Typically remediation & restoration is possible on these sites.

Ragnsells Avfallsbehandling AB Upplands-Bro, Sweden
Icke Landfill Madison, WI
Oneida County Landfill Rhinelander, WI

OTHER URBAN AREAS

Examples includes railyards, shipyards, & harbors.

PRACTICAL IMPLICATIONS

Cost-effective phytotechnologies are available to assist researchers, resource managers, regulators, etc. to improve environmental conditions while protecting human health.

Phyto-recurrent selection can help researchers & resource managers move closer to obtaining long-term (i.e., rotation age) remediation data from brownfields, landfills, & other urban areas.

Well-developed experimental designs & associated precision levels support estimation of quantitative genetic data that lead to recommendations of generalist genotypes that perform well over broad contaminant ranges or specialist genotypes that perform well for specific contaminants.

This effort supports scientists & resource managers to acquire information that contributes to the deployment of phytotechnologies that are ecologically & economically more sustainable versus traditional systems, while the general public maintains environmental quality & protection of the natural resource base on which local & regional recreation, agriculture, & forestry depend.

ACKNOWLEDGMENTS