MODELING CLIMATE CHANGE EFFECTS ON THE GROWTH OF LOBLOLLY PINE SEED SOURCES IN THE SOUTHEASTERN UNITED STATES

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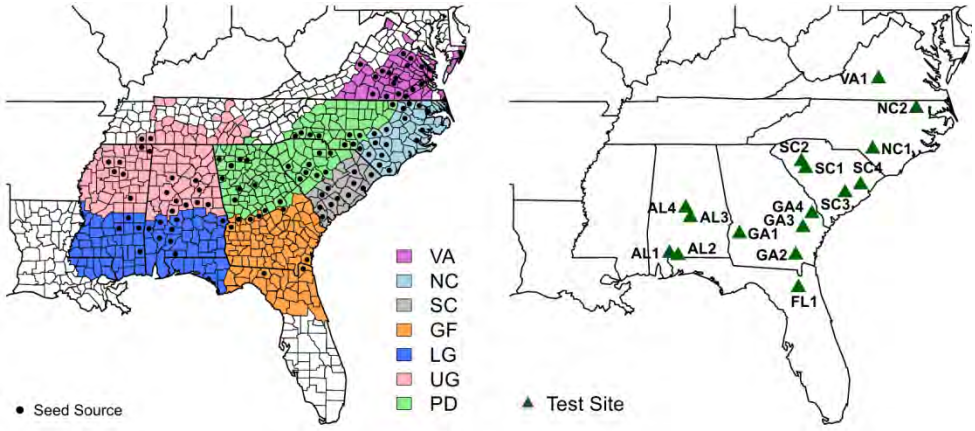
Loblolly pine (*Pinus taeda L.*) is the dominant commercial species in the southeastern United States, with almost 1 billion seedlings produced annually. Genetic improvement through breeding and selection of loblolly pine since the 1950's has greatly improved the productivity, form, and disease resistance in the species. The establishment and analysis of provenance tests for investigating the genetic variation among forest trees has a long tradition in forestry. Such tests were meant to identify superior seed sources for planting at specific locations, but they can also provide valuable information for assessing the response of populations to environmental change. In this work, a statistical model to predict the responses of different seed sources to climate change using climate variables as predictors is presented. The approach integrates both genetic and environmental effects and is meant to overcome the critical limitations of population response function and transfer function methods by making full use of data from provenance trials. The model was developed and tested using data from the Plantation Selection Seed Source Study, a large replicated provenance test of loblolly pine.

Materials and Methods

The Plantation Selection Seed Source Study (PSSSS) was initiated in 1994 by the North Carolina State University Cooperative Tree Improvement Program to determine the patterns of geographic variation in plantation selections and to understand pine genotype interactions with the environment. In total 140 families were originally planted at 25 test locations throughout the Southeastern United States, however only 16 test sites were available for this study (Figure 1b). Figure 1a shows the location of the pine plantations from where the female parents were selected (seed source locations). In the same figure, 7 geographic regions of the natural range of loblolly pine are sketched: Virginia (VA), North Carolina Coastal Plain (NC), South Carolina Coastal Plain (SC), Georgia-Florida Coastal Plain (GF), Lower Gulf Coastal Plain (LG), Upper Gulf Coastal Plain (UG), and Piedmont (PD). Growth measurements (height and diameter at breast height), straightness score, fusiform rust incidence, forking, and survival were taken at tree age 8 years. The climatic variables were estimated using the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system (PRISM Climate Group, Oregon State University). The developed statistical model follows the Universal Response Function (URF) approach (Wang et al. 2010), which consists of a multiple linear regression that integrates both the environmental and genetic effects through climatic variables for the test sites, and climatic and geographic variables for the families.

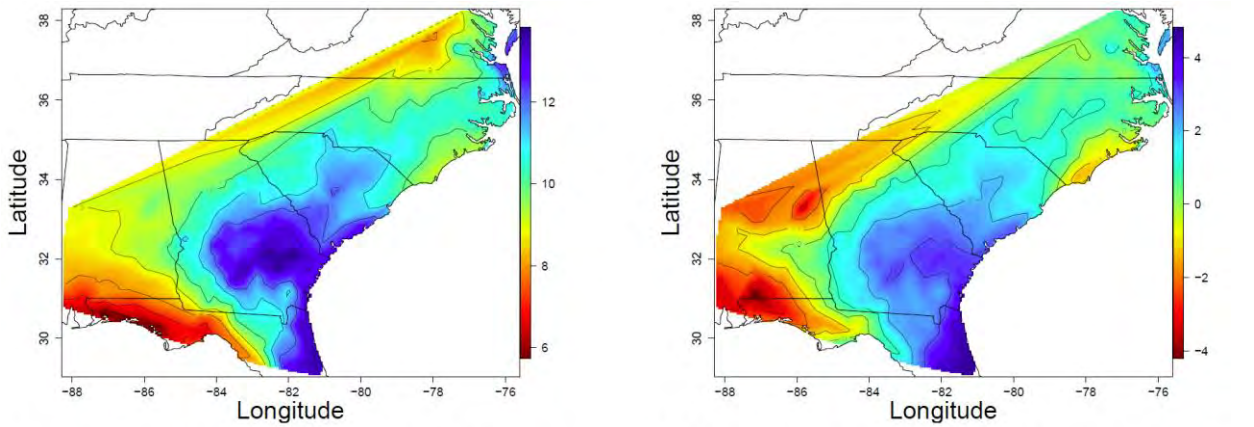


(a) Geographic regions and seed sources. (b) Test site locations.

Figure 1. a) Geographic regions and seed sources of the selected families for the Plantation Selection Seed Source Study (PSSSS). **b)** Test site locations for the PSSSS available for this study.

Results and Discussion

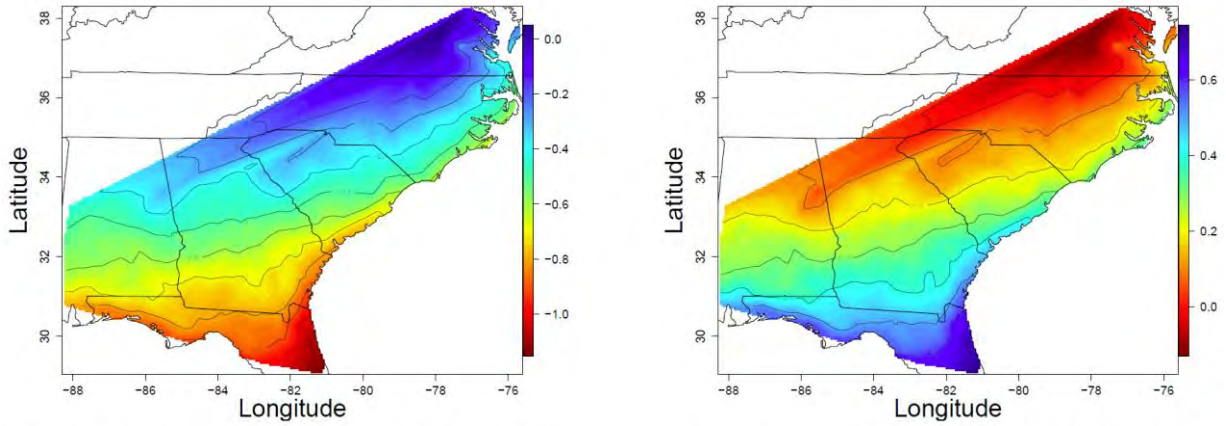
Four examples are presented to illustrate possible applications of the proposed model. A hypothetical climate scenario was created from historical data, assuming a 10% decrease in precipitation, an increase of 1°C in maximum temperatures, and an increase of 1°C in minimum temperatures. The first example consists of predicting the 8-year height growth of loblolly pine growing in their native geographical range (e.g. planting only local seeds across the Southeastern U.S.). The predicted 8-year heights using local seeds are shown in Figure 2a.



(a) Predicted height using Local Seeds. (b) Climate change effect using Local Seeds.

Figure 2. a) Model predictions for height (meters) at age 8 years using loblolly pine local seeds across the Southeastern U.S. for a hypothetical future scenario with 10% decrease in precipitation, an increase of 1°C in maximum temperatures, and an increase of 1°C in minimum temperatures, relative to historical average values. **b)** Difference of predicted height under the simulated climate scenario and current climate using loblolly pine local seeds.

The difference of predicted height under the hypothetical climate change scenario and the current climate using local seeds (Figure 2b) measures the effect of the simulated climate change scenario on the growth of these sources across the Southeastern United States. The Georgia-Florida coastal plain and South Carolina coastal plain regions exhibit the highest differences in growth relative to the current climate. It is interesting to note that local seed sources are predicted to perform much more poorly in the western part of the region under this climate scenario compared to its performance today. Figure 3a shows the model predictions for the 8-year height deviations from site mean for the same hypothetical climatic future scenario above described using loblolly pine seeds from Virginia (VA) throughout the Southeastern U.S. The blue colors in the predicted heights plot indicate that this seed source will only be superior in the most northern regions under the modeled climate change scenario. The last example corresponds to the 8-year height deviations from site mean using seeds from the Georgia-Florida coastal plain (GF) across the Southeastern U.S (Figure 3b). In this case, the trend is reversed relative to the previous example. The predicted heights plot indicate that this seed source will be superior in the southern regions under the modeled climate change scenario.



(a) Relative performance of VA seeds. (b) Relative performance of GF seeds.

Figure 3. a) Model predictions for 8-year deviations (meters) from site mean using northern seeds from Virginia (VA) for the hypothetical future scenario under consideration. **b)** Model predictions for 8-year deviations from site mean using Georgia-Florida (GF) seeds for the simulated future scenario.

To conclude, the statistical model can be used as a quantitative tool to model the effect of climatic variables on the performance of loblolly pine seed sources. Furthermore, the model could be used to estimate growth potential for a given planting site under a given future climate.

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References

Wang, Tongli, Gregory O'Neill, and Sally Aitken. "Integrating environmental and genetic effects to predict responses of tree population to climate." *Ecological Applications* 20, no. 1 (2010): 153-163