In search of optimal strategies for delineating assisted migration guidelines as applied to loblolly pine families from the Western Gulf region of the USA

Tomasz E. Koralewski[1,*], Hsiao-Hsuan (Rose) Wang[2,*], and Thomas D. Byram[1,3]

[1] Department of Ecosystem Science and Management, Texas A&M University, 2585 TAMU, College Station, TX 77843-2585, USA

[2] Department of Wildlife and Fisheries Sciences, Texas A&M University, 2258 TAMU, College Station, TX 77843-2258, USA

[3] Texas A&M Forest Service, 2585 TAMU, College Station, TX 77843-2585, USA

[*] These authors contributed equally

Introduction

Geographic Seed Source Study (GSSS) for loblolly pine (*Pinus taeda* L.) was established during 1974-1978 by the Western Gulf Forest Tree Improvement Program (WGFTIP) to improve breeding and deployment zones within the Western Gulf region of the United States. Open-pollinated first-generation selection families were sampled in two series, following N-S (Series I) and E-W (Series II) transects. In both series planting sites were scattered across the studied area. Height and diameter were measured and planted-tree volume calculated at ages 5, 10, 15 and 20.

The climate at the 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).

The recently proposed Universal Response Function (URF) approach for lodgepole pine (*Pinus contorta* Dougl. ex Loud.) populations in the Pacific Northwest (Wang et al. 2010), as applied to loblolly pine, helped better understand the impact of minimum winter temperatures on the N-S transect and precipitation on the E-W transect, however, substantial amount of variation remained unexplained by this method. We propose an approach based on Generalized Linear Model that may be seen as an alternative with the potential to offset a proportion of the variation unexplained by the URF model.

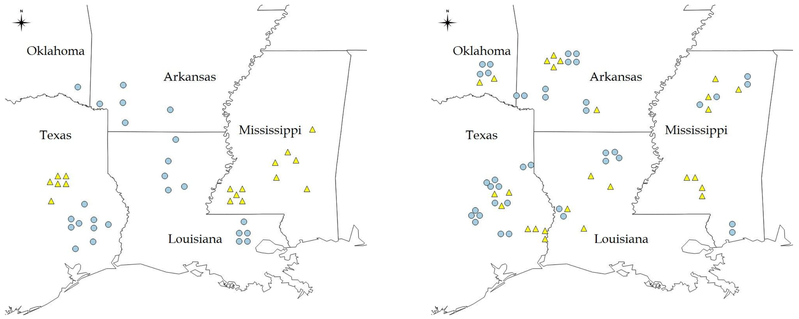

Figure 1. Approximate family (left pane) and test site (right pane) locations for Series I (blue circles) and Series II (yellow triangles) in the WGFTIP Geographic Seed Source Study.

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

- Approach: multinomial logit regression, a type of Generalized Linear Model (GLM)
- Dataset: merged data for Series I and II
- Weather variables extracted from PRISM datasets (http://www.prism.oregonstate.edu/)
  - 1st and 2nd powers
  - historical climate shaping adaptations (genetic factor): data from 1970-2000 (prefix pr- for "provenance")
  - surrogate for future climate (environmental factor): corresponding to a given test site establishment and measurements (prefix ts- for "test site")
- Weather variables selected exhibiting clinal variation and minimal colinearity (Fig. 2):
  - N-S transect: mean minimum temperature of the coldest month (MMIN) and its standard deviation (SDMMIN)
  - E-W transect: summer (June-August) precipitation (PREC) and its coefficient of variation (CVPREC)
- Response: Y_i – volume yield (age 15) ranked into five categories representing the distribution of family performance by test site *i* ($Y_i = K$, K = 1-5)
- Categories (*K*): 5 (very good; 474 obs.), 4 (good; 1,491 obs.), 3 (fair; 2,876 obs.), 2 (poor; 1,788 obs.), and 1 (very poor; 399 obs.)
- Model evaluation: area under curve (AUC)

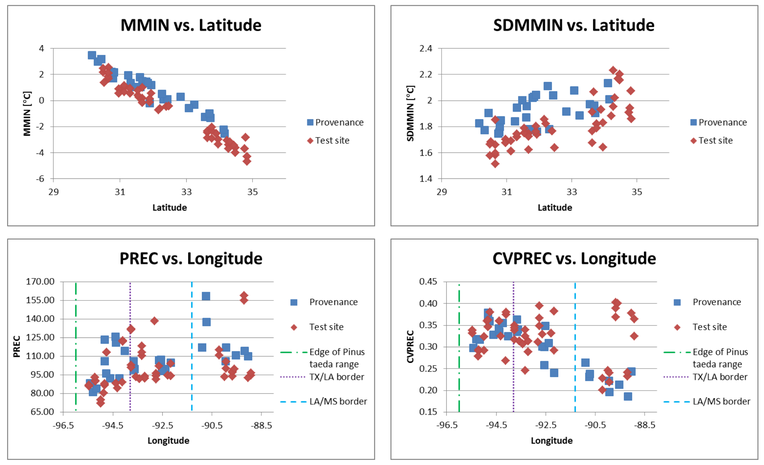

Figure 2. Weather variables showing clinal variation in north-south (MMIN and SDMMIN) and east-west (PREC and CVPREC) transects. Approximate longitudinal locations of the western edge of loblolly pine continuous range, TX/LA border and LA/MS border are shown. The provenance values are based on data from 1970-2000, whereas the test site values are based on timeframes corresponding to a given test site establishment and measurements.

Key findings

- The multinomial logit regression model accurately predicts volume yield category for each family given site climate conditions (AUC = 0.77 - considered "good").
- The model advances the standard URF approach (Wang et al. 2010) by categorizing family performance to filter out the impact of those sources of variation that have confounding effects in the URF method.
- Predicted performance categories are directly amenable to implementation within Decision Support System (DSS)

Table 1. Results of multinomial logit regression analysis predicting loblolly pine volume based on provenance and test site climate. Model AUC = 0.77. The reliability of the model is considered good for 0.75 < AUC ≤ 0.92. For each category *K*=1-4, the probability $P(Y_i=K)$ is calculated as a function of the parameters listed. Category *K*=5 probability is the remainder after the probabilities for the first four categories are calculated.

Variable	Category 1		Category 2		Category 3		Category 4	
	Estimated coefficient	P-value	Estimated coefficient	P-value	Estimated coefficient	P-value	Estimated coefficient	P-value
Constant	15.08	0.001	-10.41	0.004	-15.56	<0.001	-0.9721	0.798
tsPREC	-0.0748	0.074	0.1153	0.001	0.2877	<0.001	0.2031	<0.001
tsCVPREC	22.98	0.238	131.5	<0.001	107.4	<0.001	35.99	0.012
$tsPREC^2$	0.000505	0.008	-0.00035	0.031	-0.00131	<0.001	-0.00098	<0.001
$tsCVPREC^2$	-51.52	0.101	-235.2	<0.001	-193.1	<0.001	-72.21	0.002
$prPREC^2$	-0.00004	0.060	-0.00008	<0.001	-0.00008	<0.001	-0.00004	0.012
tsMMIN	-0.0465	0.382	-0.4304	<0.001	-0.2149	<0.001	-0.1377	<0.001
prMMIN	-0.7625	<0.001	-0.8156	<0.001	-0.68	<0.001	-0.4397	<0.001
prSDMMIN	-7.444	<0.001	-6.41	<0.001	-5.459	<0.001	-5.802	<0.001
$prMMIN^2$	0.2213	<0.001	0.238	<0.001	0.1701	<0.001	0.1191	0.001

Conclusions

- The multinomial logit regression model is a novel approach to study seed movement
- The method shows potential for direct integration into Decision Support System (DSS)

Reference

Wang T, et al. (2010) Integrating environmental and genetic effects to predict responses of tree populations to climate. Ecological Applications 20:153-163

Acknowledgements

The study was supported by The Pine Integrated Network: Education, Mitigation, and Adaptation project (PINEMAP), a Coordinated Agricultural Project funded by the USDA National Institute of Food and Agriculture, Award #2011-68002-30185. Progeny tests were established, maintained, and measured by the members of the Western Gulf Forest Tree Improvement Program.

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

PINEMAP