Two Year Survival and Growth of Seven Wetland Tree Species in Three Hydrologically Distinct Habitats

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Introduction

Ecological performance standards for forested wetland compensatory mitigation sites in Virginia include:
- >990 woody stems/ha (>400 stems/acre)[1]
- >10% increase in height/year

The woody stem density standard can be accomplished through:
- Natural tree colonization from surrounding forests[2]
- Introduction of planted trees

Wetland compensation sites are not meeting ecological performance standards[3-7] mainly as a result of:
- Poor survival of planted woody vegetation[8-15]
- Poor quality nursery stock
- Improper species selection
- Unfavorable site conditions
- Improper stocktype selection
- Improper planting techniques

Previous studies suggest that species and stocktype should be matched to hydrologic conditions[17]

The purpose of this study in part, is to determine the appropriate species and stocktype combinations for use in wetland compensation sites and other afforestation or reforestation projects

Hypotheses

Within each cell, gallon stocktypes and primary successional species will have greater probabilities of survival and height growth rates when compared to other stocktypes and secondary successional species.[18]

Bare root stocktypes will be the least expensive stocktype to ensure meeting the required stem density.[19]

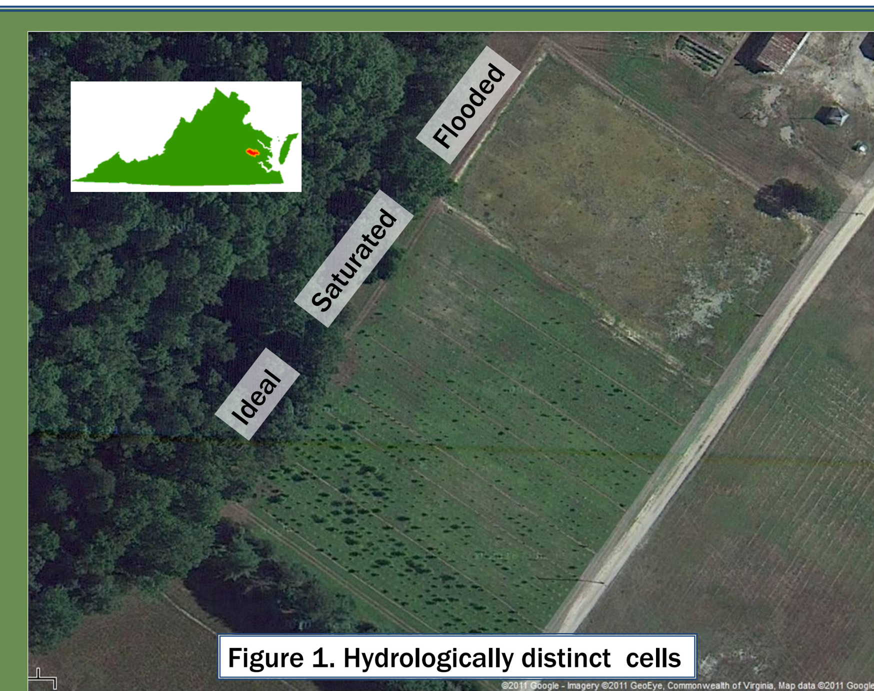
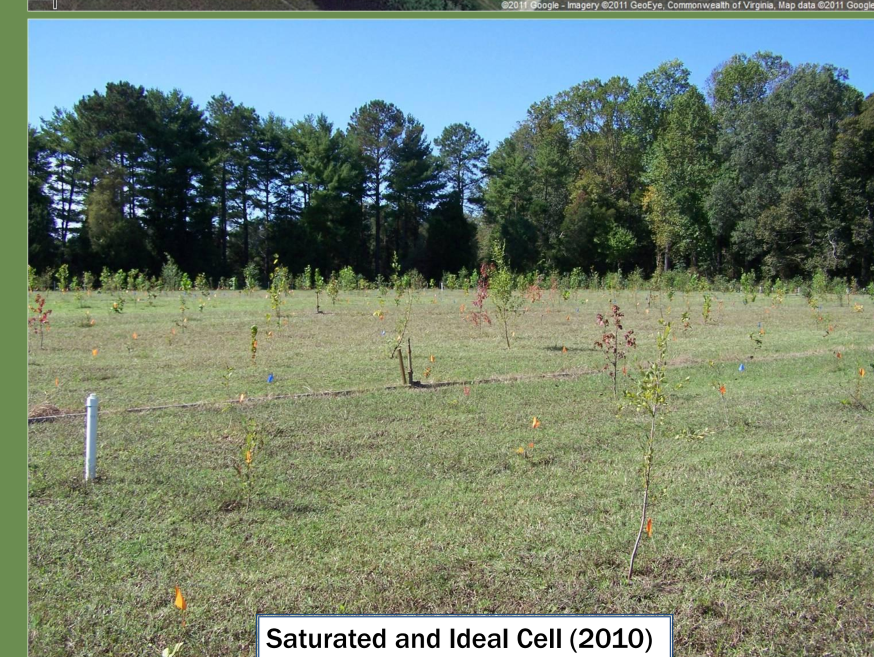
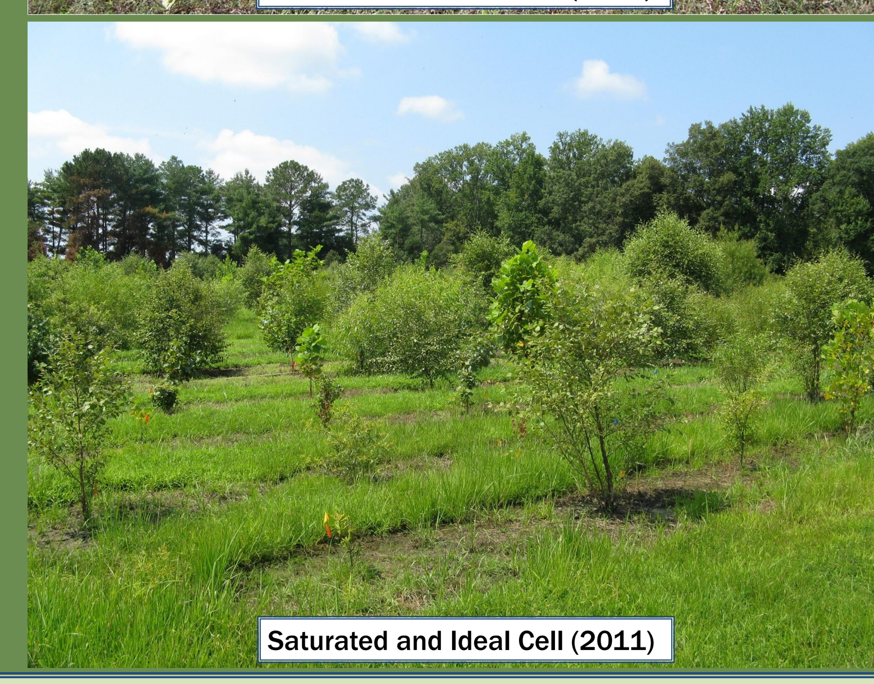


Figure 1. Hydrologically distinct cells



Saturated and Ideal Cell (2010)



Saturated and Ideal Cell (2011)

Methods

Seven Species
- *Betula nigra* L. (River Birch) (FACW)
- *Liquidambar styraciflua* L. (Sweetgum) (FAC)
- *Platanus occidentalis* L. (American Sycamore) (FACW)
- *Salix nigra* Marsh. (Black willow) (FACW)
- *Quercus bicolor* Willd. (Swamp white oak) (FACW)
- *Quercus palustris* Münchh (Pin oak) (FACW)
- *Quercus phellos* L. (Willow oak) (FAC)

Three Nursery Stocktypes

Bare root

Tubeling

1 – Gallon Container

Three Hydrologically Distinct Cells (Figure 1)
- Ideal – Only irrigated during drought conditions
- Saturated – Saturation maintained within the root zone (>30.5 cm) for ~90% of the growing season
- Flooded – Inundation above the root crown for ~90% of the growing season
- Total = 2772 Trees (Planted Spring 2009)
- Controlled competing herbaceous vegetation

Survival Data Analysis
- Measured April, August, October (2009-2010)
- Cox Proportional Hazards Model (PROC PHREG - SAS 9.2)

Growth Data Analysis
- Calculated percent change in height per year
- Two-way ANOVA within each cell and slicing

Economic Data Analysis
- Determined cost of ensuring >990 stems/ha

Survival Data Analysis

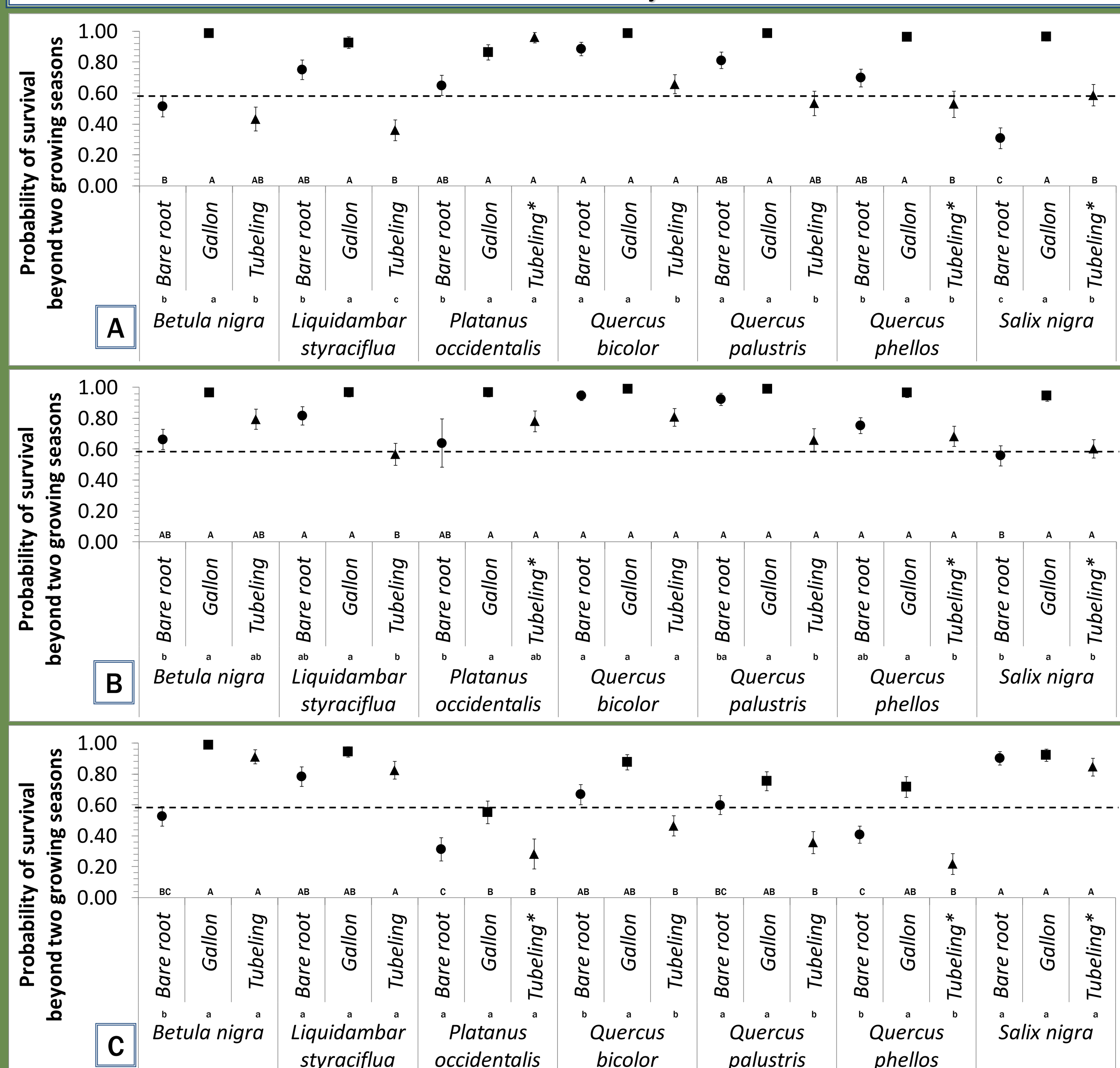


Figure 2. The probability of surviving beyond two growing seasons within the **A.** Ideal, **B.** Saturated, and **C.** Flooded cells. The dashed line represents the minimum probability of survival required to ensure 990 stems/ha. Error bars represent standard error. * Represents soil removed prior to shipping. (Lowercase letters represent no significant difference among stocktype, uppercase represent no difference among species, p>0.05)

Economic Data Analysis

			Ideal Cell			Saturated Cell			Flooded Cell		
Species	Stocktype	Price ($/Tree)	% Survival	Initial Density Required	Cost per ha	% Survival	Initial Density Required	Cost per ha	% Survival	Initial Density Required	Cost per ha
Betula nigra	Bare root	0.65	39.6	2274	$1,478	57.1	1575	$1,024	28.8	3124	$2,030
Betula nigra	Gallon	3.25	92.9	969	$3,150	90.5	995	$3,233	83.7	1075	$3,494
Betula nigra	Tubeling	1	29.7	3027	$3,027	71.1	1267	$1,267	69.2	1300	$1,300
Liquidambar styraciflua	Bare root	0.65	68.1	1322	$859	69.8	1290	$839	36.6	2460	$1,599
Liquidambar styraciflua	Gallon	3.25	88.9	1012	$3,291	90.7	992	$3,225	76.7	1173	$3,811
Liquidambar styraciflua	Tubeling	1	19.0	4725	$4,725	39.1	2300	$2,300	45.0	2000	$2,000
Platanus occidentalis	Bare root	0.56	57.1	1575	$882	33.3	2700	$1,512	0.0	NA	NA
Platanus occidentalis	Gallon	3.25	80.0	1125	$3,656	90.9	990	$3,217	25.6	3518	$11,434
Platanus occidentalis	Tubeling*	1	88.9	1012	$1,012	64.9	1387	$1,387	4.8	18900	$18,900
Quercus bicolor	Bare root	0.65	77.4	1163	$756	89.1	1010	$656	28.3	3185	$2,070
Quercus bicolor	Gallon	3.25	92.5	973	$3,162	92.9	969	$3,150	57.1	1575	$5,119
Quercus bicolor	Tubeling	1	50.9	1767	$1,767	70.2	1282	$1,282	10.2	8820	$8,820
Quercus palustris	Bare root	0.65	70.6	1275	$829	81.0	1112	$723	7.3	12375	$8,044
Quercus palustris	Gallon	3.25	92.9	969	$3,150	89.1	1010	$3,282	27.7	3254	$10,575
Quercus palustris	Tubeling	1	29.7	3027	$3,027	50.0	1800	$1,800	7.7	11700	$11,700
Quercus phellos	Bare root	0.65	50.8	1770	$1,150	60.9	1479	$961	12.5	7200	$4,680
Quercus phellos	Gallon	3.25	85.4	1054	$3,426	87.5	1029	$3,343	37.2	2419	$7,861
Quercus phellos	Tubeling*	1	36.7	2455	$2,455	58.8	1530	$1,530	0.0	NA	NA
Salix nigra	Bare root	0.48	5.4	16650	$7,992	32.7	2756	$1,323	80.4	1119	$537
Salix nigra	Gallon	7.95	86.0	1046	$8,315	86.4	1042	$8,285	77.8	1157	$9,199
Salix nigra	Tubeling*	1	38.3	2350	$2,350	37.3	2414	$2,414	78.6	1145	$1,145

Table 1. Economic comparison of species and stocktypes. The initial density required is the number of trees needed to reach the >990 stems/ha ecological performance standard based on the percent survival for each combination. * Represents soil removed prior to shipping. Highlighted cells are lowest values.

Results and Discussion

Survival

There was significant three-way interaction among cell, species and stocktype (p=0.0089), suggesting that the species and stocktype did not have similar probabilities of survival among each cell. Gallon stocktypes frequently had greater survival than other stocktypes and all species had similar survival probabilities within each cell (Figure 2). Gallon stocktypes may have increased root mass allowing for increased uptake of water and all species were matched to hydrologic conditions. Few species-stocktype combinations exhibited less than 58.8% survival in the Ideal and Saturated cells, while 6 combinations had less in the Flooded cell, including all three oak species.

Growth

There was significant three-way interaction among cell, species and stocktype (p<0.001). No stocktype consistently had greater positive percent change in height, suggesting stocktype has little influence on height growth. The primary successional species had marginally greater percent change in height in the Ideal cell, while species had similar growth within the Saturated and Flooded cells (Figure 3). Very few species-stocktype combinations satisfied the 10% increase in height standard within the Flooded cell, suggesting trees planted under stressful hydrologic conditions may not reach this required performance standard.

Economic Analysis

Gallon stocktypes often had the lowest initial planting density required to reach the >990 stems/ha performance standard, however due to the low cost, the bare root stocktype often was the least expensive per ha to ensure >990 stems/ha. This suggests that based on purchasing cost only, the bareroot stocktype is often the most economical choice.

Conclusion

Gallon stocktypes and primary successional species do not always out perform other stocktypes and secondary successional species. Forested wetland compensation efforts should focus on planting increased amounts of bare root stocktypes to ensure adequate survival.

Growth Data Analysis

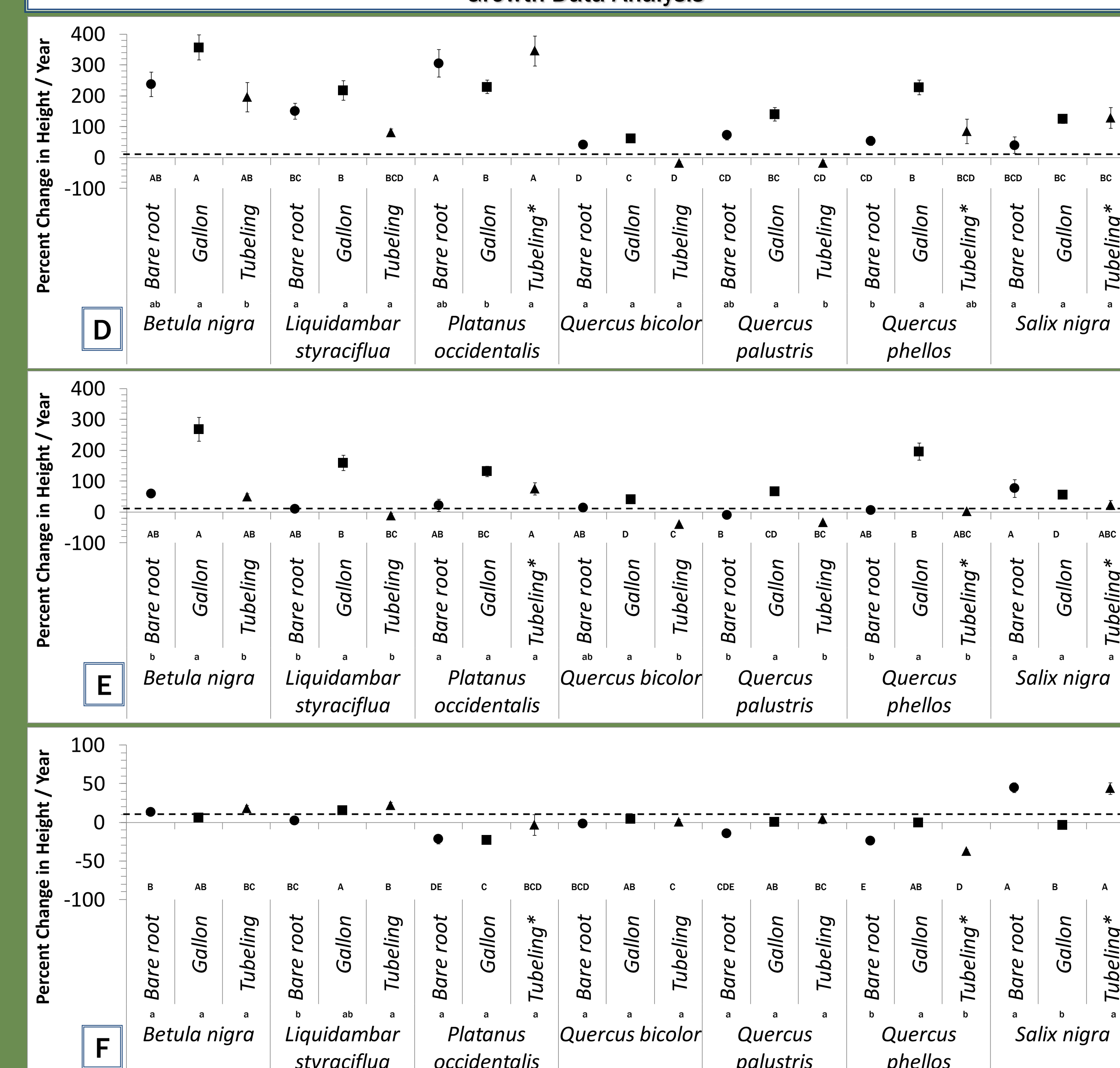
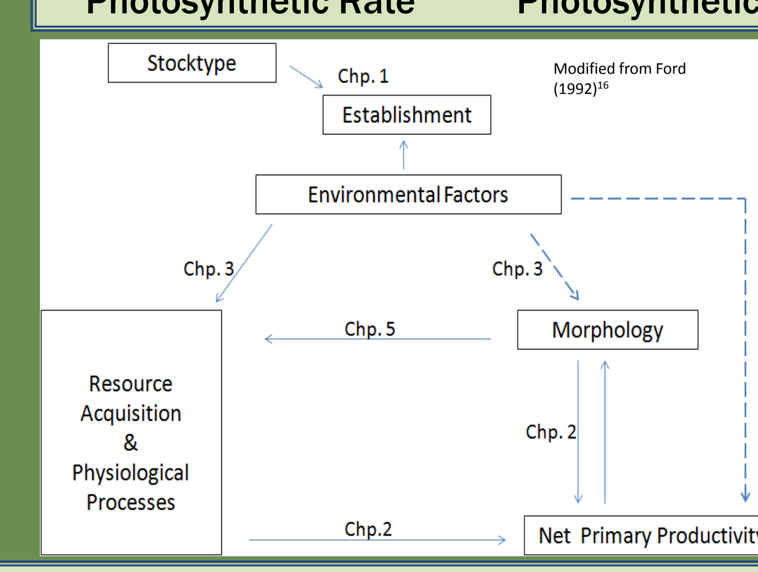


Figure 3. Percent change in height per year within the **E.** Ideal, **F.** Saturated, and **G.** Flooded cells. Dashed line represents 10% increase in height ecological performance standard. Error bars represent standard error. * Represents soil removed prior to shipping. (Lowercase letters represent no significant difference among stocktype, uppercase represent no significant difference among species, p>0.05)

Future Dissertation Work

To determine how the following variables influence the net primary production of planted trees:
- Distance to forest edge
- Soil physical and chemical properties
- Woody competition
- Hydrology Morphology
- Leaf area index
- Relative growth rates
- Photosynthetic Rate
- Photosynthetic Efficiency



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Literature Cited

1. United States Army Corps of Engineers Norfolk District and Virginia Department of Environmental Quality. 2004. Recommendations for wetland compensatory mitigation: Including site design, permit conditions, performance and monitoring criteria. Norfolk District, Norfolk, VA.
2. Hudson, III, H. W. 2010. The Effect of Adjacent Forests on Colonizing Tree Density in Restored Wetland Compensation Sites in Virginia. Master Thesis. Christopher Newport University. Newport News, Virginia.
3. Brown, S. and P. Veneman. 2001. Effectiveness of compensatory wetland mitigation in Massachusetts, USA. Wetlands 21:508-518.
4. National Research Council. 2001. Compensating for wetland losses under the Clean Water Act. National Academies Press. Washington DC.
5. Cole, C. A. and D. Shafer. 2002. Section 404 wetland mitigation and permit success criteria in Pennsylvania, USA, 1986-1999. Environmental Management 30:508-515.
6. Sharitz, R., C. Barton and De Steven, D. 2006. Tree plantings in depression wetland restorations show mixed success (South Carolina). Ecological Restoration 24:114-115.
7. Matthews, J. W. and A. G. Endress. 2008. Performance criteria, compliance success, and vegetation development in compensatory mitigation wetlands. Environmental Management 41:130-141.
8. Robb, J. T. 2002. Assessing Wetland Compensatory Mitigation Sites to Aid in Establishing Mitigation Ratios. Wetlands 22:435-440.
9. Morgan, K. L. and T. H. Roberts. 2003. Characterization of wetland mitigation projects in Tennessee, USA. Wetlands 23:65-69.
10. Stolt, M. H., M. H. Genthner, W. L. Daniels, V. A. Groover, S. Nagle and K. C. Haering. 2000. Comparison of soil and other environmental conditions in constructed and adjacent palustrine reference wetlands . Wetlands 20:671-683.
11. Campbell, D. A., C. A. Cole and R. P. Brooks. 2002. A comparison of created and natural wetlands in Pennsylvania, USA. Wetlands Ecology and Management. 10:41-49.
12. Bruland G. L. and C. J. Richardson. 2004. Hydrologic gradients and topsoil additions affect soil properties of Virginia created wetlands. Soil Science Society of America Journal 68:2069-2077.
13. Bergshneider, C. 2005. Determining an appropriate organic matter loading rate for a created coastal plain forested wetland . Master Thesis. *Virginia Polytechnic Institute and State University*. Blacksburg, VA.
14. Daniels, W. L., J. E. Perry and R. G. Whittecar. 2005. Effects of soil amendments and other practices upon the success of the Virginia Department of Transportation's non-tidal wetland mitigation efforts. Virginia Transportation Research Council. Final Contract Report. VTRC 06-CR25
15. Bailey, D. E., J. E. Perry and W. L. Daniels. 2007. Vegetation dynamics in response to organic matter loading rates in a created freshwater wetland in southeastern Virginia. Wetlands 27:936-950.
16. Ford, E. D. 1992. The control of tree structure and productivity through the interaction of morphological development and physiological processes. International Journal of Plant Sciences 153:147-162.
17. McLeod, K.W., Reed, M.R., Moyer, B.P. and Ciravolo, T.G. 2006. Species selection trials and silvicultural techniques for the restoration of bottomland hardwood forests - A 10 year review. *In* Connor, K. F. (ed.) Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-92
18. Farmer Jr., R.E. 2004. Comparative analysis of first-year growth in six deciduous tree species Canadian Journal of Forestry, 1980, Vol. 10, pp. 35-41.
19. McLeod, K. 2000. Species selection trials and silvicultural techniques for the restoration of bottomland hardwood forests. Ecological Engineering Vol. 15, pp. S35-S46..