Ecosystem services of poplar at long-term phytoremediation sites in the Midwest and Southeast, United States

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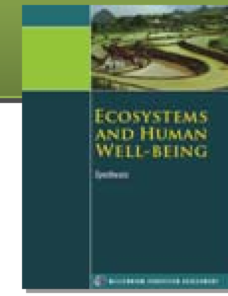
Ecosystem Services



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

“The benefits people obtain from ecosystems”

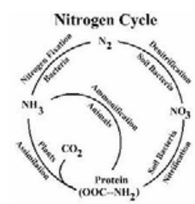
(Source: http://www.greenfacts.org/glossary/def/ecosystem-services.htm)

Cultural Services
The nonmaterial benefits obtained from ecosystems (e.g., values)

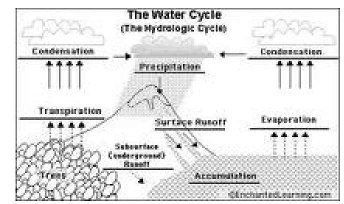

Spiritual


Educational

Supporting Services
The natural processes that maintain the other ecosystem services



Nitrogen



Water

Provisioning Services
The goods or products obtained from ecosystems


Freshwater


Biomass

Regulating Services
The benefits obtained from an ecosystem’s control of natural processes

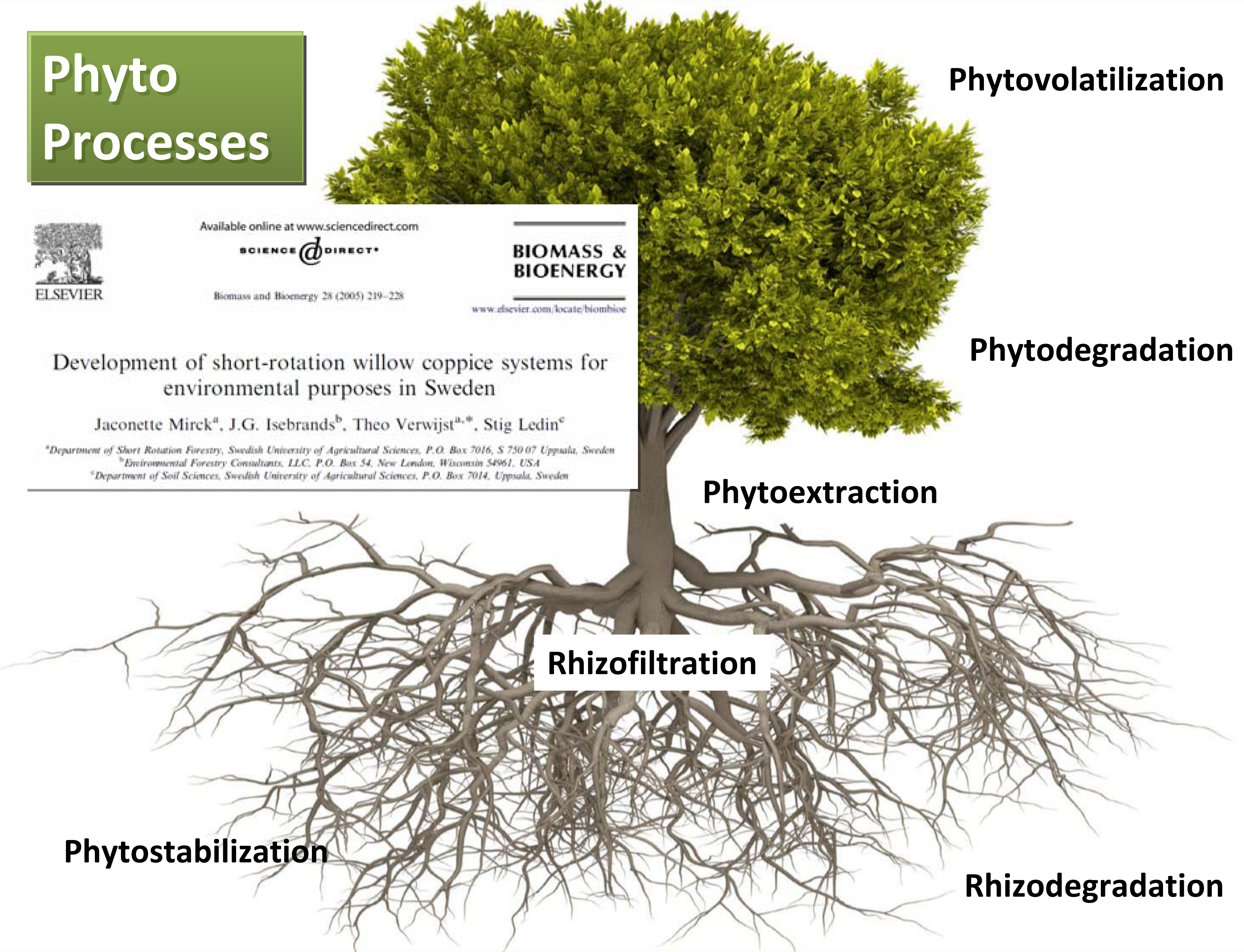

Erosion Control


Soil Quality

Ecosystem Services

Provisioning Services Aboveground Biomass	Regulating Services Aboveground Carbon Sequestration
	

Phyto Processes



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Development of short-rotation willow coppice systems for environmental purposes in Sweden

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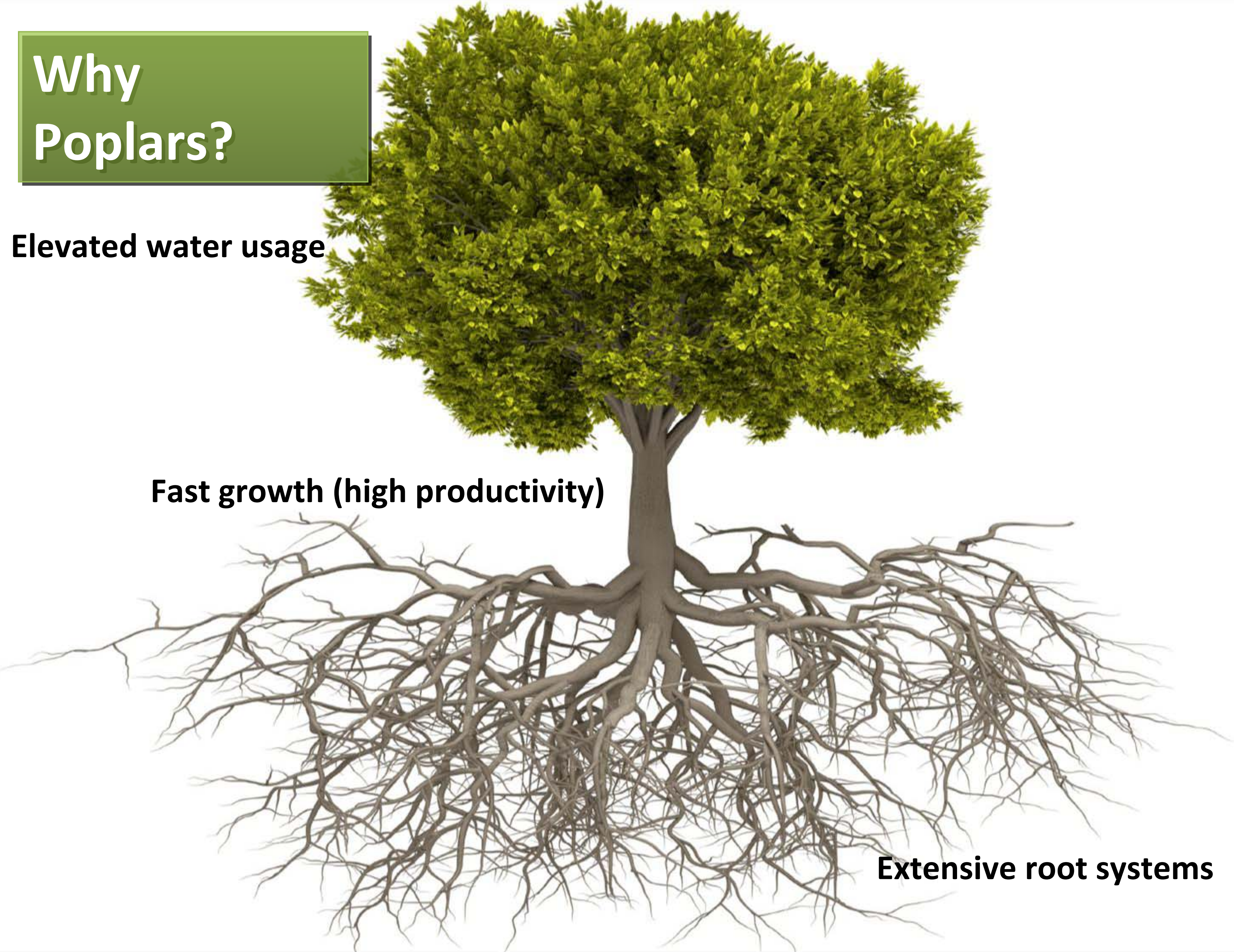
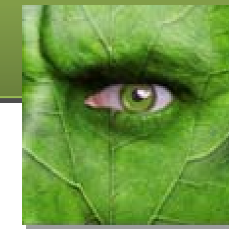
Why Poplars?



Elevated water usage
Fast growth (high productivity)
Extensive root systems

Rationale

Objectives



- One of the most challenging responsibilities for phytoremediation applications is the commitment & ability to continue measurements & monitoring throughout the rotation
- To address this need, our objectives were to evaluate differences in aboveground biomass & carbon sequestration potential of hybrid poplars grown at long-term phytoremediation sites in the Midwest & Southeast, United States

Rhinelander Municipal Landfill
Rhinelander, WI
13.5 yrs old

Oneida County Landfill
Rhinelander, WI
12.5 yrs old

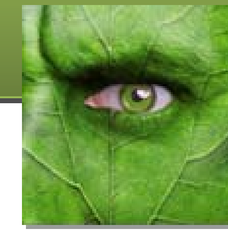
Industrial Brownfield
LaSalle, IL
10 yrs old

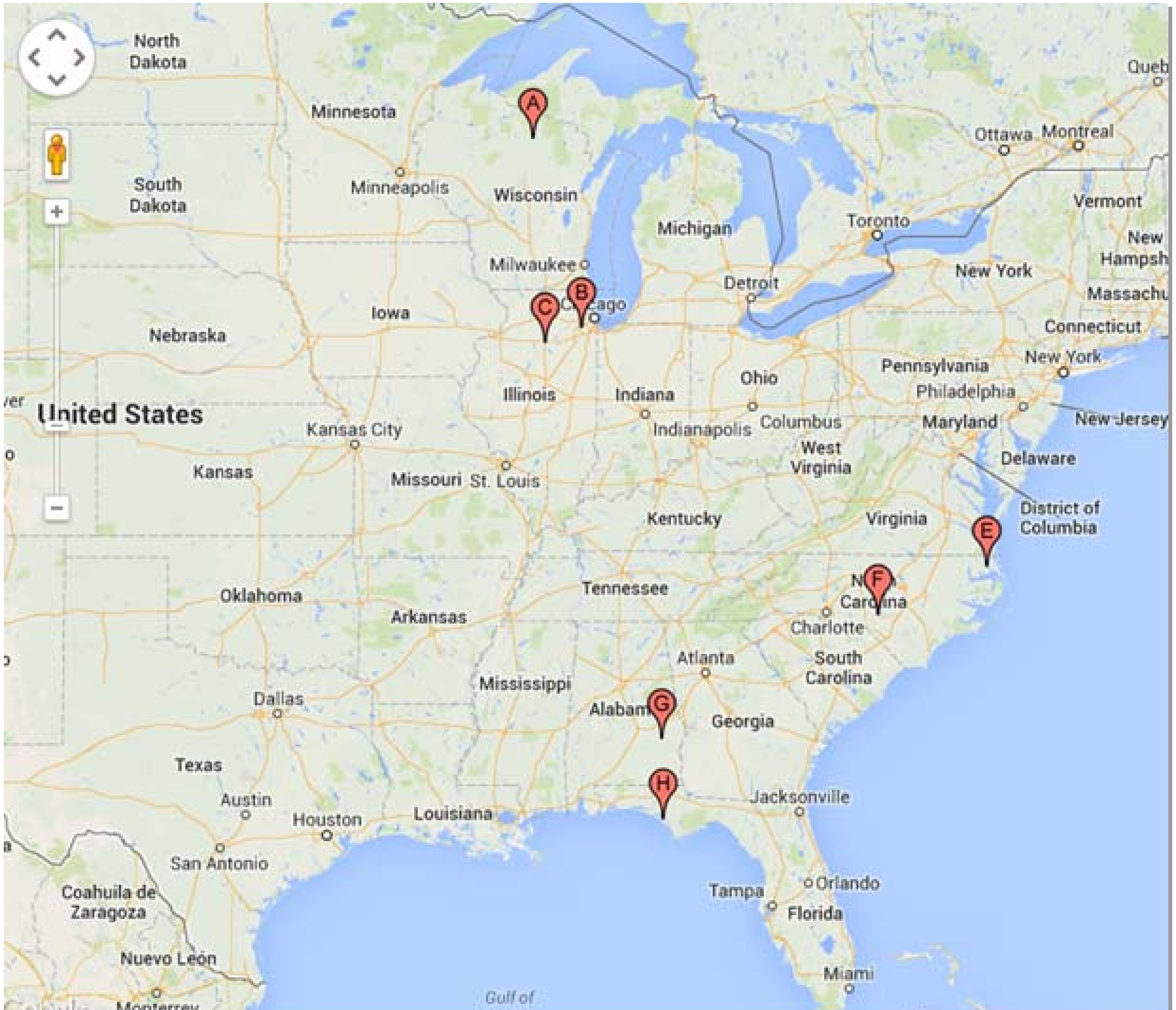
Phytoremediation Sites

Site	# Plantings	Lat. (°N)	Long. (°W)	Avg. Summer Temp. (°C)	Avg. Annual Precip. (mm)
A: Rhinelander, WI	4	45.63	89.48	18.2	675
B: Lemont, IL	1	41.60	88.08	22.3	1018
C: LaSalle, IL	2	41.35	89.11	22.3	964
D: Midwest	1	--	--	22.7	946
E: Elizabeth City, NC	3	36.31	76.21	25.2	1183
F: Aberdeen, NC	1	34.99	79.22	25.3	1182
G: Union Springs, AL	1	32.01	85.75	25.9	1408
H: Panama City, FL	1	30.21	85.68	27.7	1551
I: Northeast NC	1	--	--	25.3	1125

×9 ×15

Phytoremediation Sites



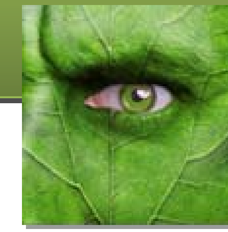


Planting	Issue	Stocking (trees/ha)	Year Planted	Age (yr)	# Clones	# Trees
A1: Rhinelander Landfill (I)	Nitrates	1076	1999	14.5	2	165
A2: Rhinelander Landfill (II)	Nitrates	1076	2000	13.5	1	200
A3: Oneida Co. Landfill (I)	Salts in leachate	1789	2005	8.0	1	123
A4: Oneida Co. Landfill (II)	Fiber cake recycling	1076	2001	12.5	2	531
B1: Argonne National Lab	VOCs, tritium	434	1999	14.0	1	179
C1: Industrial Brownfield (I)	TCE, PCE	1328	2002	11.0	19	144
C2: Industrial Brownfield (II)	TCE, PCE	2691	2002	11.0	8	68
D1: Ag Production Facility	Salts, metals, nitrates	1681	2002	11.0	34	359
E1: US Coast Guard Base (I)	Petroleum hydrocarbons	1111	2006	6.0	4	99
E2: US Coast Guard Base (II)	Petroleum hydrocarbons	1111	2007	5.0	4	263
E3: US Coast Guard Base (III)	Petroleum hydrocarbons	2500	2007	5.0	4	1637
F1: Industrial Brownfield	DDT, lindane	2315	1998	15.0	2	178
G1: Industrial Brownfield	Misc. organics	4310	2008	5.0	6	101
H1: Industrial Brownfield	Arsenic	1346	2008	5.4	15	135
I1: Hog Lagoon	Nitrates	1795	2003	10.0	×54	180

Genomic group (×10)	Clone(s)
P. deltoides 'D'	7300501; 8000105; 91.05.02; 220-5; 252-4; 42-7; 51-5; 3-1; Ohio Red; D121; D123; D124; 79-4; 90-3; 92-4; 93-6; 94-4; 100-3; 115-1; 119-6; 147-1; 189-4; 72C-2; Ken8; S13C20; S7C1
P. deltoides × *P. deltoides* 'DD'	80X01107; 80X00601; 80X01015; ISU.25-4; ISU.25-12; ISU.25-21; ISU.25-35; ISU.25-R2; ISU.25-R4; ISU.25-R5; 119.16
P. deltoides × *P. nigra* 'DN'	DN5; DN21; DN31; DN34; DN182; OP-367; I4551
P. nigra × *P. maximowiczii* 'NM'	NM2; NM6
P. trichocarpa × *P. deltoides* 'TD'	15-29; 49-177
(*P. trichocarpa* × *P. deltoides*) × *P. deltoides* 'TDD'	NC13992
P. maximowiczii × *P. trichocarpa* 'MT'	NE41
P. charkowiensis × *P. cv incrassata* 'CI'	NE308
P. deltoides × *P. maximowiczii* 'DM'	DM115; Belgian25; 313.23
P. alba × *P. grandidentata* 'AG'	Crandon

Authorities for the aforementioned species are: *P. alba* L.; *P. charkowiensis* R.I. Schrod.; *P. deltoides* Bartr. ex Marsh; *P. grandidentata* Michx.; *P. incrassata* Dode; *P. maximowiczii* A. Henry; *P. nigra* L.; *P. trichocarpa* Torr. & Gray.

Data Collection



- Measured diameter at breast height (DBH) at each site
- Estimated individual-tree, aboveground dry biomass (a × dbh^b)
- Estimated mean carbon concentration (watch Headlee et al. after break)

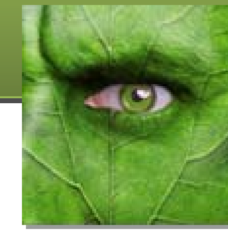
Genomic Group(s)	Equation #	a	b	R^2	Carbon (%)
D, DD	1	0.2257	2.0145	0.87	46.85
DN	2	0.0962	2.3537	0.91	47.31
NM	3	0.1445	2.2061	0.73	47.71
TD, TDD	4	0.3795	1.7762	0.69	47.48
AG, CI, DM, MT	5	0.0901	2.3441	0.86	47.28

- Integrated biomass, carbon, stocking, & age
- Final data: DBH (cm)

  $Biomass_{MAI}$ (Mg ha^{-1} yr^{-1})

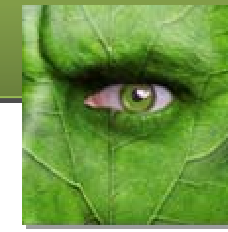
  $Carbon_{MAI}$ (Mg C ha^{-1} yr^{-1})

Case Studies



Planting	DBH (cm)	$Biomass_{MAI}$ ($Mg\ ha^{-1}\ yr^{-1}$)	$Carbon_{MAI}$ ($Mg\ ha^{-1}\ yr^{-1}$)
A1: Rhinelander Landfill (I)	15.3 ± 0.4	5.0 ± 0.2	2.4 ± 0.1
A2: Rhinelander Landfill (II)	14.0 ± 0.3	4.4 ± 0.2	2.1 ± 0.1
A3: Oneida Co. Landfill (I)	13.7 ± 0.3	11.2 ± 0.5	5.3 ± 0.3
A4: Oneida Co. Landfill (II)	19.0 ± 0.3	9.4 ± 0.3	4.5 ± 0.1
B1: Argonne National Lab	23.3 ± 0.6	5.4 ± 0.3	2.5 ± 0.1
C1: Industrial Brownfield (I)	**16.1 ± 0.6**	**9.3 ± 0.6**	**4.4 ± 0.3**
C2: Industrial Brownfield (II)	**10.8 ± 0.4**	**7.3 ± 0.6**	**3.4 ± 0.3**
D1: Ag Production Facility	19.6 ± 0.3	15.5 ± 0.4	7.3 ± 0.2
E1: US Coast Guard Base (I)	6.8 ± 0.4	2.4 ± 0.2	1.2 ± 0.1
E2: US Coast Guard Base (II)	**4.5 ± 0.2**	**1.3 ± 0.1**	**0.6 ± 0.1**
E3: US Coast Guard Base (III)	**4.3 ± 0.1**	**2.6 ± 0.1**	**1.3 ± 0.0**
F1: Industrial Brownfield	12.3 ± 0.2	5.5 ± 0.2	2.6 ± 0.1
G1: Industrial Brownfield	6.5 ± 0.4	11.2 ± 1.3	5.3 ± 0.6
H1: Industrial Brownfield	**7.0 ± 0.2**	**2.9 ± 0.1**	**1.4 ± 0.1**
I1: Hog Lagoon	12.5 ± 0.4	8.3 ± 06	3.9 ± 0.3

Results



Planting			DBH	$Biomass_{MAI}$	$Carbon_{MAI}$
C1	Industrial Brownfield (I)	(LaSalle, IL)	<0.0001	0.0001	0.0001
E2	U.S. Coast Guard Base (II)	(Elizabeth City, NC)	0.0260	0.0048	0.0045
E3	U.S. Coast Guard Base (III)	(Elizabeth City, NC)	<0.0001	<0.0001	<0.0001
H1	Industrial Brownfield	(Panama City, FL)	<0.0001	<0.0001	<0.0001
C2	Industrial Brownfield (II)	(LaSalle, IL)			
		Clone	0.0092	0.0132	0.0129
		System[1]	<0.0001	0.0057	0.0057
		Clone × System	0.4812	0.6061	0.6010

[1] Groundwater treatment units with trees grown in wells were compared to open-grown trees.

LaSalle, IL

- Industrial Brownfield (TCE, PCE)
- 2 Plantings
  - C1: open, 11 yrs, 19 clones
  - C2: GTU, 11 yrs, 8 clones

Planting	Clone	Treatment	DBH (cm)		$Biomass_{MAI}$ ($Mg\ ha^{-1}\ yr^{-1}$)		$Carbon_{MAI}$ ($Mg\ ha^{-1}\ yr^{-1}$)	
C1, C2	220-5	--	18.1	a	13.3	a	6.2	a
C1, C2	Crandon	--	17.5	ab	12.7	ab	6.0	ab
C1, C2	[illegible]	--	15.6	abc	[illegible]	[illegible]	4.5	abcd
C1, C2	I4551	--	14.2	bc	9.5	[illegible]	4.5	abc
C1, C2	7300501	--	13.1	bc	8.5	bc	[illegible]	bcd
C1, C2	ISU.25-R4	--	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	cd
C1, C2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C1, C2	[illegible]	[illegible]	[illegible]	c	[illegible]	c	[illegible]	[illegible]
C1			17.9	A	10.7	A		
C2			10.9	B	7.4	B		

DBH_{exp} = 15.0
Open = + 19%
GTU = - 27%

+ 64%

+ 45%

$Biomass_{MAIexp}$ = 11.6
Open = - 8%
GTU = - 36%

LaSalle, IL

+ 34%

Crandon

15.2 cm

20.3 cm

+ 83%

7300501

14.4 cm

26.3 cm

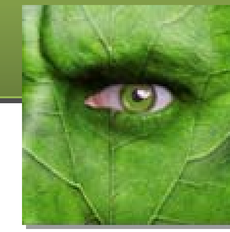
+ 151%

220-5

13.7 cm

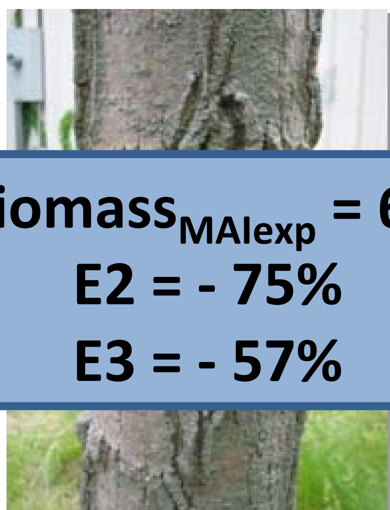
34.5 cm

Elizabeth City, NC

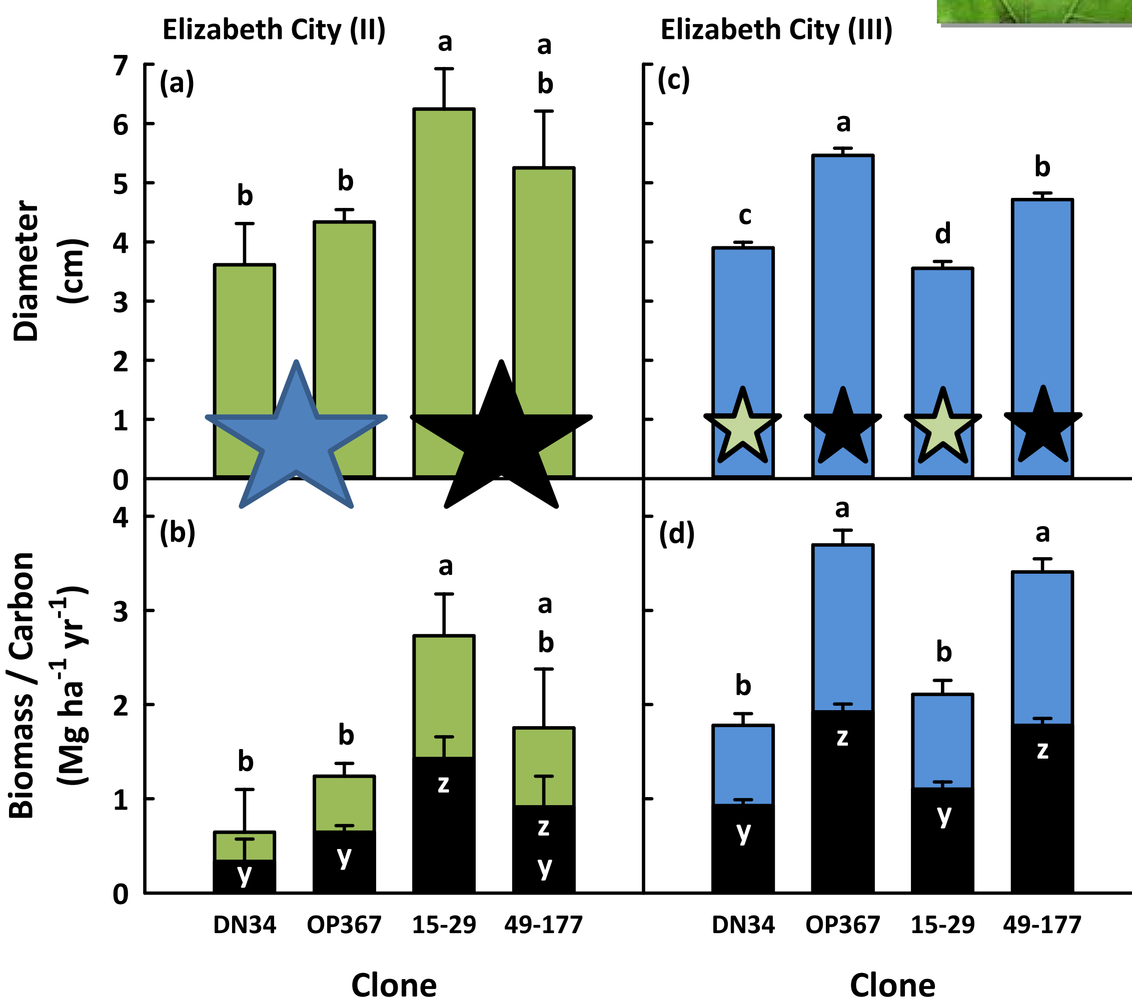


- US Coast Guard Base
- Petroleum Hydrocarbons
- 3 Plantings
  - E1: 6
  - E2: 5
  - E3: 5

DBH_{exp} = 8.1
E2 = - 40%
E3 = - 46%

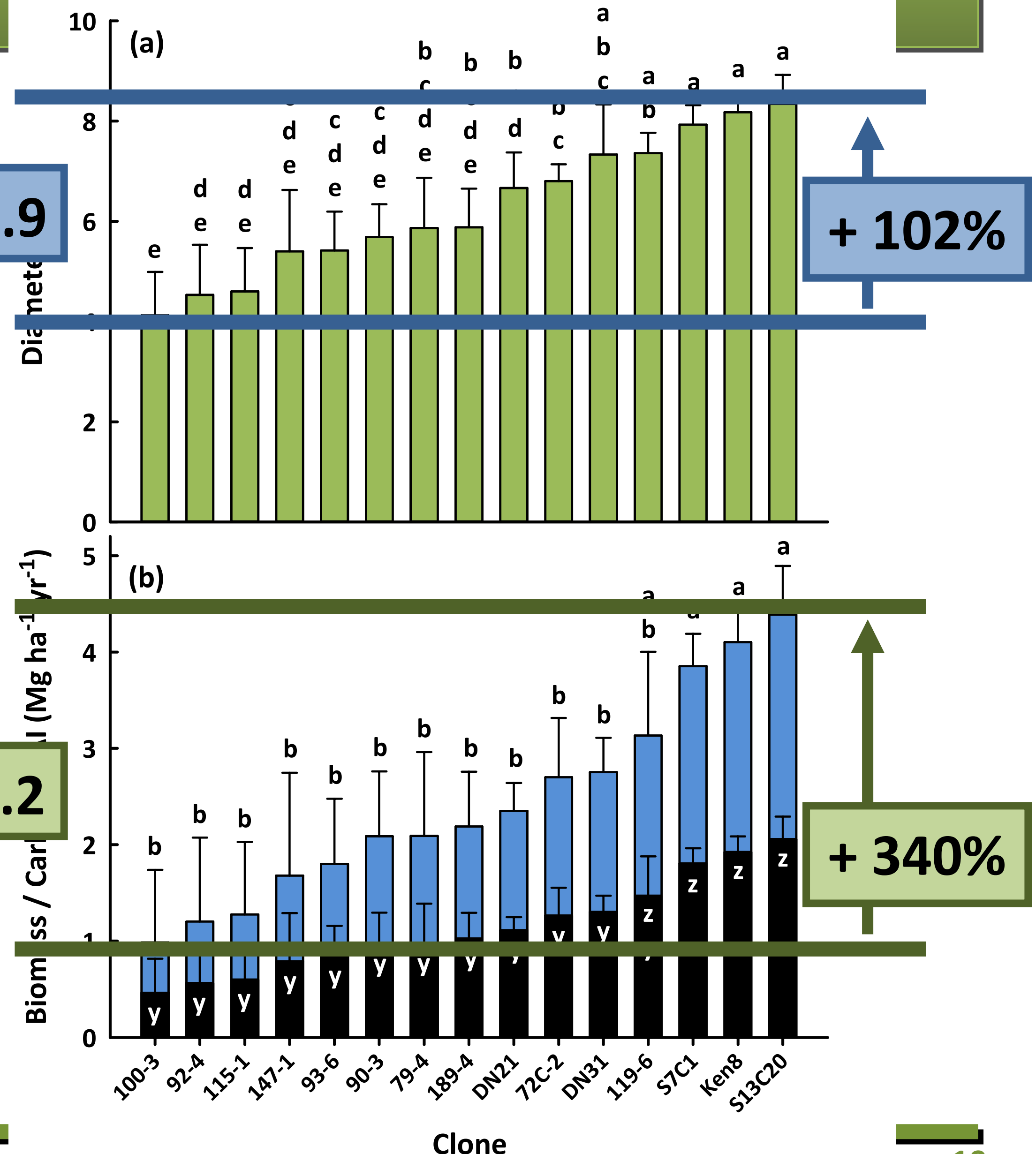


$Biomass_{MAIexp}$ = 6.3
E2 = - 75%
E3 = - 57%

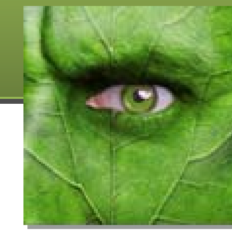


Panama City, FL

- Industrial Brownfield
- Arsenic
- 1 Planting
- 5.4 yrs
- 15 Clones



Conclusions



- In general, biomass & carbon of trees grown on liability sites were within the range of expected values, using production plantings as the control
- Specific genotype × environment interactions resulted in similar (or greater) productivity from contaminated sites than production plantings
- Genotype selection is critical for success – using phyto-recurrent selection or other methods is essential for the provision of ecosystem services, especially biomass & carbon

Thank you!

Contact Information

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