Development of wetland structure and ecological functions in created palustrine forested wetlands: A large scale field experiment in Virginia, USA

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Virginia Department of Forestry

Goals of Ecological Restoration

- Technically and socially feasible
- Scientifically valid

Replacement of:
- Structure
- Function
- Services

Self Sustaining
Connectivity
Resiliency

Forested Headwater Wetlands

Determining Creation/Restoration Success

- Measure structure and function
  - Ecosystem functions are difficult to measure
  - Wetland Functional Assessment Procedures
    - >100 different procedures (Kusler 2006) (Ex. HGM)
- Comparison to reference sites
  - Reference sites are often much older and mature

Forested Headwater Wetlands

Determining Restoration Success

- Ecological Performance Standards (Mitigation)
  - Based on conditions in reference sites
  - Use measurements of structure
    - May be poor indicators of functions (NRC 2001, Cole 2002)
  - Virginia Woody Vegetation Requirements (USACE and VADEQ 2004, VADEQ 2010a)
    - >990 stems/ha (440 stems/acre)
    - 50% of all dominant woody plants FAC or wetter
    - 10% height growth / year (5 ft in 5 years, 10 ft in 10 years)
    - OR 30% canopy closure

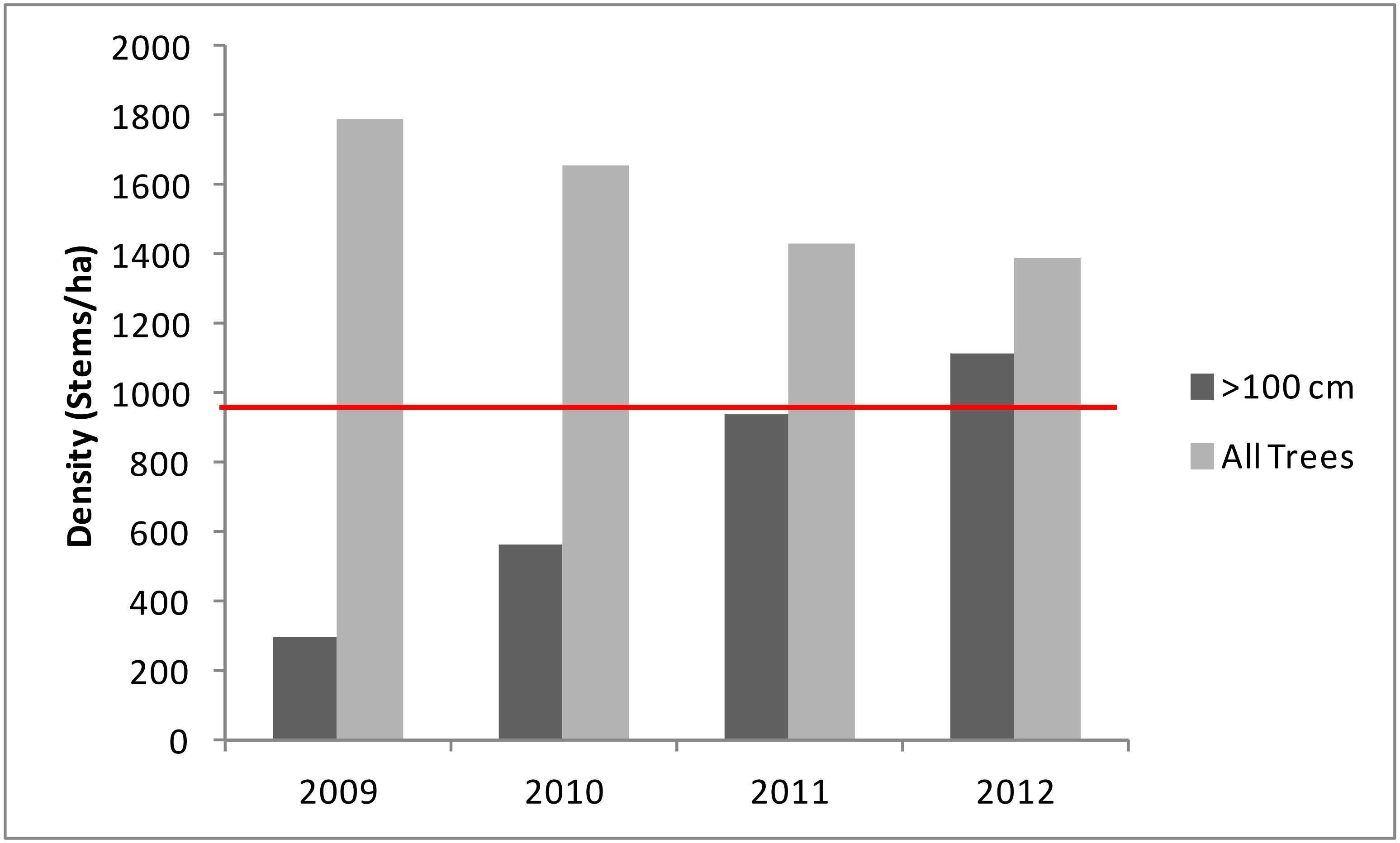
The purpose of this study is to determine the establishment and maturation of ecological functions in a created and/or restored palustrine forested wetlands and to determine how those functions are influence by, and how their maturity may possible be indicated by, planted woody wetland tree structure.

We measured woody structure (height, cover, basal area) and functioning (biomass, growth), in a large scale hydrological controlled created forested headwater wetlands.


Seven Species
Betula nigra (River Birch) (FACW)
Liquidambar styraciflua (Sweetgum) (FAC)
Platanus occidentalis (Sycamore) (FACW)
Salix nigra (Black willow) (FACW)
Quercus bicolor (Swamp white oak) (FACW)
Quercus palustris (Pin oak) (FACW)
Quercus phellos (Willow oak) (FAC)
Flooded
Saturated
Ambient
63 Unique Combinations (n=44)

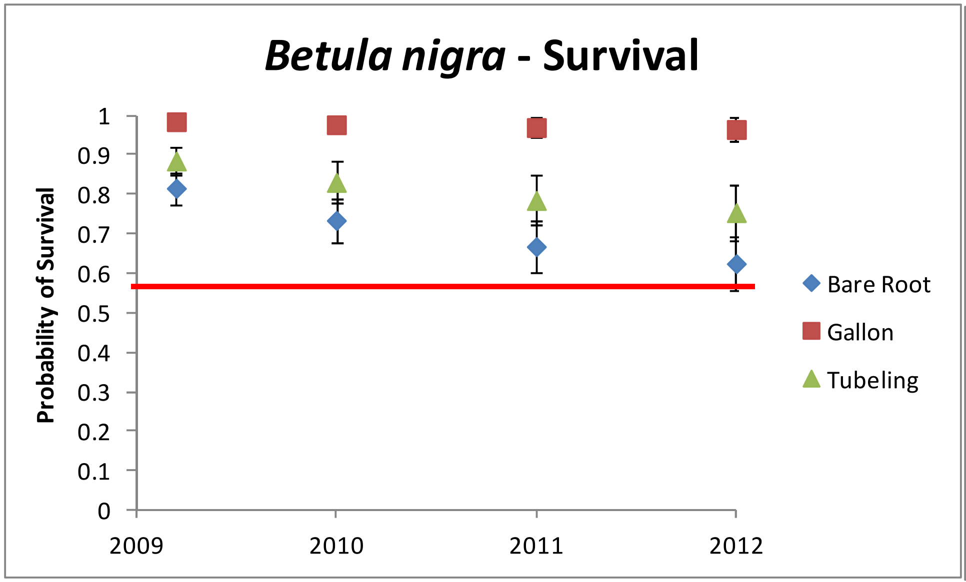

Results to Date

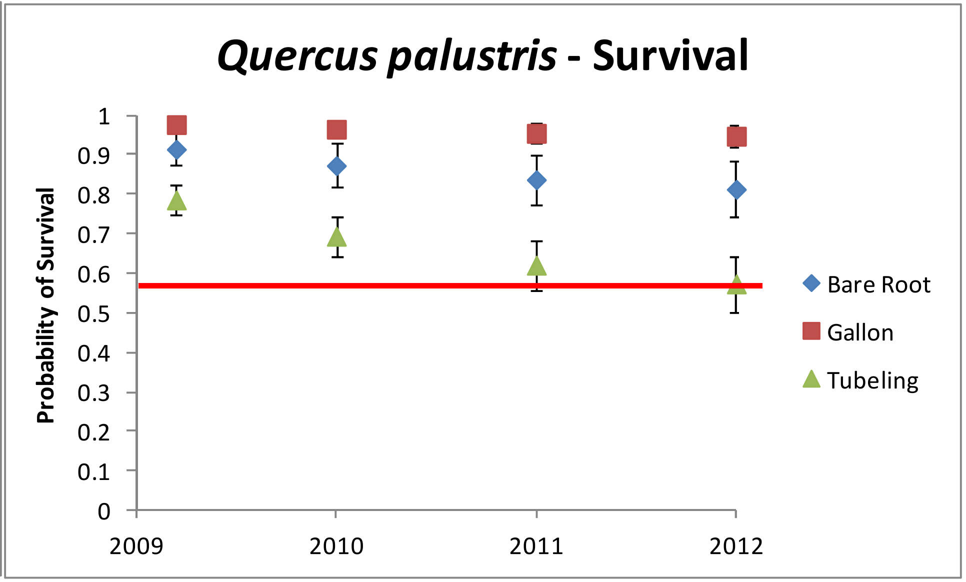
Saturated Cell – All Species and Stocktypes

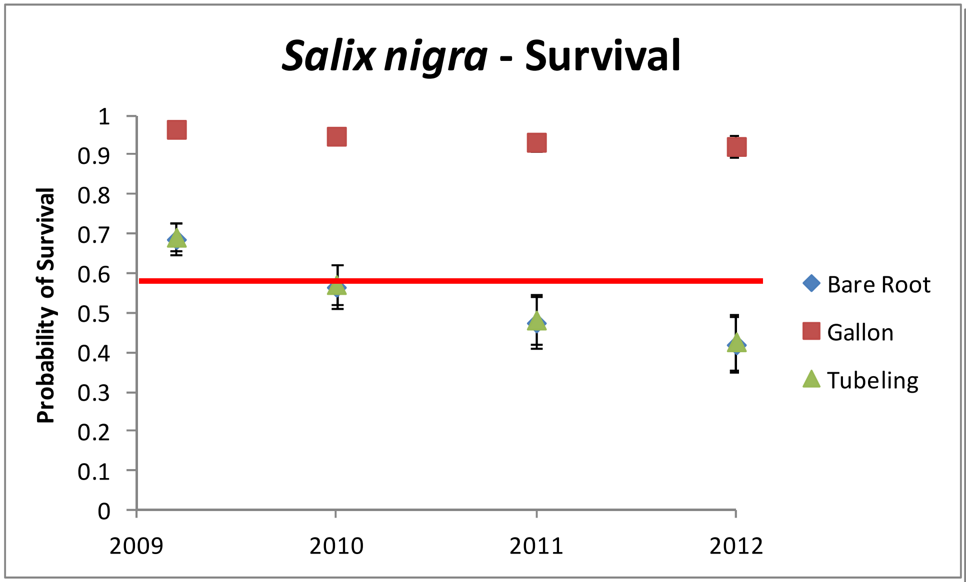


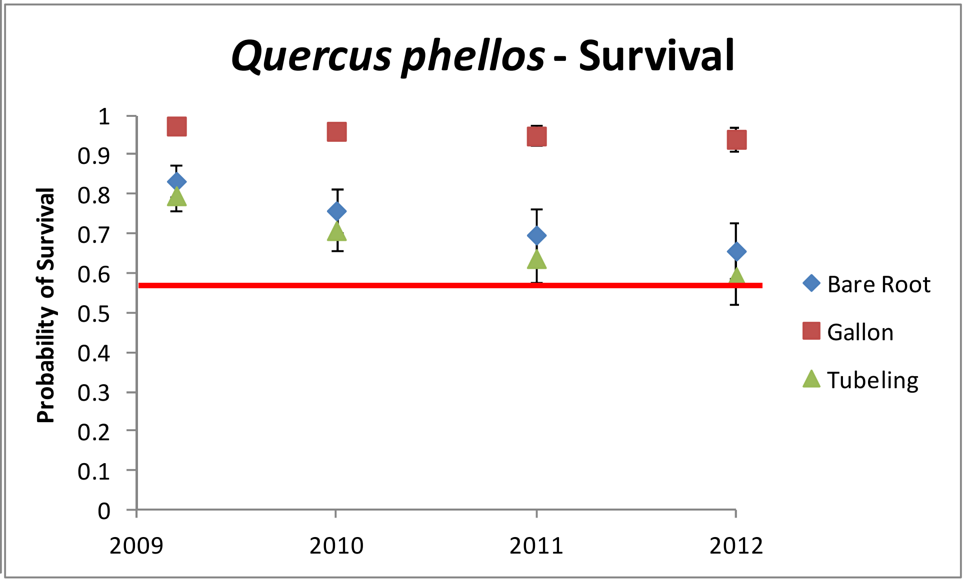
Stem Density

Saturated Cell – All Tree Heights – *Betula nigra*



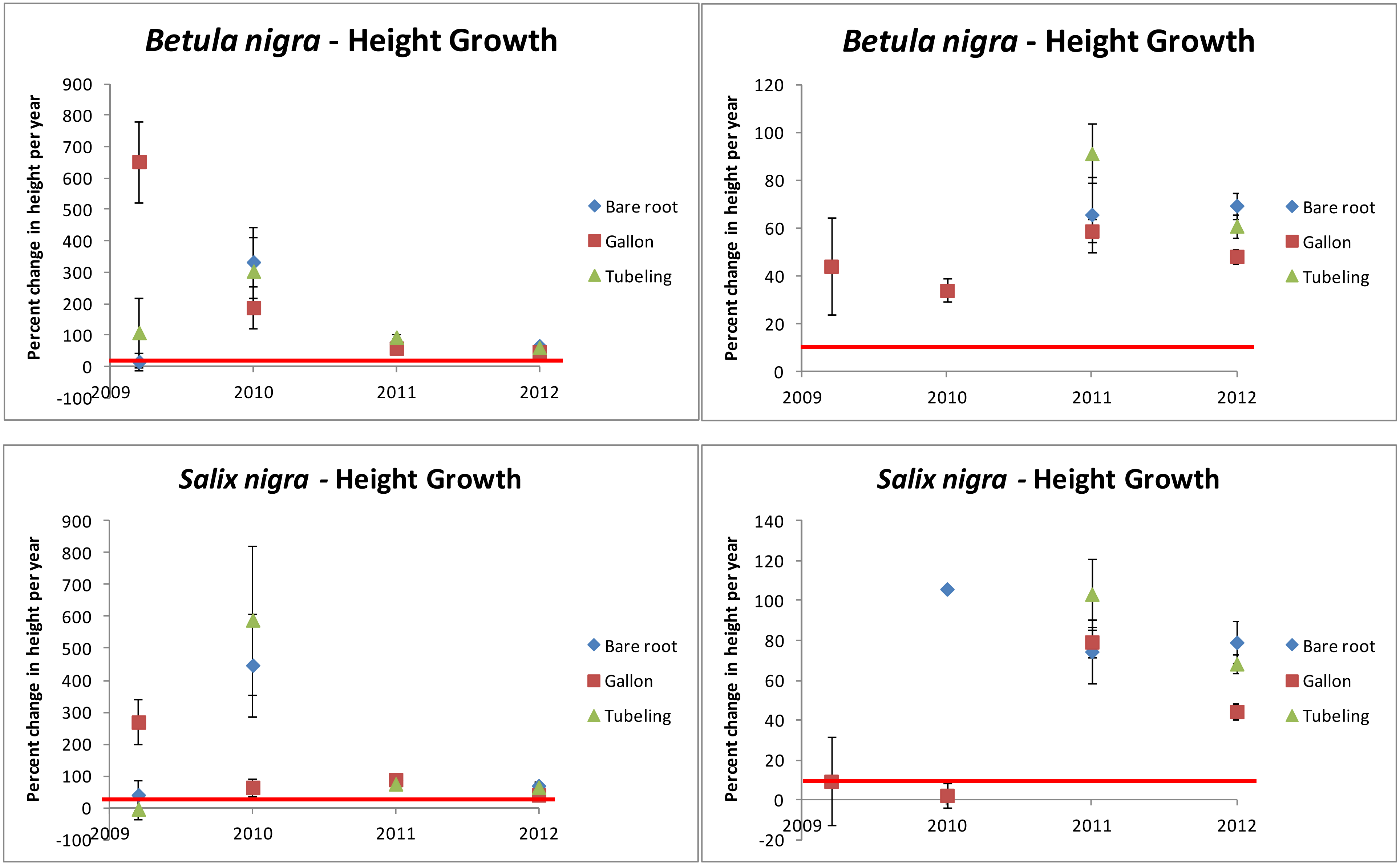






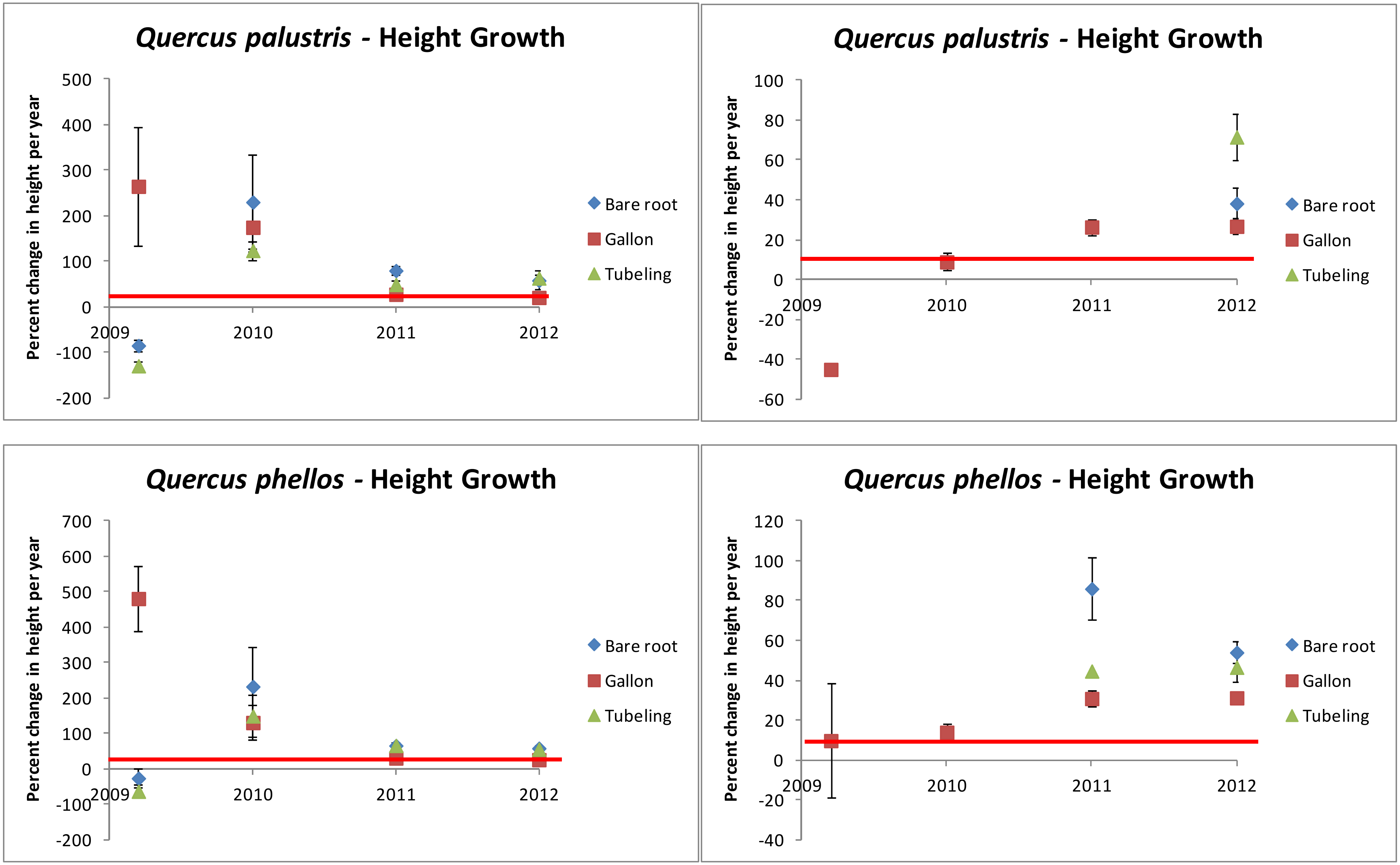
A. Saturated Cell – All Tree Heights

B. Excluding Trees <1m



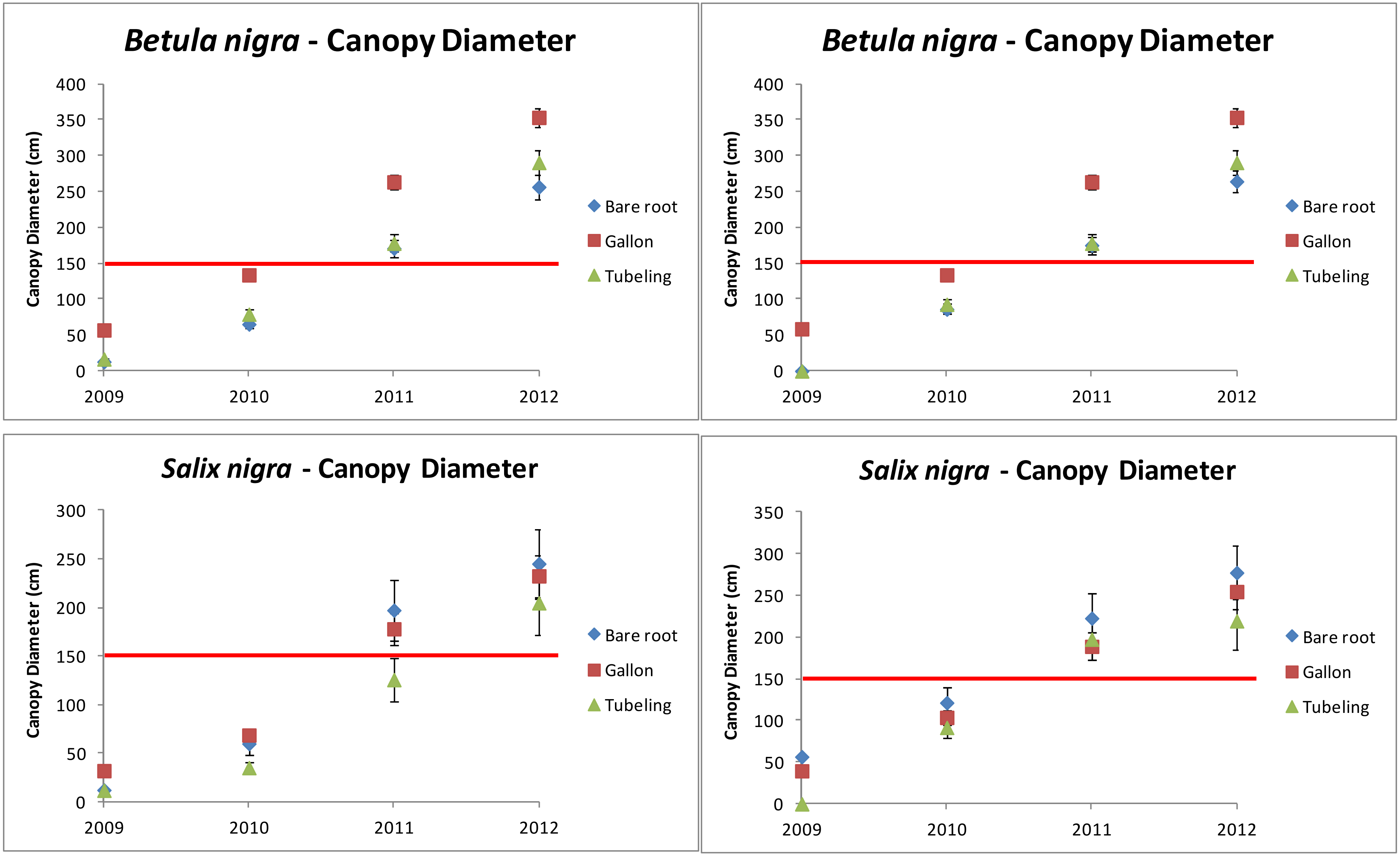
A. Saturated Cell – All Tree Heights

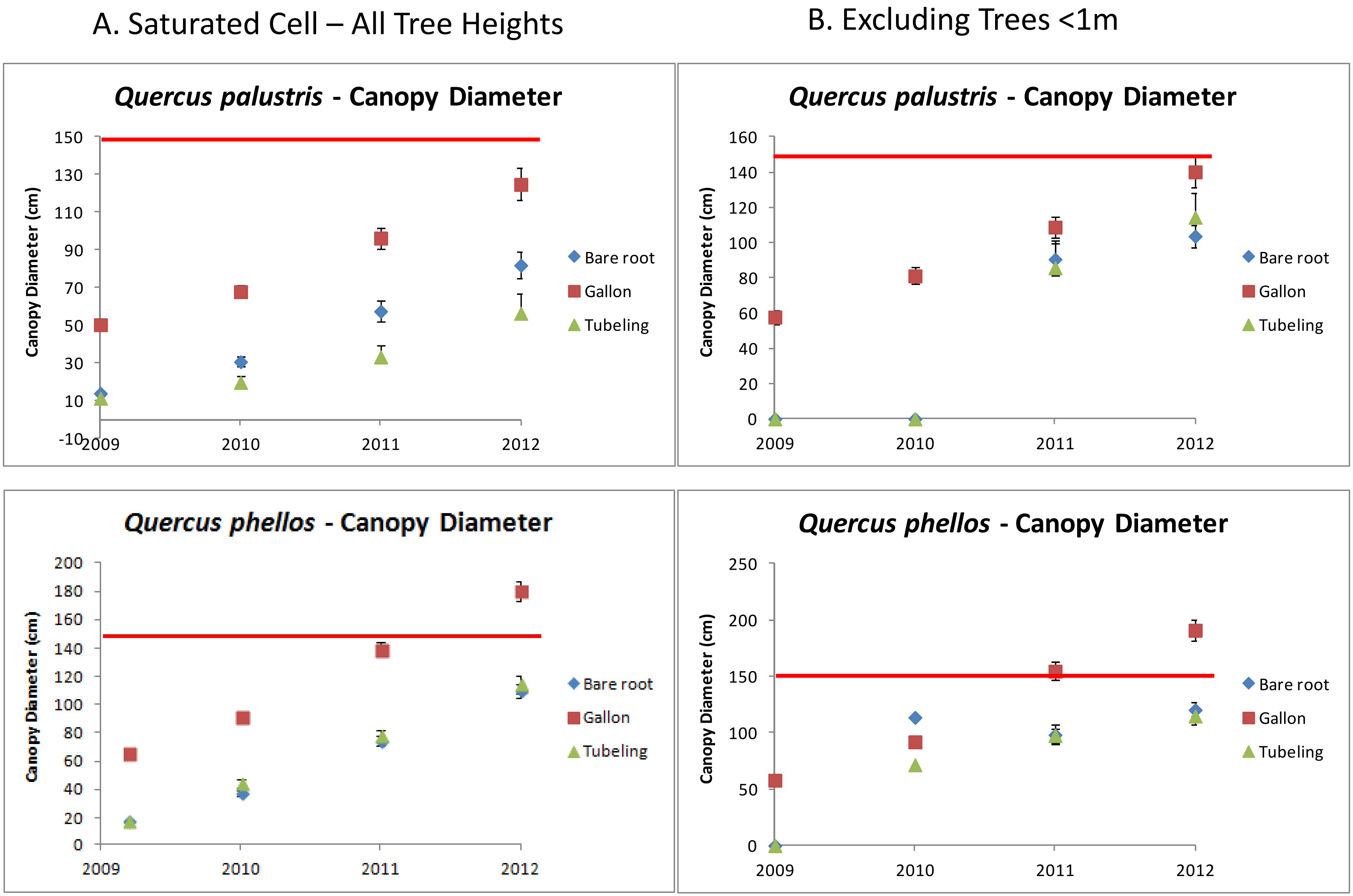
B. Excluding Trees <1m



A. Saturated Cell – All Tree Heights

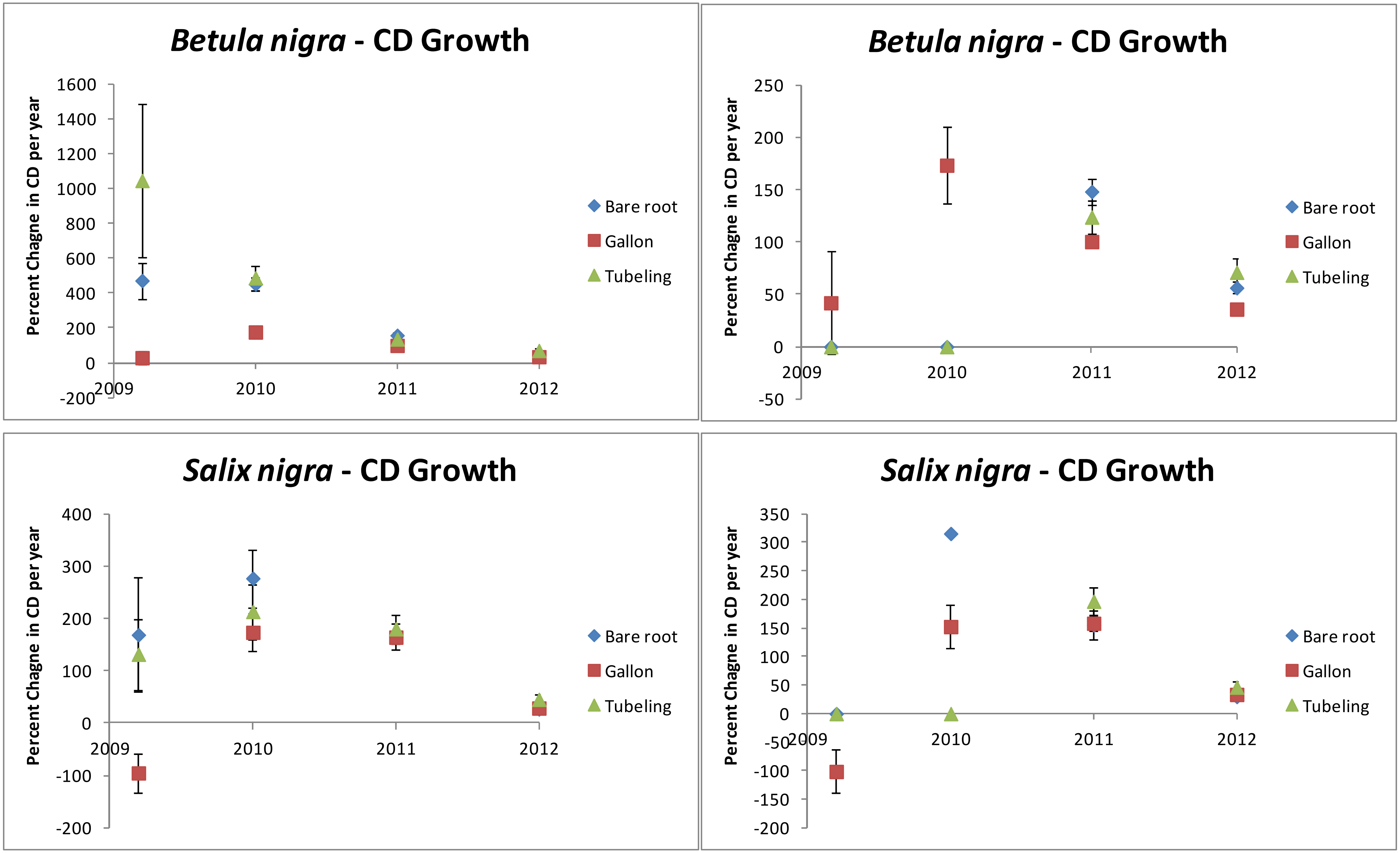
B. Excluding Trees <1m




A. Saturated Cell – All Tree Heights
B. Excluding Trees <1m
Quercus palustris - Canopy Diameter
Canopy Diameter (cm)
150
130
110
90
70
50
30
10
-10
2009
2010
2011
2012
Bare root
Gallon
Tubeling
Quercus palustris - Canopy Diameter
Canopy Diameter (cm)
160
140
120
100
80
60
40
20
0
2009
2010
2011
2012
Bare root
Gallon
Tubeling
Quercus phellos - Canopy Diameter
Canopy Diameter (cm)
200
180
160
140
120
100
80
60
40
20
0
2009
2010
2011
2012
Bare root
Gallon
Tubeling
Quercus phellos - Canopy Diameter
Canopy Diameter (cm)
250
200
150
100
50
0
2009
2010
2011
2012
Bare root
Gallon
Tubeling

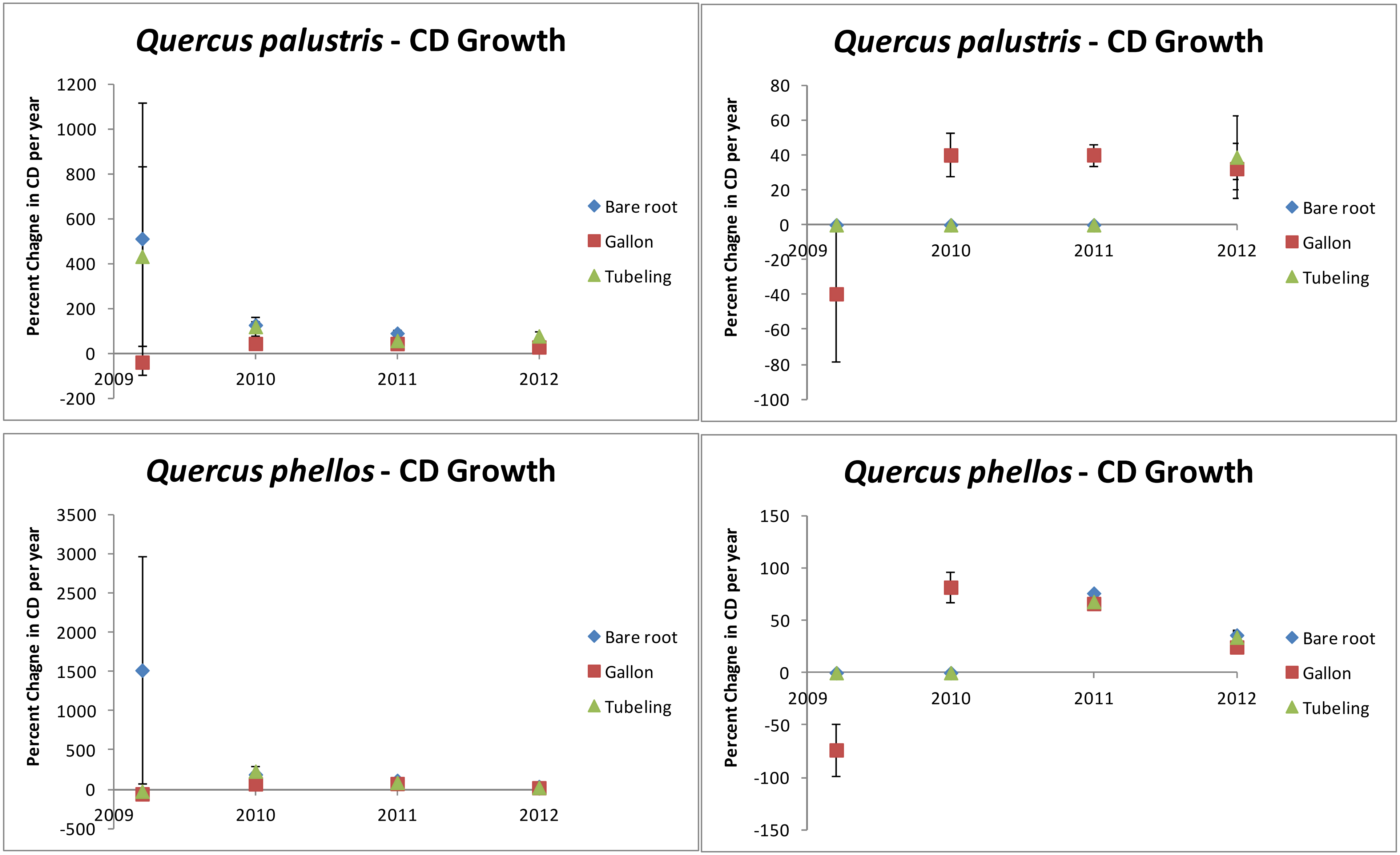
A. Saturated Cell – All Tree Heights

B. Excluding Trees <1m



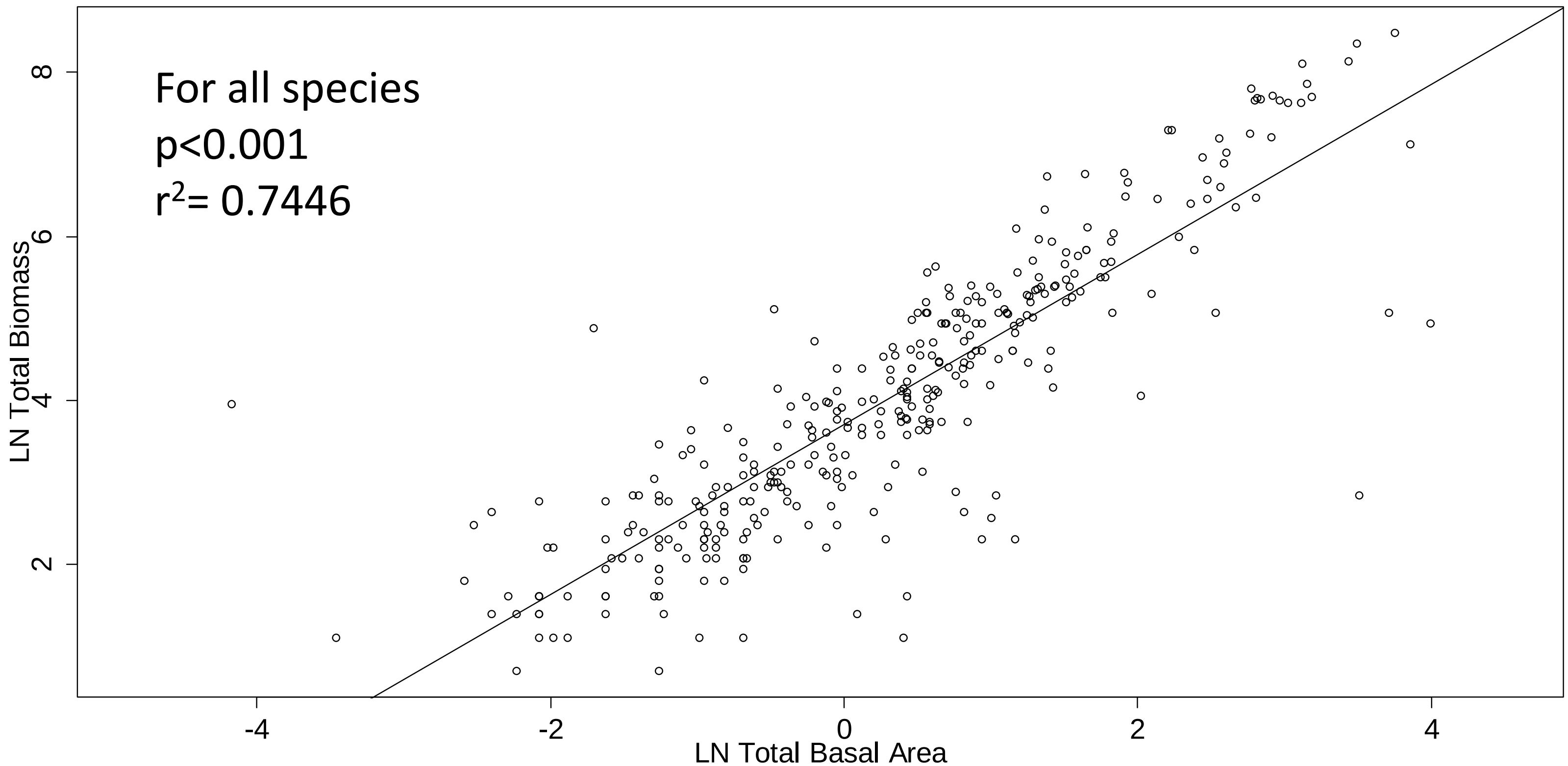
A. Saturated Cell – All Tree Heights

B. Excluding Trees <1m



Results

- Survival
  - Gallons typically greater than bare root and tubeling (dropping below 58% in ~3 yr
  - Primary successional species did slightly better (Except *P. occidentalis* and *Q. bicolor*)
  - *Q. palustris* and *Q. phellos* fell below 58% (~3 yr)
- Height Growth
  - Differences initially (gallon high) – All 3 converge through time
  - Some bare-root and tubeling initially below 10% (Approach 10% ~4 yr)
  - Primary species higher typically
- Canopy Diameter
  - Gallons typically larger but other stocktypes catching up (*P. occidentalis* bare root and tubeling surpassing)
  - Primary species reaching CD performance standard in ~3yr
  - Oaks not reaching CD performance standard in ~4yr
- CD Growth
  - Bare-roots and tubelings high initially – All 3 converge through time
  - Oaks have slower canopy growth



Betula nigra: $p<0.001$ $r^2=0.8596$ n=45

Liquidambar styraciflua: $p<0.001$ $r^2=0.7918$ n=51

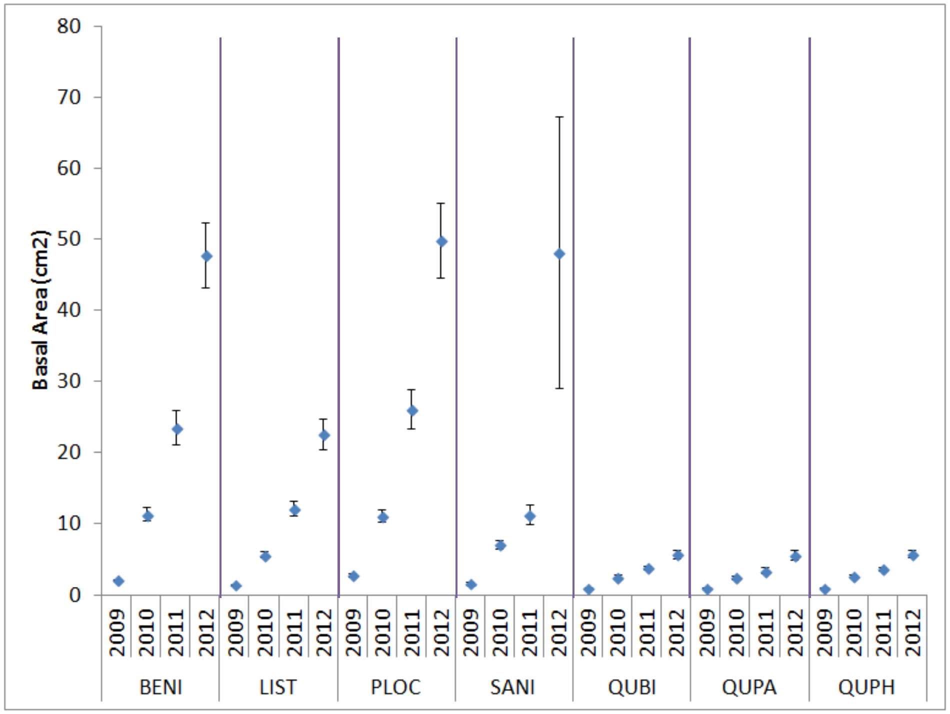
Platanus occidentalis: $p<0.001$ $r^2=0.7883$ n=54

Salix nigra: $p<0.001$ $r^2=0.5429$ n=46

Quercus bicolor: $p<0.001$ $r^2=0.4099$ n=52

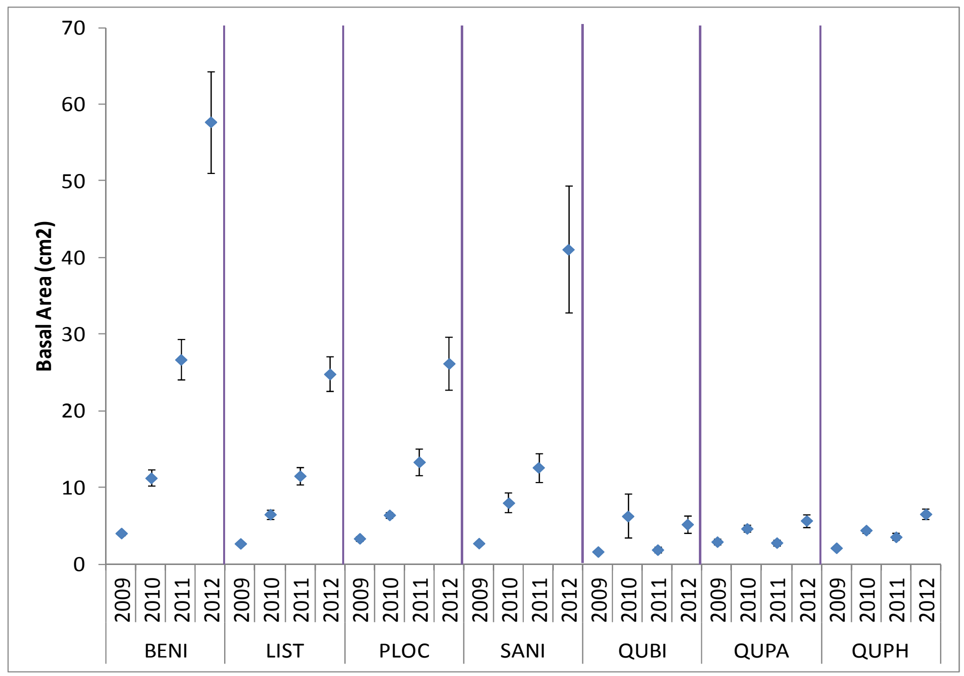
Quercus palustris: $p<0.001$ $r^2=0.7248$ n=50

Quercus phellos: $p<0.001$ $r^2=0.8236$ n=52



Basal Area All Trees

Basal Area Trees >100 cm



Conclusions

- Stocktype is important for survival (only initially for growth)
  - Suggests that stocktype is not an important factor for restoring primary production following establishment
- Stocktypes have differences in structure (gallon typically bigger CD)
  - May support other functions
    - Animal habitat
    - Plant habitat (nurse species - shade)
- Primary species increase in basal area suggest that they may quickly restore primary productivity
- Restoration Applications
  - Balance costs with survival
  - Established bare roots may eventually (~3 years) have similar primary production to gallon stocktypes
  - Plant variety of species and stocktypes to insure restoration of several functions (biodiversity)

Cost per ha
<5000
5000-10000
10000-15000
>15000

Economic Analysis

			Ambient Cell		Saturated Cell		Flooded Cell	
Species	**Stocktype**	**Total Cost**	**Initial Density Require**	**Cost per ha**	**Initial Density Requir**	**Cost per ha**	**Initial Density Required**	**Cost per ha**
Betula nigra	Bare root	1.90	2345	$4,455	1626	$3,090	5040	$9,576
Betula nigra	Gallon	10.25	990	$10,148	1016	$10,415	1131	$11,597
Betula nigra	Tubeling	4.00	3060	$12,240	1333	$5,331	1320	$5,280
Liquidambar styraciflua	Bare root	1.90	1405	$2,670	1366	$2,594	3135	$5,956
Liquidambar styraciflua	Gallon	10.25	1040	$10,655	990	$10,148	1320	$13,530
Liquidambar styraciflua	Tubeling	4.00	4826	$19,305	2504	$10,016	2155	$8,619
Platanus occidentalis	Bare root	1.81	1687	$3,053	1980	$3,584	NA	NA
Platanus occidentalis	Gallon	10.25	1155	$11,839	1015	$10,401	5657	$57,986
Platanus occidentalis	Tubeling NO SOIL	4.00	1021	$4,084	1463	$5,854	17819	$71,274
Quercus bicolor	Bare root	1.90	1207	$2,294	1066	$2,026	5321	$10,110
Quercus bicolor	Gallon	10.25	990	$10,148	990	$10,148	2758	$28,268
Quercus bicolor	Tubeling	4.00	1904	$7,615	1452	$5,808	22769	$91,076
Quercus palustris	Bare root	1.90	1358	$2,580	1245	$2,366	25242	$47,960
Quercus palustris	Gallon	10.25	990	$10,148	1038	$10,642	6081	$62,335
Quercus palustris	Tubeling	4.00	3366	$13,464	1824	$7,295	35637	$142,549
Quercus phellos	Bare root	1.90	1912	$3,632	1584	$3,010	22439	$42,634
Quercus phellos	Gallon	10.25	1106	$11,341	1047	$10,727	3600	$36,900
Quercus phellos	Tubeling NO SOIL	4.00	2673	$10,692	1760	$7,040	NA	NA
Salix nigra	Bare root	1.73	16831	$29,118	2846	$4,924	1120	$1,938
Salix nigra	Gallon	14.95	1070	$16,001	1068	$15,969	1041	$15,559
Salix nigra	Tubeling NO SOIL	4.00	2420	$9,680	2918	$11,671	1207	$4,826

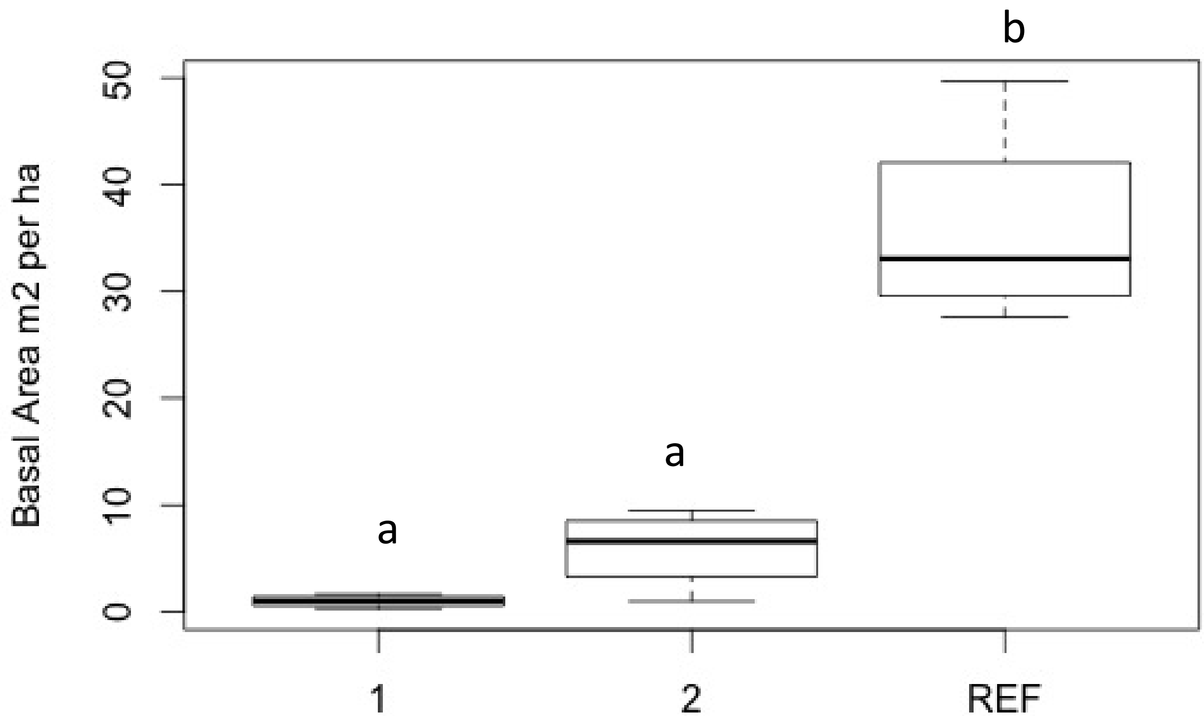
Measuring Ecological Functions and Regulatory Success in Created Forested Wetlands

Maintenance of a characteristic Plant community

Question: Do created wetlands maintain plant communities functionally equivalent to natural wetlands within 20 years, and if not, are they on an appropriate trajectory to do so eventually.

- H_1 Created and reference wetlands will be different in terms of floristic quality and basal area.
- H_2 Created wetlands of ~10 and ~20 years post creation will be different in terms of floristic quality and basal area.
- H_3 Created wetlands will change over 8 years since they were last monitored and will be more like reference sites.

Basal Area of trees ≥10 cm DBH by age class



All age classes include 2 sites from the Piedmont and 2 from the Coastal Plain

Age 1: average age: 11.5 years

Dominant Trees: Salix nigra (IV = 70.4)

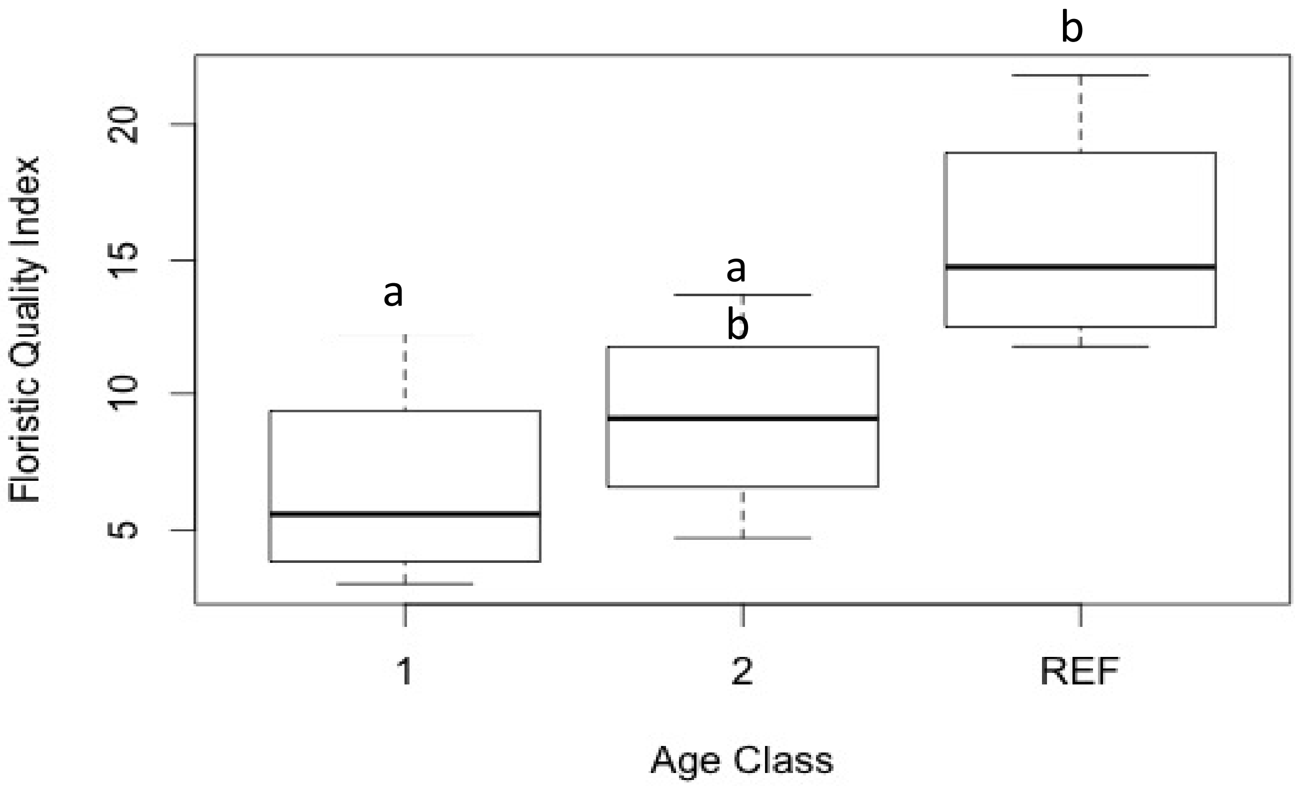
Age 2: average age: 21 years

Dominant Trees: Salix nigra (37.3), Pinus taeda (21.9)

Reference sites: average time since major disturbance (79 years)

Dominant Trees: Acer rubrum (35.5), Fraxinus pennsylvanica (16.9)

Floristic Quality Index (weighted by relative importance value) for the tree strata (≥10 cm DBH)



$$FQI_{modified}=[\Sigma\ C_i(IV_i/100)](\sqrt{N})$$

Acknowledgements

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- **WM and VIMS Students**

Questions?

Would you trust this person with your data?