Modeling Climate Effects on the Growth of Loblolly Pine Families

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Research Objectives

Understand the effect of climate variables on the growth of different families of loblolly pine to develop models and guidelines for future breeding and deployment decisions.

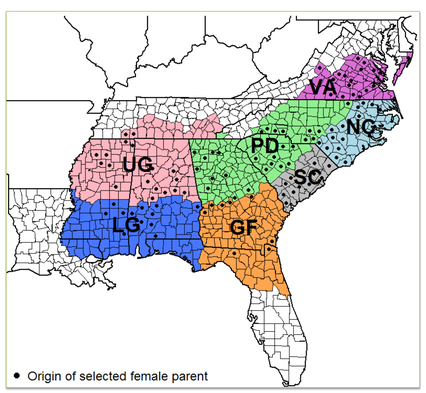
Plantation Selection Seed Source Study

Provenance-progeny test: seedlings from 140 families sampled from 7 geographic regions were planted at 25 test locations throughout the southeastern U.S.

Checklots

The local genetically unimproved checklots were assumed to be adapted to the local climate and used as a reference to measure relative performance.

Geographic regions and locations of the plantations where seeds were collected (black dots).



Methods

A hypothetical climate scenario was created from historical data assuming that future climate conditions would be the same as the average of the last 20 years.

Climate Variables

The climate variables (Yearly Average) of the test sites were estimated using the PRISM climate mapping system

- **PPT**$_i$: Total precipitation of the *i*-th site.
- **TMIN**$_i$ Minimum temperature of the *i*-th site.
- **TMAX**$_i$: Maximum temperature of the *i*-th site.

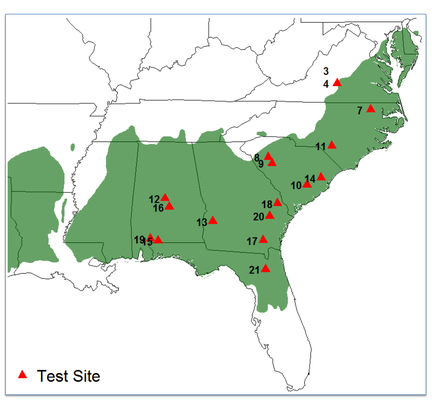
Statistical Model

Multiple linear regression was used to model the scaled deviations as function of climate variables.

$$Z_{ikl} = \beta_0 + \beta_1 \mathrm{TMIN}_i + \beta_2 \mathrm{PPT}_i + \beta_3 \mathrm{TMAX}_i + \beta_4 (\mathrm{TMIN}\times\mathrm{PPT})_i + \beta_5 (\mathrm{TMIN}\times\mathrm{TMAX})_i + \beta_6 (\mathrm{PPT}\times\mathrm{TMAX})_i + E_{ikl}$$

- Z_{ikl} is the scaled deviation.
- β_m for m = 0,…,6 are the regression coefficients.
- TMIN_i, PPT_i, and TMAX_i are the climate variables.
- E_{ikl} is a random error term.

Test site locations and natural range of loblolly pine in the east of Mississippi river (green shadow)

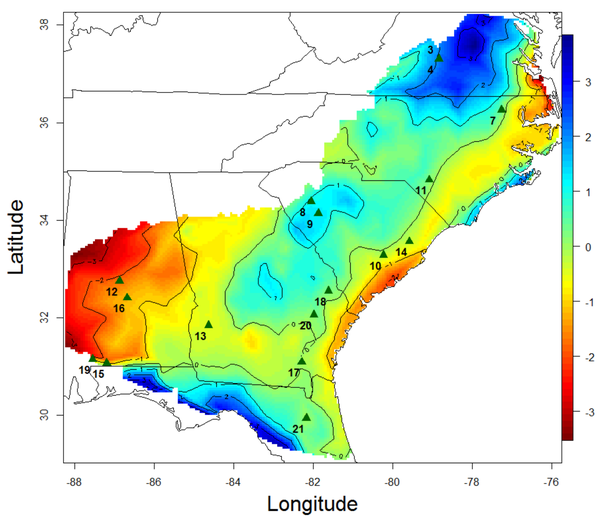


Results

Statistical model for 8-year relative performance of pine family # 119. The model explained about 55% of the observed total variation.

Variable	Estimate	Std. Error	Pr(> | t |)
Intercept	0.05	0.04	0.246
TMIN	-32.6	3.8	< 0.001
PPT	70.3	13.6	< 0.001
TMAX	16.9	3	< 0.001
TMIN × PPT	18.1	1.2	< 0.001
TMIN × TMAX	13.1	3.4	< 0.001
PPT × TMAX	-75.6	14.4	< 0.001

Predicted 8-year scaled deviations from local checklots across the Southeast for family #119 (from VA) under current climate conditions. This family is predicted to perform better than local checklots (blue and green) in the northern regions and in inland South Carolina.

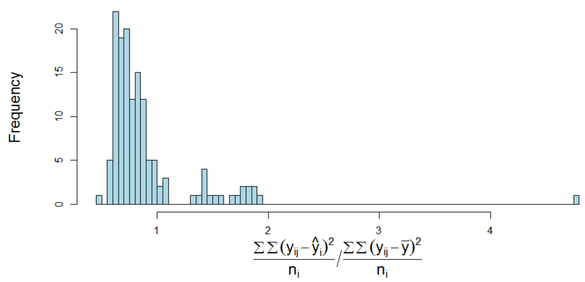


Cross validation

The predictive power of the model was assessed with a K-fold cross validation using test sites to define the folds.

The climate variables given in the Table were used in modeling the performance of all 140 families planted in the PSSSS trials. The models explained between 40% to 60% of the variation in 8-year height for most of the 140 loblolly pine families in the PSSSS trials.

Histogram of the ratio between mean squared errors from cross-validation and total sum of squares. For 116 out of the 140 families the ratio is less than one, showing the stability of the model. Families with ratio >1 were generally planted in fewer sites.



The predictive power of the model is lower for families planted in fewer sites or sites with less variation in climate variables.

Conclusions

The results indicate that climate variables affect pine height growth, and given enough data to train a model, future performance of pine families can be predicted for a given planting site.

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