TRANSITIONING FROM THE BUCKET TO THE BARREL
WEBINAR SERIES
NC STATE UNIVERSITY

Short Rotation Woody Crops for Phytoremediation

The webinar starts at 2:00 PM(Eastern Time)

Presenter(s): Shawn Dayson Shifflett, North Carolina State University
Host: Brent Bailey, 25x'25
Moderator: Helene Cser, NCSU-Extension Forestry

IBSS
Southeastern Partnership for Integrated Biomass Supply Systems

"The IBSS project is supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30410 from the USDA National Institute of Food and Agriculture."

USDA United States Department of Agriculture
National Institute of Food and Agriculture

"The webinar project is supported by The Renewable Resources Extension Act National Focus Fund Grant no. 2011-46401-31144 from the USDA National Institute of Food and Agriculture."

Webinar Program

- Orientation: Helene Cser
- Introduction: Brent Bailey, 25x'25
- Speakers:

  Shawn Dayson Shifflett, North Carolina State University

  Moderated Q&A: Helene Cser & Brent Bailey

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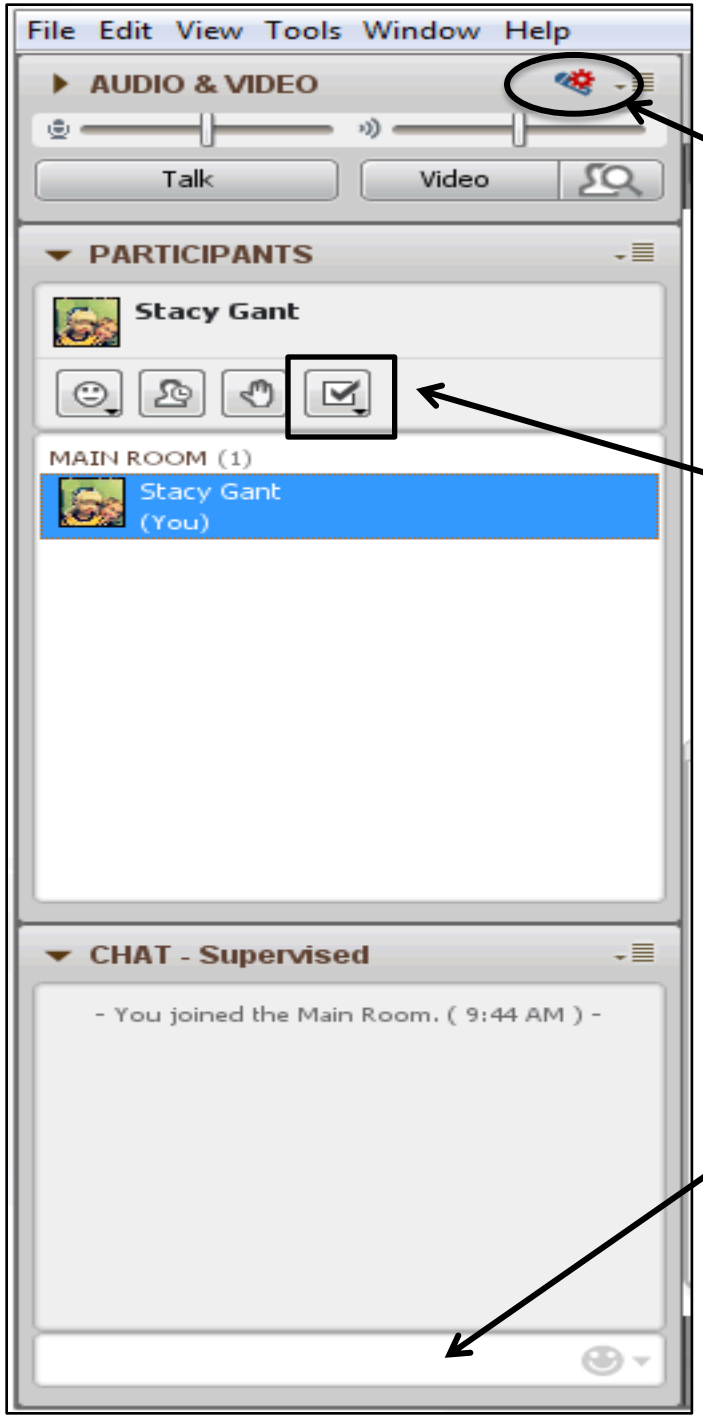

Orientation

1. Audio Setup Wizard – Allows you to ensure your audio is set up properly.

2. Polling - Allows you to answer yes/no questions and respond in a multiple choice format

3. Chat - If the chat says “Supervised,” be aware that the presenter/moderator can see all messages, even those marked private.

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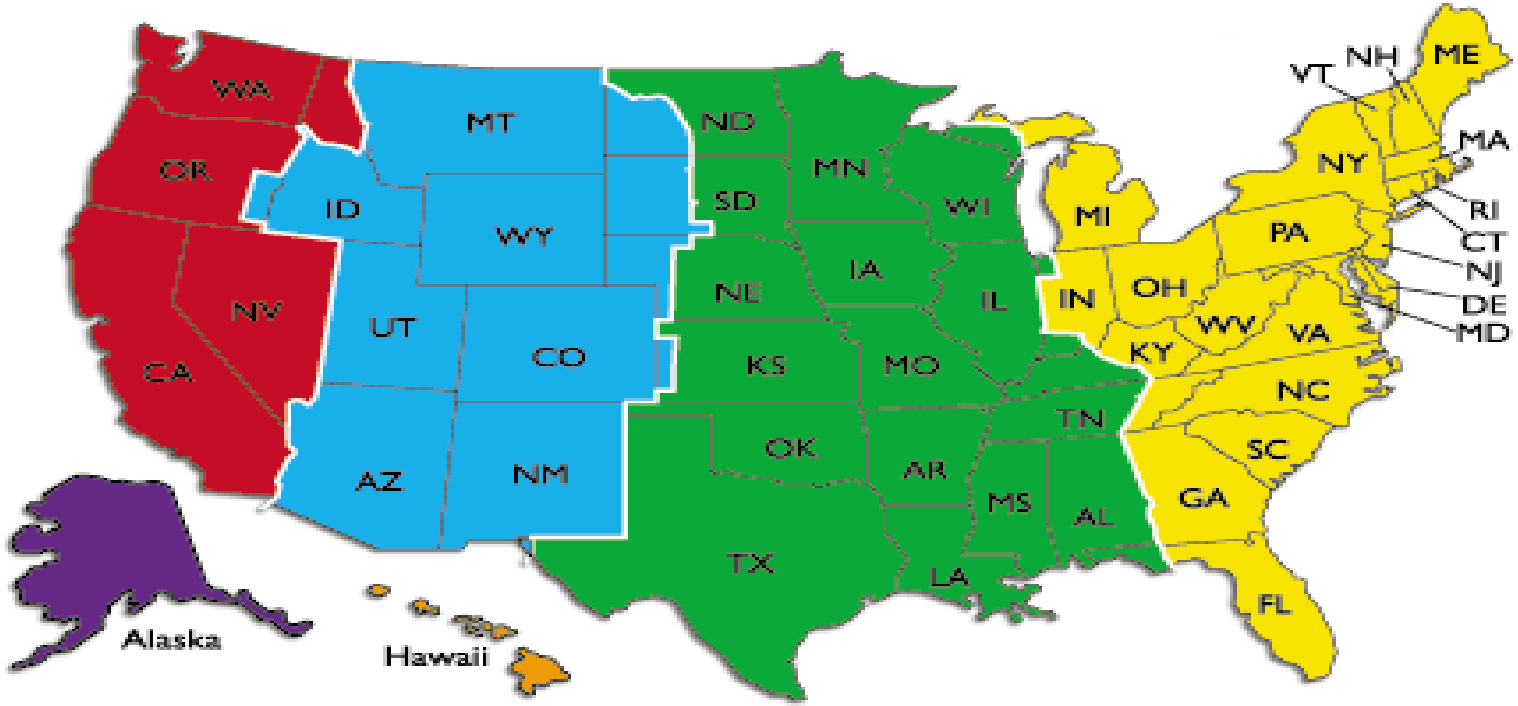

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Brent Bailey

State Activities Coordinator
25x'25 Alliance

Bio

Brent began his professional career as an Environmental Consultant for two central Mississippi environmental engineering firms. In 1999, Brent went to the Mississippi Farm Bureau Federation to become the organization's Environmental Programs Coordinator and served in that capacity for over seven years.

In October 2006, Brent began an association with the 25x'25 Initiative and serves as the State Activities Coordinator. The 25x'25 vision entails production agriculture and forestry producing 25% of total U.S. energy needs by the year 2025 while continuing to produce safe and abundant food and fiber. Brent is working with agriculture and forestry leaders to mobilize support for renewable energy solutions from the agriculture and forestry sectors.

Brent also serves as the Project Coordinator for the Southeast Agriculture and Forestry Energy Resources Alliance.

Shawn Dayson Shifflett

Department of Forestry & Environmental Resources North Carolina State University

Bio

Shawn Dayson Shifflett is a PhD student in the department of Forestry and Environmental Resources at North Carolina State University and is expecting to dissertate in 2016. He received his Masters of Science in Natural Resources at NCSU after completing his research on the establishment of tree species trials on municipal wastewater application sites under the direction of Drs. Elizabeth Guthrie Nichols and Dennis Hazel. Shifflett's current work explores the impacts of growing woody biomass on marginal and degraded lands to meet the future demands of the bioenergy industry. His interests lie in the use of phytoremediation to mitigate human environmental impacts through the integration of the hydrological cycle, water quality assessments, and nutrient balances of lands converted for bioenergy production.

Short Rotation Woody Crops for Phytoremediation Applications

Exploring the use of marginal and degraded lands for bioenergy feedstock production

SHAWN DAYSON SHIFFLETT
PHD STUDENT
DEPARTMENT OF FORESTRY AND ENVIRONMENTAL RESOURCES
COLLEGE OF NATURAL RESOURCES
NORTH CAROLINA STATE UNIVERSITY

Short rotation woody crops (SRWC) are a cellulosic bioenergy feedstock.

- Could be either coniferous or deciduous species
- Characterized by high tree planting density
  - 162 trees·Acre^{-1} to 8,100 trees·Acre^{-1} (400 stems·Ha^{-1} to 20,000 stems·Ha^{-1})
  - Can be as 16,200 trees·Acre^{-1} (40,000 stems·Ha^{-1})
- Short harvest cycles: 1 to 20 years
- Common genera:

Populus spp.

Salix spp.

Eucalyptus spp.

There are questions about where we should grow short rotation woody crops.

Productive agricultural lands

Established forests

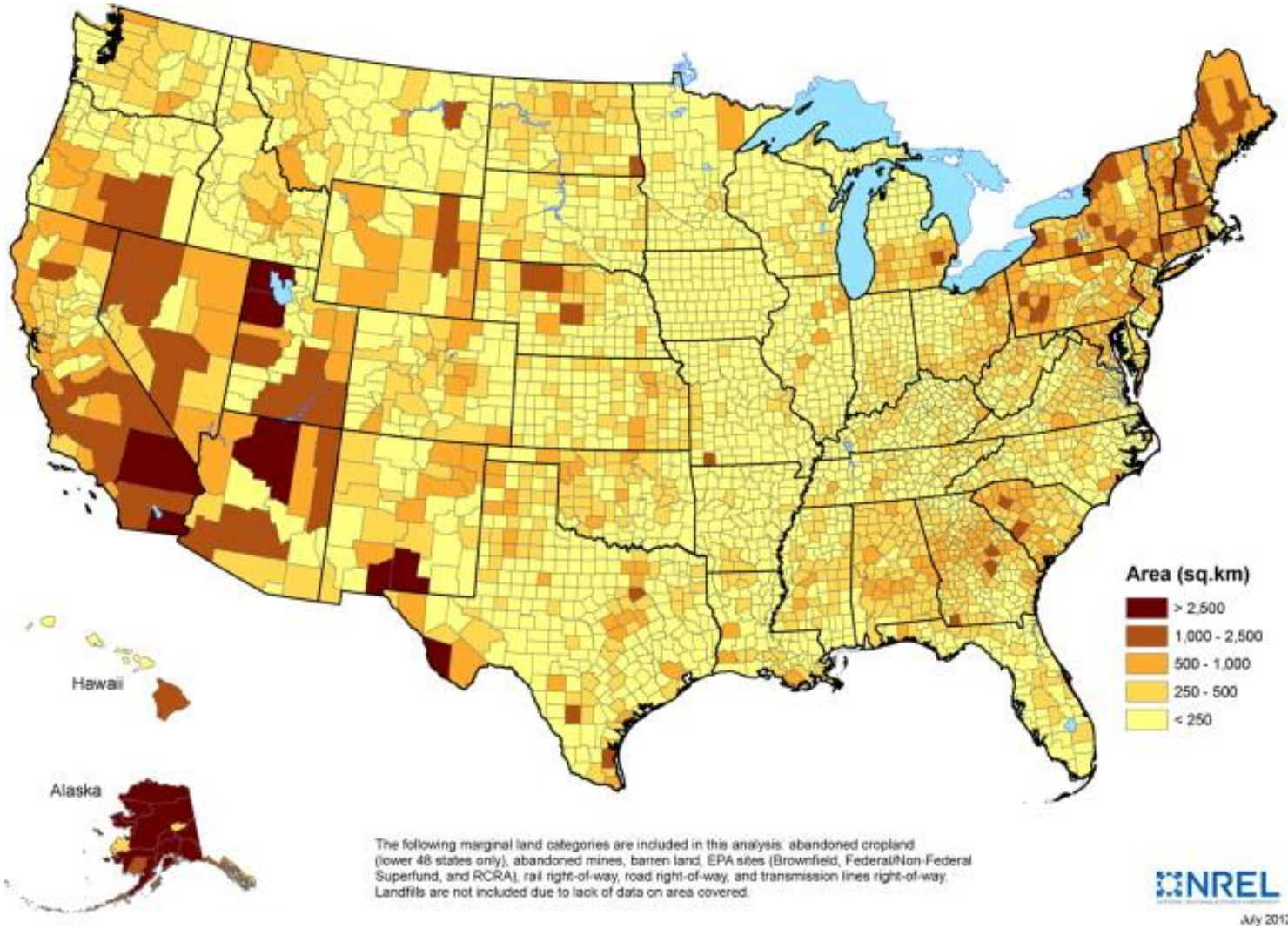
Marginal and degraded lands planted with woody biomass offer many potential benefits.

- Avoids directly competing with food production.
- Helps to preserve biodiversity in “pristine” ecosystems.
- Can improve degraded lands with certain bioenergy crops
- Provide financial gains on lands that are otherwise not generating dollars.

There are an estimated 1062 - 1433 million acres (430 – 580 Mha) of degraded lands globally.

Nijsen et al. 2011

Approximately 56 to 60 million hectares (140 to 150 million acres) could be targeted within the USA.



Milbrandt et al. 2014

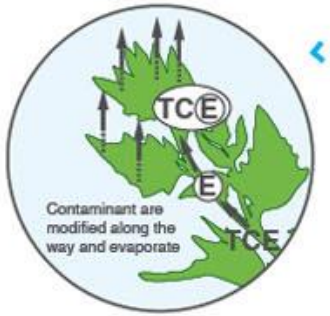
Lands outfitted with phytotechnologies are a subset of marginal and degraded lands.

- Marginal and degraded lands are sites where agricultural production is not suggested for either economic purposes or human health purposes.

- Phytotechnology: A set of technologies using plants to remediate or contain contaminants in soil, groundwater, surface water, or sediments. (Definition provided by Interstate Technology & Regulatory Council [ITRC])

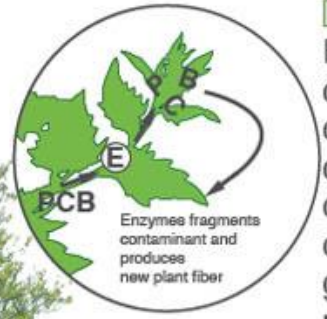
PHYTO VOLATILIZATION:

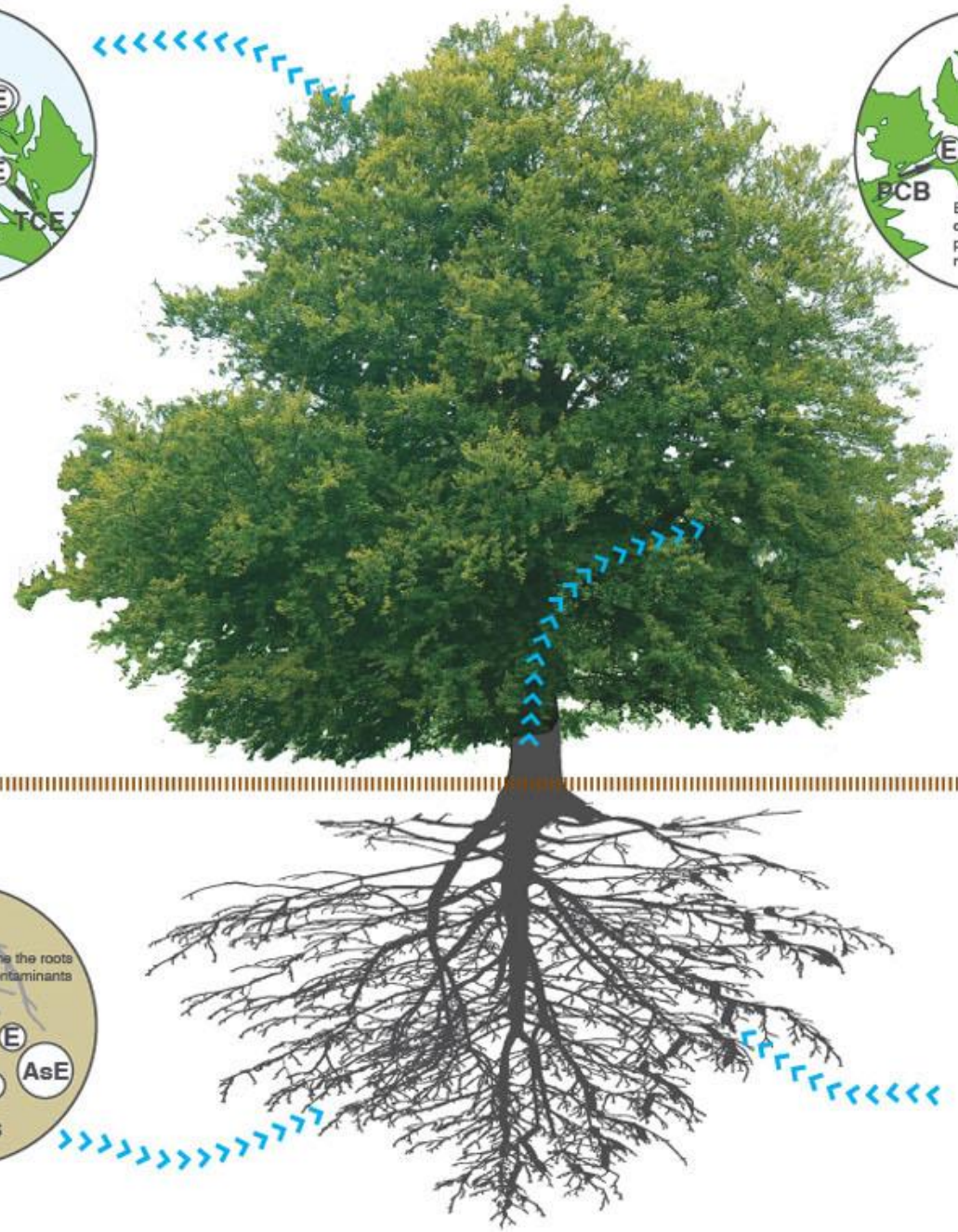
Some plants take up volatile contaminants and release them into the atmosphere through transpiration. The contaminant is transformed or degraded within the plant to create a less toxic substance before and then released into the air.



PHYTO DEGRADATION:

Plants take up and break down contaminants through the release of enzymes and metabolic processes such as photosynthetic oxidation/reduction. In this process organic pollutants are degraded and incorporated into the plant or broken down in the soil.



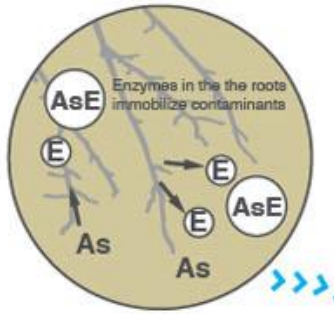


PHYTO EXTRACTION:

Plants take up contaminants - mostly metals, metaloids and radionucleids- with their roots and accumulate them in large quantities within their stems and leaves. These plants have to be harvested and disposed as special waste.

PHYTO STABILIZATION:

Some plants can sequester or immobilize contaminants by absorbing them into their roots and releasing a chemical that converts the contaminant to a less toxic state. This mechanism limits the migration of contaminants through water erosion, leaching, wind, and soil dispersion.



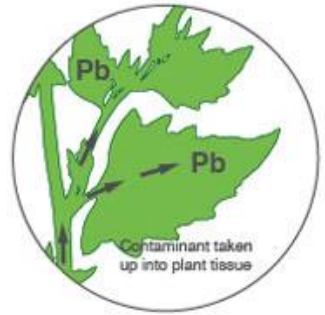


Image Source: popupcity.net

Many plant species can be used as a phytotechnology.

Annuals

Pumpkin (*Curcurbita spp.*)

Sunflower (*Helianthus annuus*)

Perennials

Fescue grass (*Festuca arundinacea)*

Duckweed (*Lemna minor*)

Switchgrass (*Panicum virgatum*)

Paul's Scarlet Rose (*Rosa spp.*)

Trees

Loblolly pine (*Pinus taeda*)

Bald cypress (*Taxodium distichum*)

American sweetgum (*Liquidambar styraciflua*)

Hybrid poplars (*Populus spp.*)

Willows (*Salix spp.*)

However, each species must be matched to site conditions and site contaminant(s).

There are several resources available to extension agents to gain more information on phytotechnologies.

- Consult with an expert
- Consult with the ITRC training (itrcweb.org)

- US EPA has a Citizen's Guide to Phytoremediation
- Kühl's Brownfields to Greenfields: A Field Guide to Phytoremediation

BROWNFIELDS TO GREENFIELDS

A Field Guide to Phytoremediation

Trees can reach deep contamination as they mature. They can be planted inexpensively as bare-root whips, available in nurseries and seed catalogs.

J F M A M J J A S O N D

50'

25'

10'

5'

-5'

-10'

-25'

Taxodium distichum
Bald Cypress

native

Pb

Bald Cypress, a swamp species, can transpire large quantities of water, which can prevent migration of some contaminants to

Pinus taeda
Loblolly Pine

native

PAH TCE

Fast-growing Loblolly Pine is commonly used in plantation forestry, so is easy to source for mass plantings.

Populus deltoides x P. nigra
Hybrid Poplar

native range of P. deltoides

As $C_6H_5CH_3$ $CHCl_3$ DDT

MBTE PAH PCE TCE

Eastern cottonwood (P. deltoides) also performs phytoremediation, but grows less quickly and addresses fewer contaminants.

Image Source: Kühl, 2011

Research is underway on the generation of woody biomass on phytoremediation lands in North Carolina.

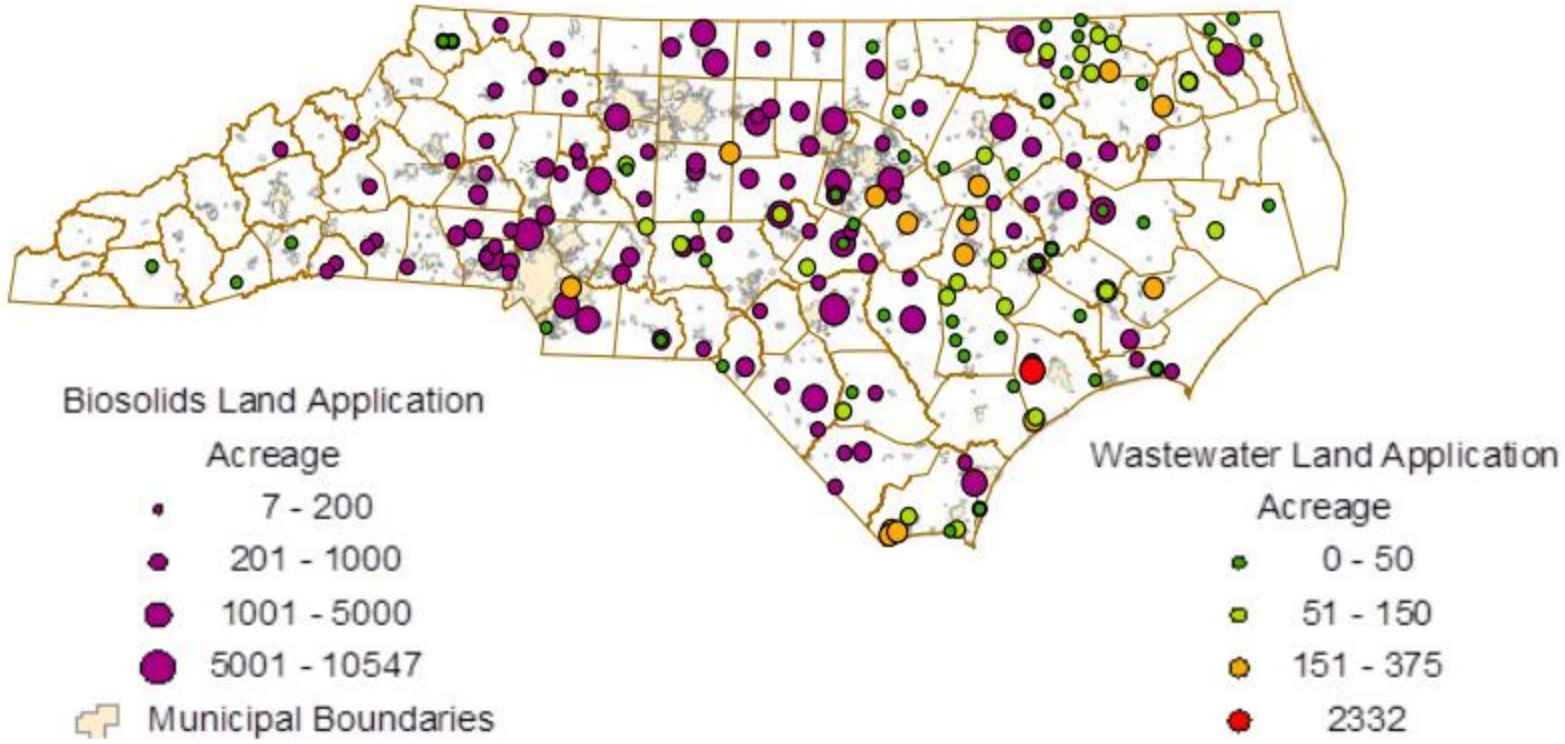


Image Source: Nielsen et al. 2012

Land application of wastewaters to tree stands is another form of phytoremediation

- Municipal waste water application sites are another type of “marginal and degraded” land where a phytotechnology is managing both the hydraulic loading and the nutrient loading to shallow groundwater.
- Research from around the world has shown land application of municipal waste waters can support woody biomass production and be a source of nutrients for fertilization.
- Waste water application has been used in the USA for almost thirty years (Hue et al. 2006)

25 yr Loblolly pine stand in Jacksonville, NC

SRWCs on Wastewater Application Fields have multiple benefits

A Short rotation woody crop on wastewater application field can:

(1) Respond to the applied water and nutrients
(2) Remove large amounts of nutrients supplied by the effluent through harvestings
(3) Transpire water at a high rate over a long growing system
(4) Prevent soil erosion by water or wind
(5) Maintain soil structure so as to maintain or improve the water infiltration rate and permeability of the soil
(6) Be utilized by society without transmitting harmful pathogenic organisms, nutrients, or heavy metals into the food chain
(7) Provide a cash return to cover operating and maintaining the system and perhaps a return on capital investment

Growing woody biomass on wastewater application lands helps meet two primary objectives.

Objective 1: Mitigate shallow ground water contamination from nitrogen (shown on the right) and other nutrients.

Objective 2: Produce woody biomass that can be safely harvested.

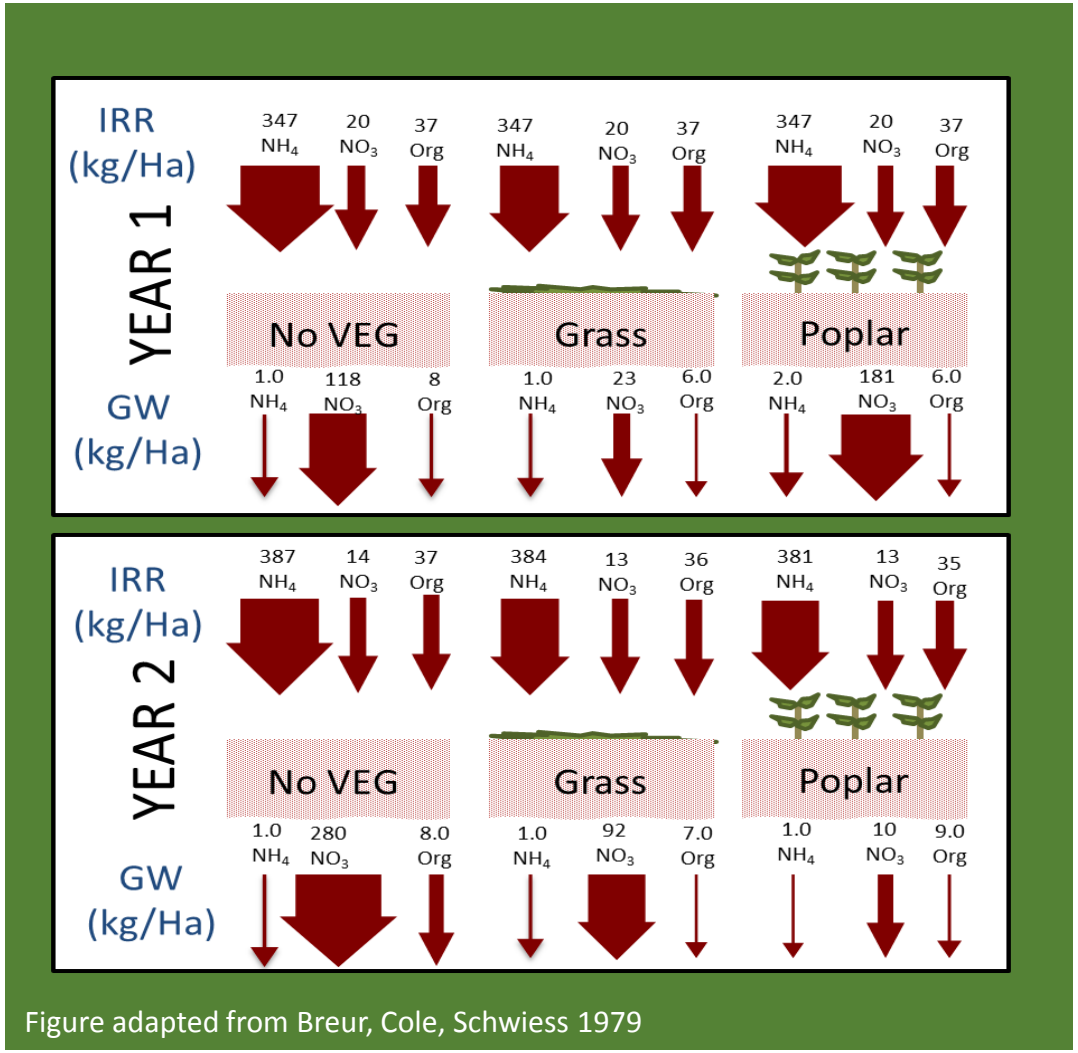
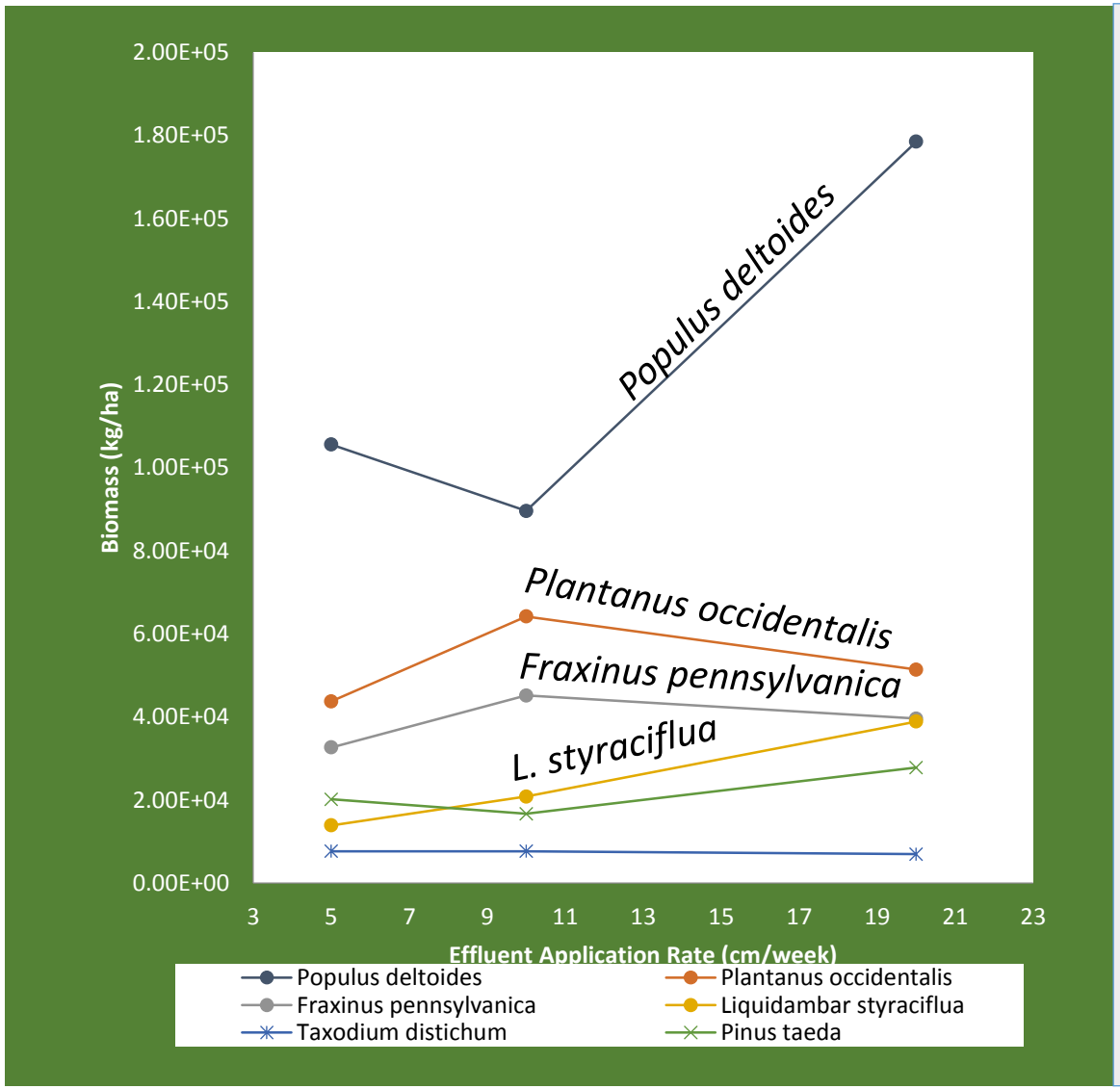


Figure adapted from Breur, Cole, Schwiess 1979

Species selection is critical to meet both objectives.



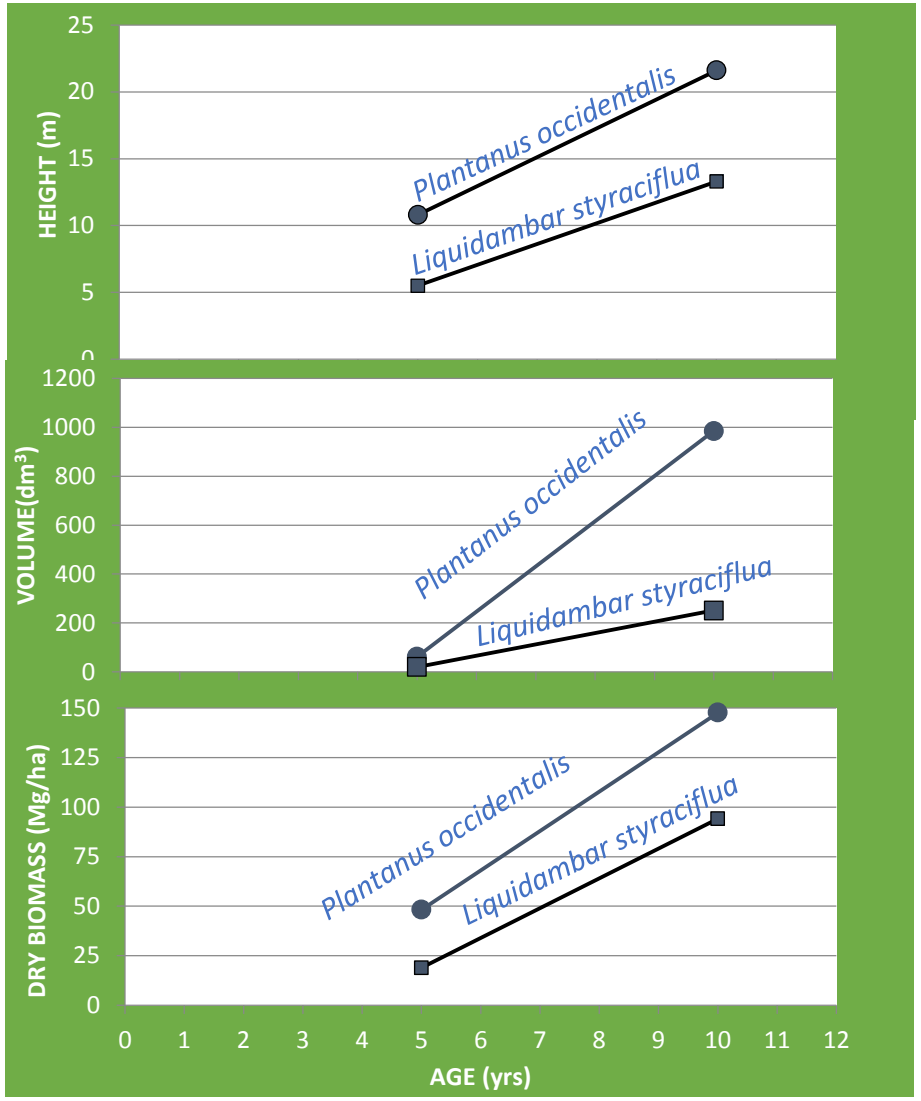
Field studies in the southeastern USA have suggested that *Populus spp.* and other tree species can be efficient producers of biomass on wastewater sites.

FIELD GROUND WATER WELL

- NO_3: 17.3 mg/L
- NH_4: <1 mg/L
- Total N: 18.6 mg/L

Graph adapted from smith et al. 1979.
Nitrogen data adapted from overman1979.

Previous research in North Carolina has focused on the survival and productivity on these sites (Obj. 2).

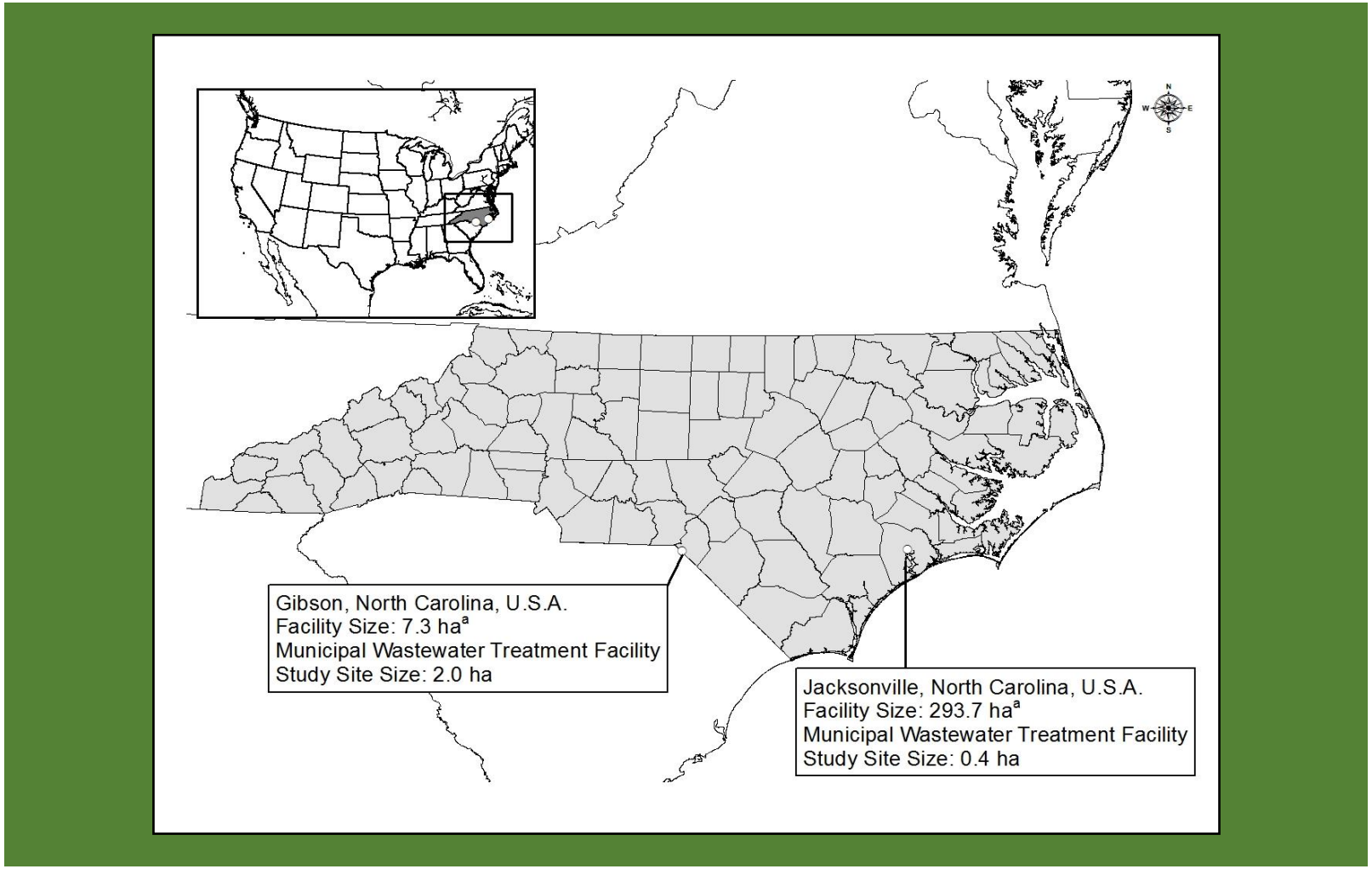


- 360 acre facility
- 45% Sweetgum (*Liquidambar styracifla*)
- 45% American sycamore (*Platanus occidentalis*)
- 10% Loblolly pine

Species	Year 5	Year 10
Platanus occidentalis	93%	91%
Liqiuidambar styraciflua	100%	98%

Adapted from Frederick et al. 1998.

New research was needed to evaluate stand establishment for phytoremediation and woody biomass establishment.



From Shifflett et al., 2013.

Climate, site, and experimental characteristics

	Gibson Waste Water Application Facility	Jacksonville Waste Water Application Facility
Location	34°45'N, 79°36'W	34°45'N, 77°25'W
Average Annual Precipitation [a]	1300 mm	1400 mm
Average Annual Irrigation	1102 $mm \cdot ha^{-1}$ [b]	1109 $mm \cdot ha^{-1}$ [c]
Total applied nitrogen	223 kg	93 kg
Total applied phosphorous	31.1 kg	14.2 kg
Total nitrogen per tree	0.11 kg $N \cdot tree^{-1}$	0.17 kg $N \cdot tree^{-1}$
Total phosphorous per tree	0.015 kg $N \cdot tree^{-1}$	0.025 kg $N \cdot tree^{-1}$
Daily Wastewater Outflow	275 m^3 [b]	19700 m^3 [d]
Soil Series [e]	Ailey loamy sand & Pelion loamy sand	Norfolk loamy fine sand
Soil pH	5.8 – 6.4	5.3 – 7.0
Mean Depth to Groundwater	1.9 ± 0.24 m	0.83 ± 0.26 m
Mean Depth of Monitoring Wells	3.2 ± 1.3 m	2.8 ± 0.26 m
Previous Use	Managed American sycamore plantation	Fallow ground
Planting Date(s)	03/2011, 03/2012, 05/2012	03/2012, 05/2012
Experimental Design	Randomized block design	Randomized block design
Tree Spacing	1.8 m x 1.8 m	1.8 m x 1.8 m

Two research objectives were developed for this study.

- Evaluate woody biomass production by different tree species under waste water irrigation.
- Evaluate impact of land applied municipal wastewater during tree establishment

Taxodium distchum
(JG)

Pinus taeda
(JG)

Liquidambar styraciflua
(JG)

Eucalyptus benthamii
(JG)

Populus spp.
(JG)

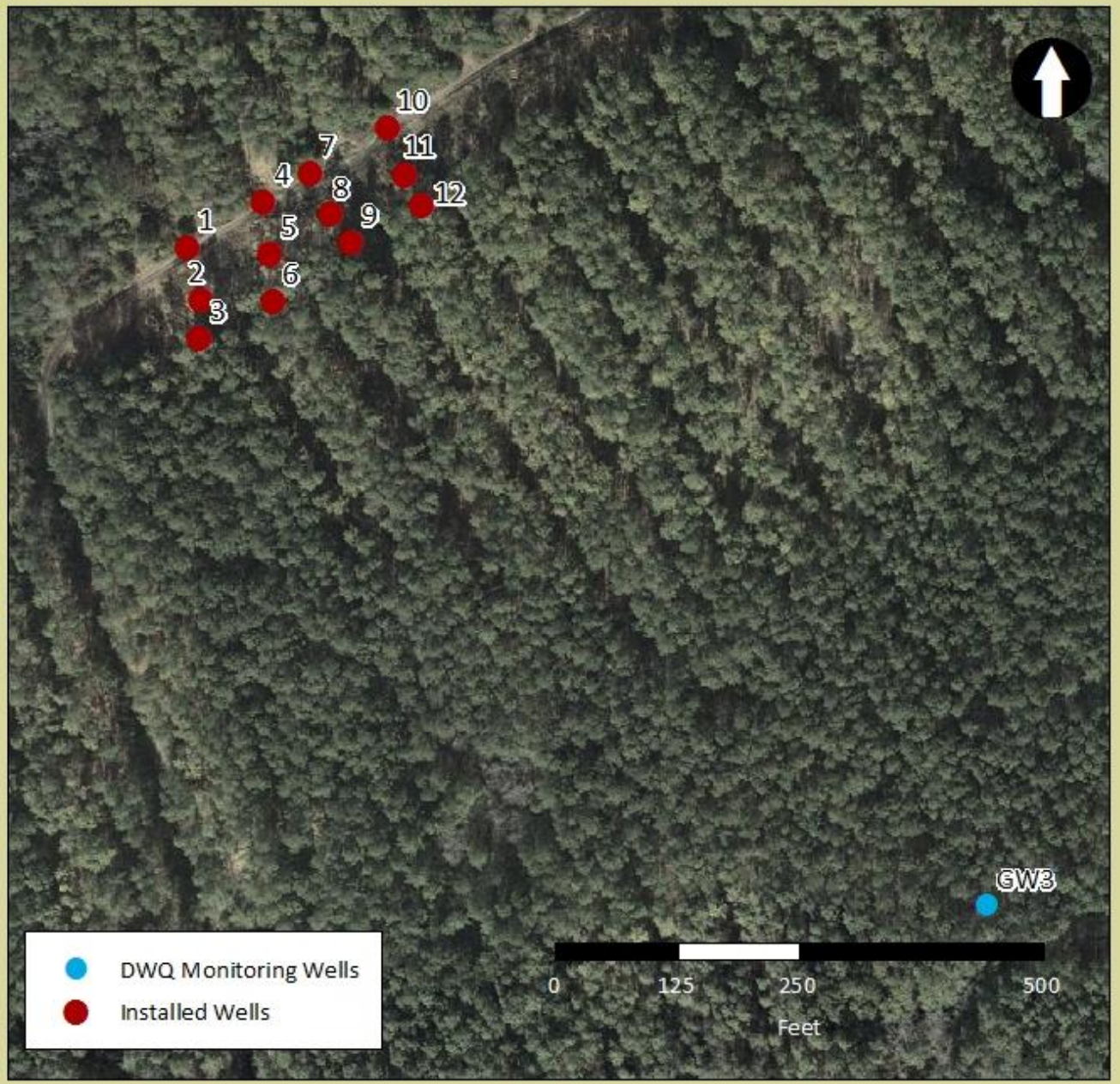
Fraxinus pennsylvanica
(JG)

Quercus pagoda
(G)

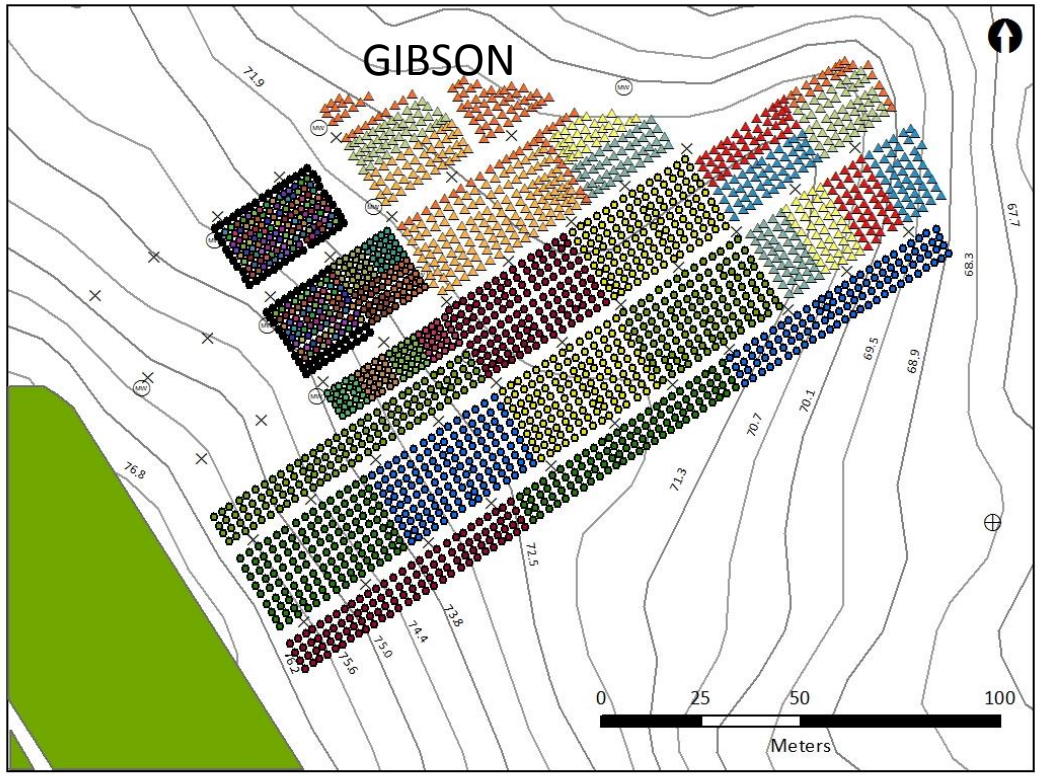
Quercus alba
(G)

Monitoring wells were installed to evaluate nutrient concentrations in groundwater at Gibson and Jacksonville.

Study Site Location



Study Site Location



HYBRID POPLAR CLONES

0	221	345	423
138	224	379	427
140	229	380	429
147	230	381	432
148	302	406	434
176	303	409	444
185	304	410	448
187	337	411	449
188	339	412	450
198	341	413	451
200	342	414	

FEATURES

- MUNICIPAL WASTE LAGOONS
- 0.6-M CONTOURS
- INSTALLED MONITORING WELL
- NCDENR MONITORING WELL

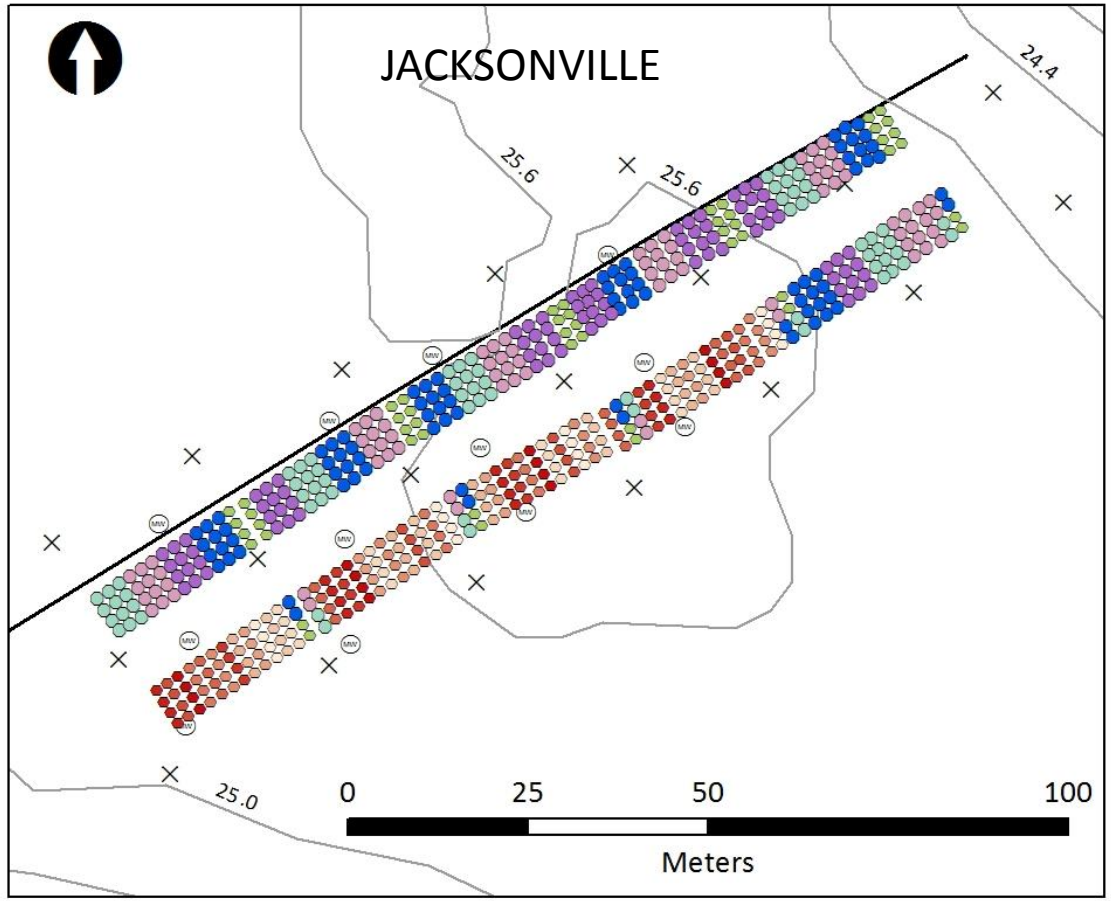
OTHER PLANTINGS

2011 PLANTINGS

- AWC
- BC
- CBO
- GA
- HYP
- LLP
- WO

2012 PLANTINGS

- SWEETGUM
- LOBLOLLY PINE
- BALD CYPRESS
- GREEN ASH
- EUCALYPTUS



HYBRID POPLARS

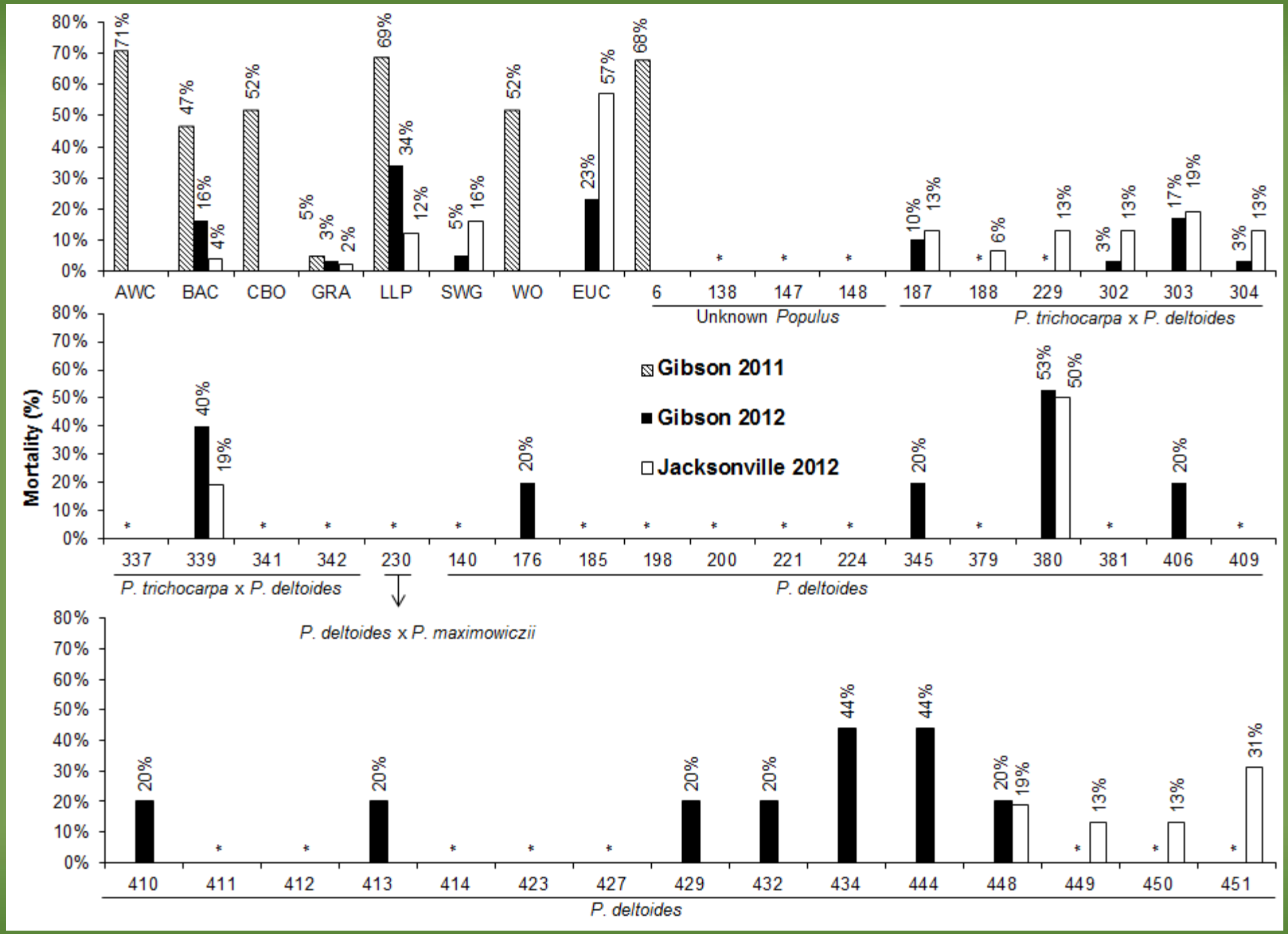
187	339
188	380
229	448
302	449
303	450
304	451

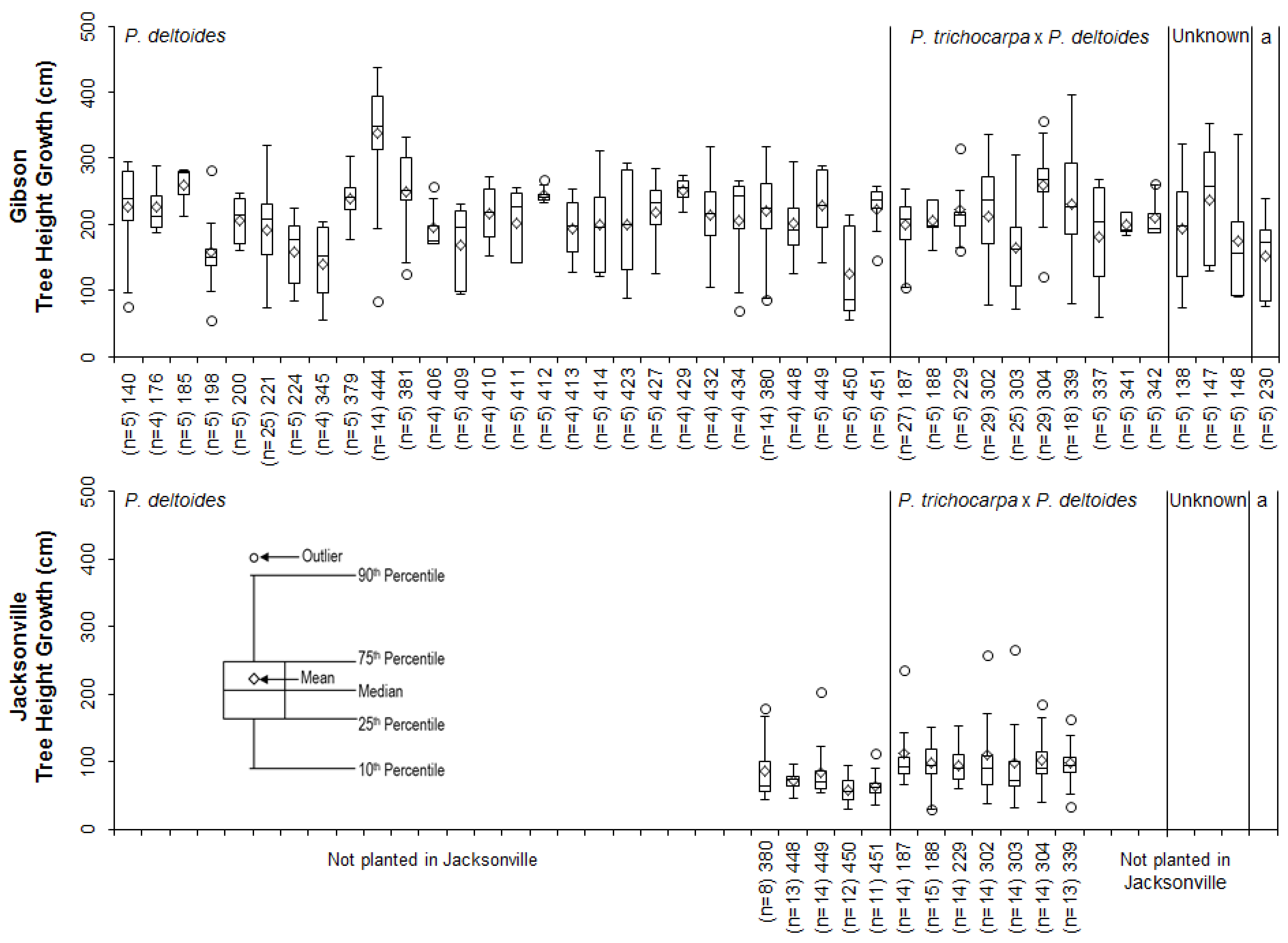
FEATURES

- IRRIGATION RISER
- INSTALLED WELLS
- 0.6 M Contours
- ROAD

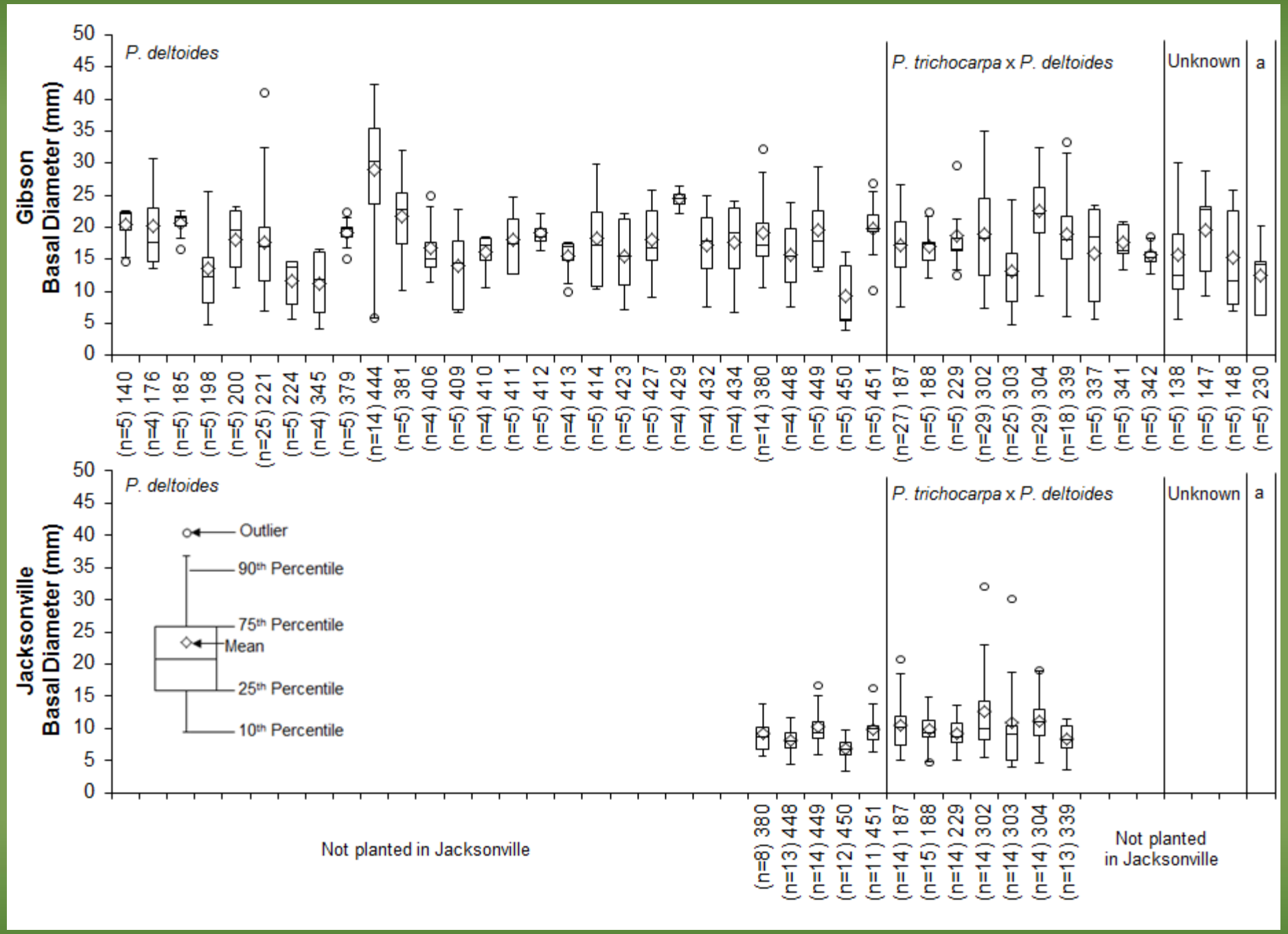
OTHER PLANTINGS

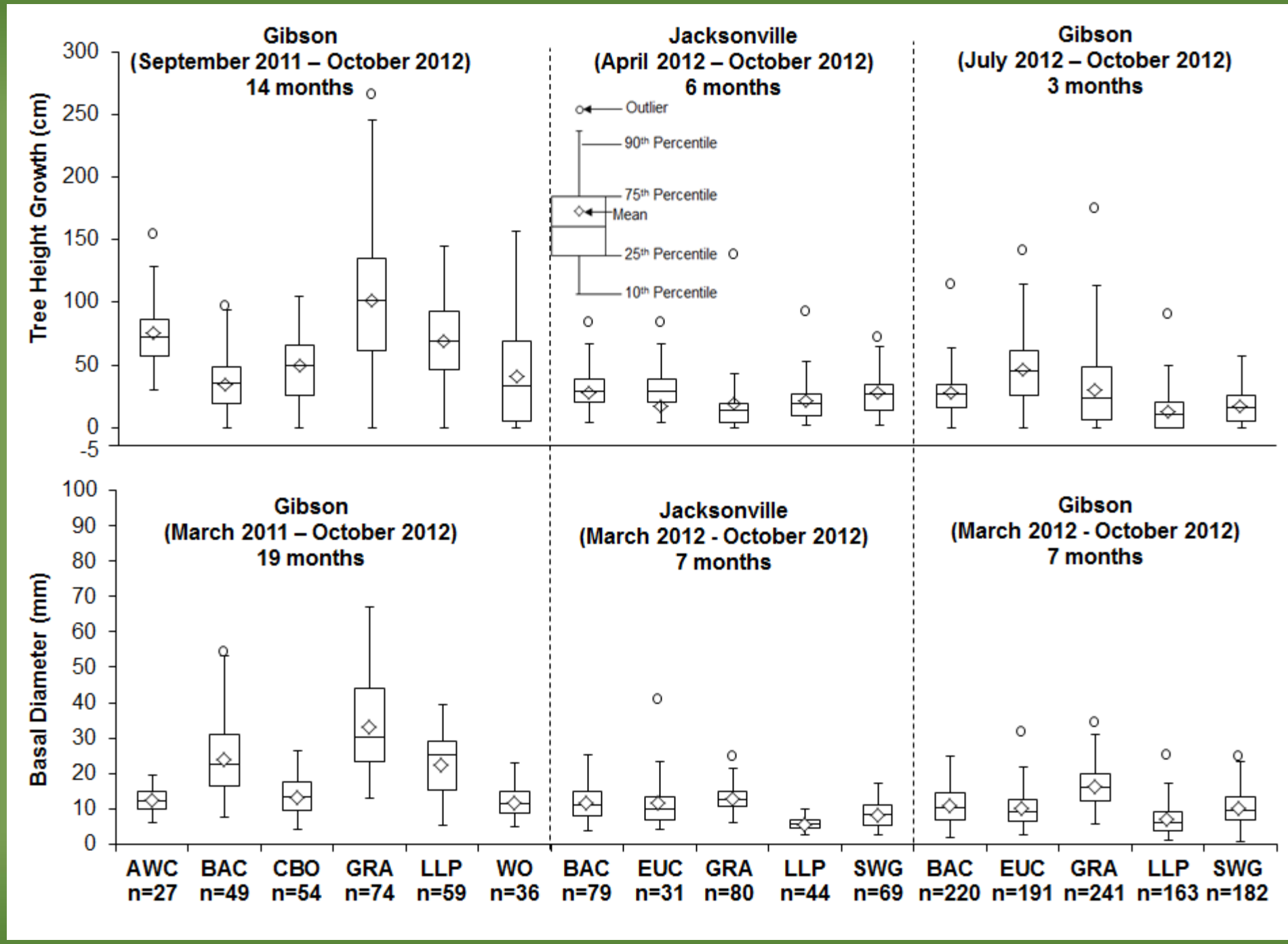
- BALD CYPRESS
- EUCALYPTUS
- GREEN ASH
- LOBLOLLY PINE
- SWEETGUM

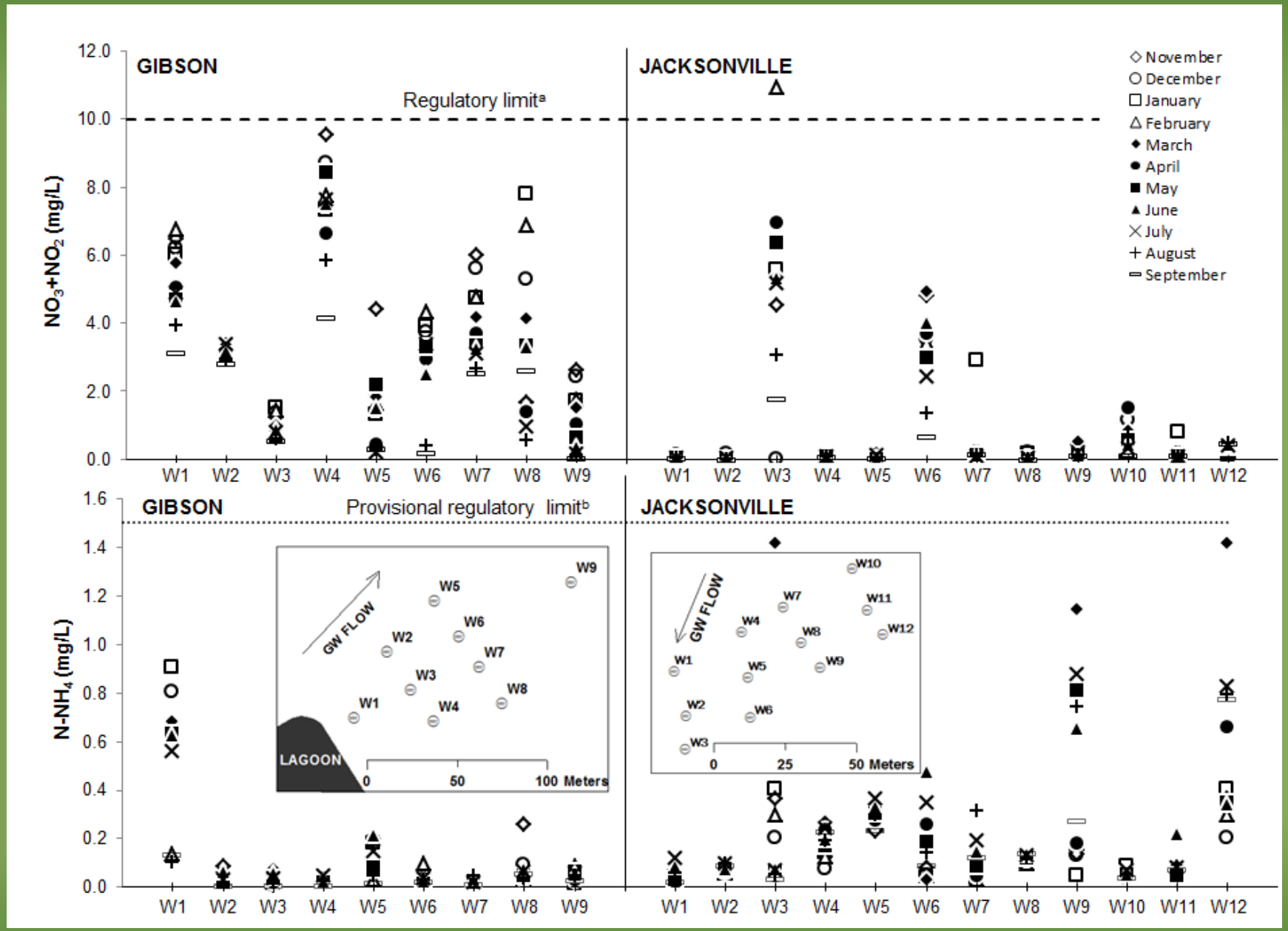

Mortality (%)
Gibson 2011
Gibson 2012
Jacksonville 2012
AWC
BAC
CBO
GRA
LLP
SWG
WO
EUC
6
138
147
148
187
188
229
302
303
304
Unknown Populus
P. trichocarpa x P. deltoides
337
339
341
342
230
140
176
185
198
200
221
224
345
379
380
381
406
409
P. trichocarpa x P. deltoides
P. deltoides
P. deltoides x P. maximowiczii
410
411
412
413
414
423
427
429
432
434
444
448
449
450
451
P. deltoides



Gibson
Tree Height Growth (cm)
P. deltoides
P. trichocarpa x P. deltoides
Unknown
a
(n=5) 140
(n=4) 176
(n=5) 185
(n=5) 198
(n=5) 200
(n=25) 221
(n=5) 224
(n=4) 345
(n=5) 379
(n=14) 444
(n=5) 381
(n=4) 406
(n=5) 409
(n=4) 410
(n=5) 411
(n=5) 412
(n=4) 413
(n=5) 414
(n=5) 423
(n=5) 427
(n=4) 429
(n=4) 432
(n=4) 434
(n=14) 380
(n=4) 448
(n=5) 449
(n=5) 450
(n=5) 451
(n=27) 187
(n=5) 188
(n=5) 229
(n=29) 302
(n=25) 303
(n=29) 304
(n=18) 339
(n=5) 337
(n=5) 341
(n=5) 342
(n=5) 138
(n=5) 147
(n=5) 148
(n=5) 230
Jacksonville
Tree Height Growth (cm)
P. deltoides
P. trichocarpa x P. deltoides
Unknown
a
Outlier
90th Percentile
75th Percentile
Mean
Median
25th Percentile
10th Percentile
Not planted in Jacksonville
(n=8) 380
(n=13) 448
(n=14) 449
(n=12) 450
(n=11) 451
(n=14) 187
(n=15) 188
(n=14) 229
(n=14) 302
(n=14) 303
(n=14) 304
(n=13) 339
Not planted in Jacksonville
0
100
200
300
400
500


Gibson
Basal Diameter (mm)
Jacksonville
Basal Diameter (mm)
P. deltoides
P. trichocarpa x P. deltoides
Unknown
a
Outlier
90th Percentile
75th Percentile
Mean
25th Percentile
10th Percentile
Not planted in Jacksonville
Not planted in Jacksonville


Gibson
(September 2011 – October 2012)
14 months
Jacksonville
(April 2012 – October 2012)
6 months
Gibson
(July 2012 – October 2012)
3 months
Outlier
90th Percentile
75th Percentile
Mean
25th Percentile
10th Percentile
Tree Height Growth (cm)
300
250
200
150
100
50
0
-5
Gibson
(March 2011 – October 2012)
19 months
Jacksonville
(March 2012 - October 2012)
7 months
Gibson
(March 2012 - October 2012)
7 months
Basal Diameter (mm)
100
90
80
70
60
50
40
30
20
10
0
AWC n=27
BAC n=49
CBO n=54
GRA n=74
LLP n=59
WO n=36
BAC n=79
EUC n=31
GRA n=80
LLP n=44
SWG n=69
BAC n=220
EUC n=191
GRA n=241
LLP n=163
SWG n=182


GIBSON
JACKSONVILLE
Regulatory limit[a]
Provisional regulatory limit[b]
NO_3+NO_2 (mg/L)
N-NH_4 (mg/L)
November
December
January
February
March
April
May
June
July
August
September
W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12
GW FLOW
LAGOON
0 50 100 Meters
0 25 50 Meters

Lessons Learned

- Weed management is critical to successful establishment of SRWC.
- Damage from herbivory can stunt growth and management may be needed.
- Mean nutrient concentration of nitrate (NO_3+NO_2) were maintained below regulatory limits at both sites.
- Species/clone selection may not reveal statistically significant differences in growth after establishment.
  - 3 to 4 years may be necessary to identify the most productive species

Lessons Learned

- Though wetland species are not the most productive with respect to biomass, they have shown continued success at Jacksonville with high survival.
- Poplars have performed superior to all planted species at Gibson.
- Having a strong grip on site conditions (both previous and current) can help in management of new SRWC systems.

Looking to the future, we need to consider the proximity of these lands to biorefineries and pellet mills.

Each circle represents an area of 80-km radius with sufficient biomass resources to produce at least 89 Ml of cellulosic ethanol per year.

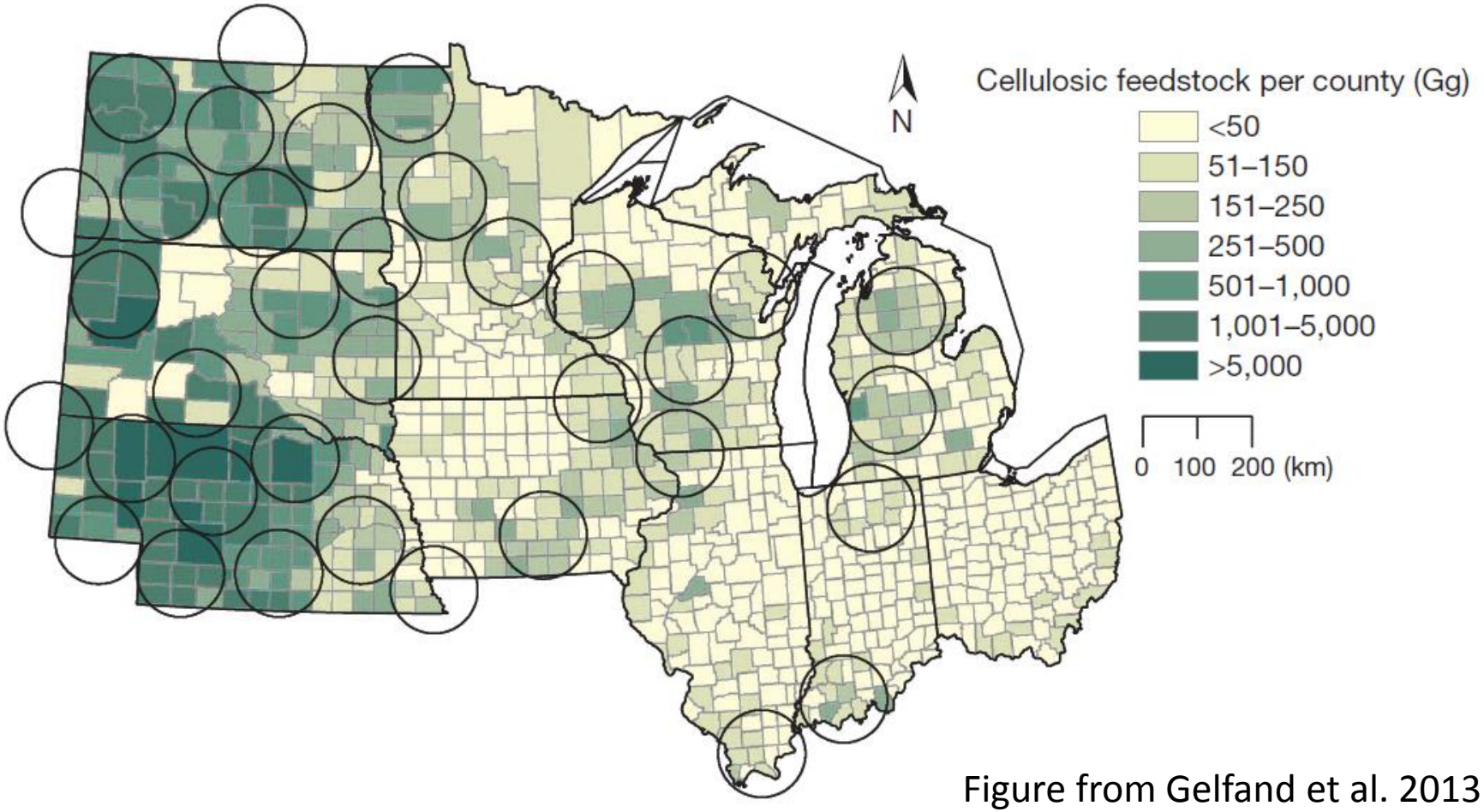


Figure from Gelfand et al. 2013

Thank You!

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COMMITTEE MEMBERS

DR. DENNIS HAZEL

DR. ELIZABETH GUTHRIE NICHOLS

DR. DOUGLAS FREDERICK

Questions and Discussion

Moderated by Brent Bailey and Helene Cser

Thank You For Your Participation!

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Biomass Market Access Standards (BMAS)

http://www.se-ibss.org/webinars-1/upcoming-webinars/index.html