A climate change response function for loblolly pine (*Pinus taeda* L.) from the Western Gulf region of the United States.

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Introduction

- 1974-1978 - Western Gulf Forest Tree Improvement Program (WGFTIP) established Geographic Seed Source Study (GSSS) for loblolly pine (*Pinus taeda* L.).
- Original objective of GSSS: to better delineate breeding and deployment zones within the Western Gulf region of the United States.
- 73 plantings were established in two series (Fig. 1).
- Sampling and planting locations ranged from the maritime conditions of the Mississippi Gulf Coast to the more xeric and continental conditions encountered beyond the northern and western edges of the current natural range for the species in Arkansas and Oklahoma (but within the current range of commercial planting for the species).
- Series I:
  - 26 open-pollinated first-generation selection families (N-S transect).
  - 43 test sites scattered across the studied area.
- Series II:
  - 17 open-pollinated first-generation selection families (E-W transect).
  - 30 test sites scattered across the studied area.
- Each family was established in four-tree row plots replicated in six randomized complete blocks.
- Height and diameter were measured and planted-tree volume calculated at ages 5, 10, 15 and 20.

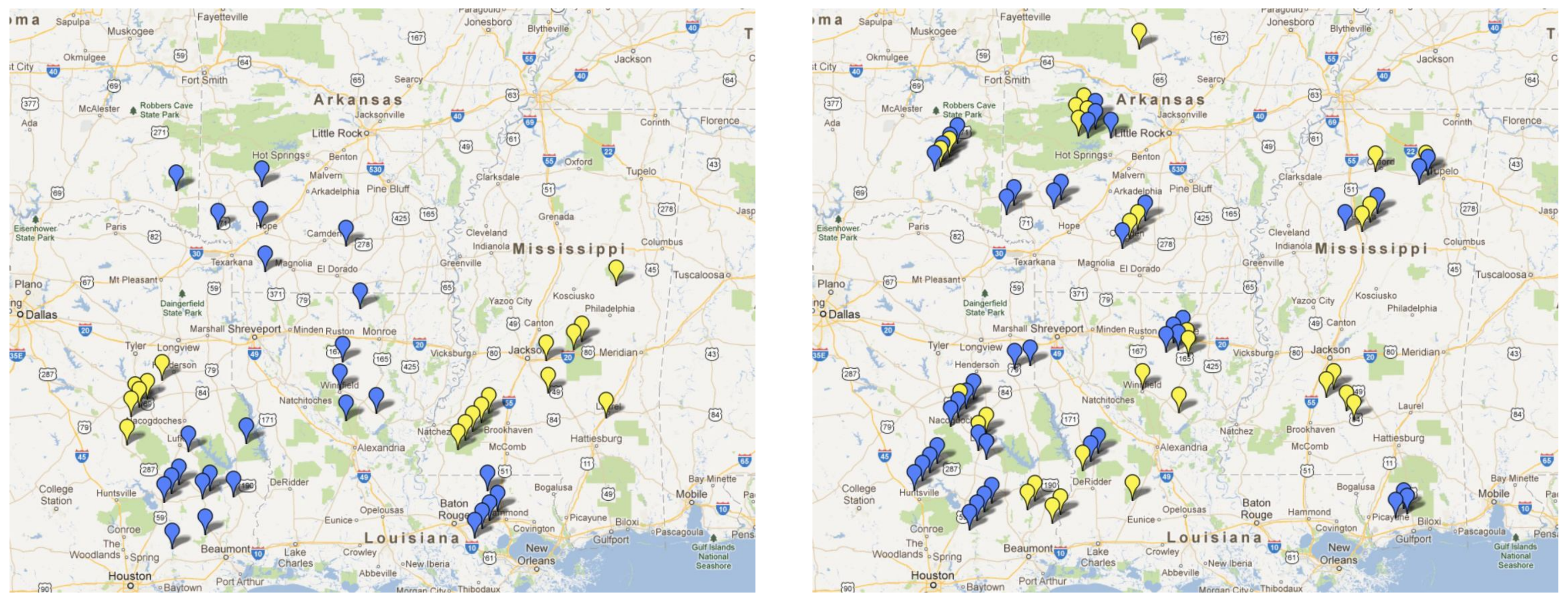

Figure 1. Family (left pane) and test site (right pane) locations for series I (blue markers) and series II (yellow markers) in the WGFTIP Geographic Seed Source Study.

Objective

Develop models that could be used to:

- support projections of future forest productivity when combined with climate models.
- guide future deployment decisions to optimize productivity and resilience.
- direct future breeding efforts by quantifying the variation among families for phenotypic plasticity exhibited in response to changing environments.

Methods

- SAS: PROC REG – Variance Inflation Factor (VIF < 10) and *P*-values (*P* < 0.05) for all variables were examined.
- Response variables: height and planted-tree volume at age 15 (plot level mean for each family before thinning).
- Weather variables were extracted from PRISM datasets (http://www.prism.oregonstate.edu/)
  - linear, quadratic and crossproduct form.
  - 1970-2000 data were used to represent **historical climate** shaping adaptations (genetic factor) – prefix pr* ("provenance").
  - Time frame corresponding to a given test site establishment and measurements were considered an environmental factor and surrogate for **future climate** – prefix ts* ("test site") .
- Weather variables selected exhibiting clinal variation and minimal colinearity (Fig. 2):
  - N-S transect: mean minimum temperature of the coldest month (MMIN).
  - E-W transect: summer (June-August) aridity index (AI; similar to Eckert et al. 2010) and its coefficient of variation (CV(AI)).

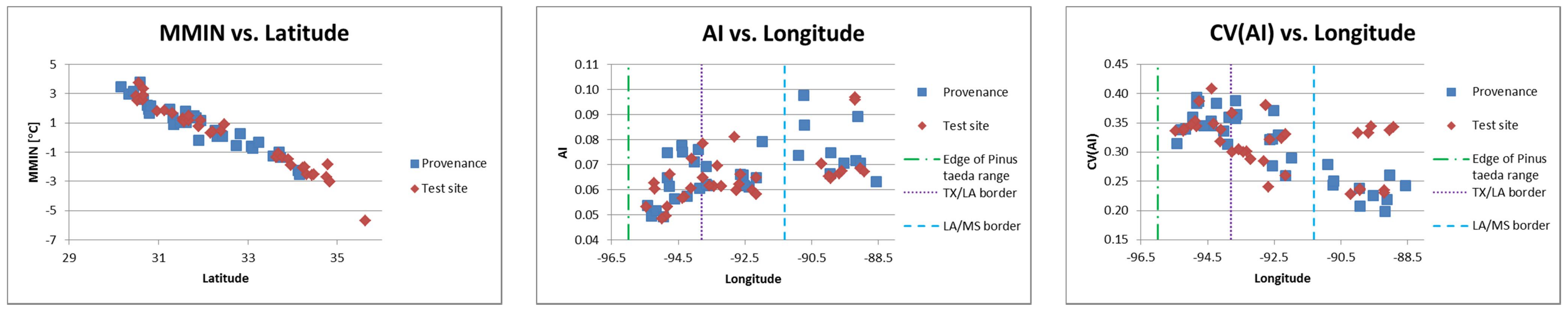

Figure 2. Weather variables showing clinal variation in north-south (MMIN) and east-west (AI and CV(AI)) transects. Approximate longitudinal locations of the western edge of *Pinus taeda* L. continuous range, TX/LA border and LA/MS border are shown.

Key findings

- Regression models were defined as shown in Table 1.
- AI as variously expressed is a key factor in determining site productivity.
- Earlier observations were confirmed that south to north seed movement affects productivity and that the relationship is curvilinear (Schmidtling 1994).
- The data were insufficient to delineate the adaptability-limiting factors in the east-west transect although both mean AI and its variance reached extremes near the western species boundary. Both factors may need to be considered in future modeling efforts.

Table 1. Results of multiple regression analysis predicting loblolly pine height and volume based on provenance and test site climate. All parameters were significant at $\alpha = 0.05$. Final model R^2 values are in bold.

Series I								Series II (west of Mississippi river)							
Height				Volume				Height				Volume			
Parameter	Parameter Estimate	Partial R^2	Model R^2	Parameter	Parameter Estimate	Partial R^2	Model R^2	Parameter	Parameter Estimate	Partial R^2	Model R^2	Parameter	Parameter Estimate	Partial R^2	Model R^2
Intercept	15.975			Intercept	0.133			Intercept	3.455			Intercept	-0.081		
$tsAI^2$	-681.216	0.354	0.354	$tsAI^2$	-9.082	0.125	0.125	$[CV(tsAI)]^2$	54.059	0.371	0.371	$[CV(tsAI)]^2$	1.525	0.162	0.162
$prAI^2$	172.641	0.054	0.408	$tsMMIN^2$	-0.004	0.085	0.210	tsMMIN x prMMIN	0.088	0.020	0.391	$tsMMIN^2$	0.003	0.009	0.171
$tsMMIN^2$	-0.132	0.017	0.425	prMMIN x tsAI	0.092	0.037	0.247	$tsMMIN^2$	0.049	0.011	0.401	tsMMIN x prMMIN	0.003	0.008	**0.178**
tsMMIN x CV(prAI)	-1.152	0.021	0.446	tsMMIN x CV(prAI)	-0.028	0.017	0.264	prAI x CV(tsAI)	101.288	0.006	0.408				
prMMIN x tsAI	2.712	0.008	0.455	$prAI^2$	4.798	0.009	0.273	tsAI x CV(prAI)	79.585	0.013	**0.421**				
prAI x CV(prAI)	-32.012	0.002	0.456	$prMMIN^2$	-0.001	0.007	0.280								
tsMMIN x prMMIN	0.017	0.001	**0.458**	tsMMIN x prMMIN	0.001	0.004	0.284								
				$[CV(tsAI)]^2$	0.073	0.001	0.285								
				prAI x CV(prAI)	-0.663	0.001	**0.286**								

Conclusions

- Additional gains in productivity and resilience can be obtained from:
  - supporting provenance movement (common evolutionary background) with information on the tree-to-tree genetic variation obtained through progeny testing.
  - improvements in silvicultural methods that focus on altering the aridity index through optimal site preparation, competition control, thinning and drainage.
- Interactions between targeted seedling deployment and site specific management practices were relatively unimportant when compared to main effects.

References

Eckert AJ, et al. (2010) Patterns of population structure and environmental associations to aridity across the range of loblolly pine (*Pinus taeda* L., Pinaceae). Genetics 185:969-982.

Schmidtling RC (1994) Use of provenance tests to predict response to climatic change: loblolly pine and Norway spruce. Tree Physiol 14:805-817.

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