Modeling the Growth of Loblolly Pine in the Southeastern U.S.

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PINEMAP

Introduction

Provenance tests provide valuable information for assessing the response of populations to environment. In this work we present a statistical model to predict the responses of different loblolly pine seed sources to climate change using climate variables as predictors.

Research Objectives

1. Understand the effect of climate variables on the growth of different seed sources
2. Develop models and guidelines for future breeding and deployment decisions

Plantation Selection Seed Source Study (PSSSS)

- Designed to determine the pattern of geographic variation in loblolly pine and to assess pine genotypes by environment interactions.
- Seedlings from 180 families sampled from 7 geographic seed sources were planted at 25 test locations throughout the southeastern U.S.

***Fig. 1**: Seven seed sources sampled and locations of the plantations where seed were collected (black dots).*

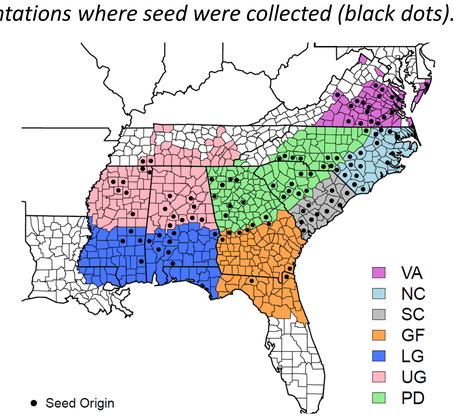
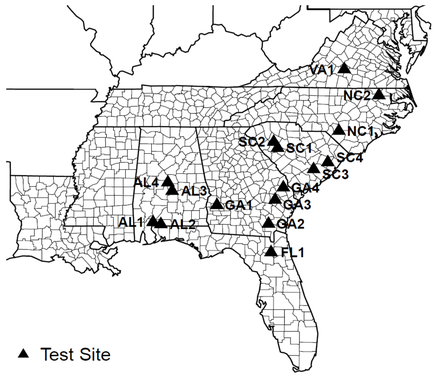


***Fig. 2**: Test Site Locations*



Climate Variables

The following climatic variables obtained from PRISM system were used as predictors to model height growth.
The PRISM mapping system (Parameter-elevation Regressions on Independent Slopes Model) is basically an advanced spatial interpolation that is used to convert point-based historical climate into a gridded raster surface.

Climatic variable

PPTs	Site yearly average total precipitation
TMINs	Site yearly average min temps
TMAXs	Site yearly average max temps
PPTp	Seed source yearly average total precipitation
TMINp	Seed source yearly average min temps
TMAXp	Seed source yearly average max temps

Statistical Model

The general linear model is

$$\mathbf{Y} = \mathbf{X}\beta + \mathbf{e}$$

Y is the n x 1 vector of observations
β is the p x 1 vector of coefficients
X is the n x p design matrix of predictors, including the main effects, quadratic order terms, and linear interactions terms.
e is the n x 1 vector of random errors with zero mean and constant variance.

Since we had many predictors to choose from we explored three different regression models.

OLS Regression

$$\arg\min_{\beta} RSS = \|\mathbf{Y} - \mathbf{X}\beta\|^2 \quad \hat{\beta}_{OLS} = (\mathbf{X}^{\mathbf{T}}\mathbf{X})^{-1}\mathbf{X}^{\mathbf{T}}\mathbf{Y}$$

Ridge Regression

$$\arg\min_{\beta} PRSS = \|\mathbf{Y} - \mathbf{X}\beta\|^2 + \lambda \sum_{i=1}^{p} \beta_i^2$$

$$\hat{\beta}_R = (\mathbf{X}^{\mathbf{T}}\mathbf{X} + \lambda \mathbf{I}_p)^{-1}\mathbf{X}^{\mathbf{T}}\mathbf{Y}$$

LASSO

$$\arg\min_{\beta} PRSS = \|\mathbf{Y} - \mathbf{X}\beta\|^2 + \lambda \sum_{i=1}^{p} |\beta_i|$$

Results

***Fig. 3**: Height growth response of seven seed sources at 16 sites analyzed. Notice variation among trees (black dots) at a particular site.*

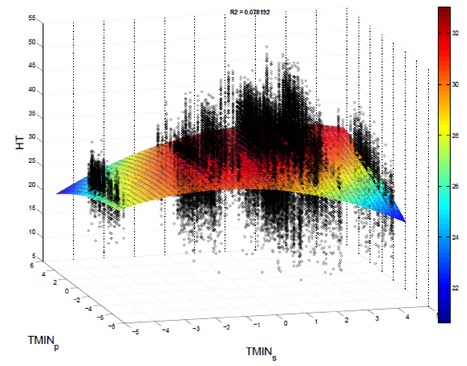
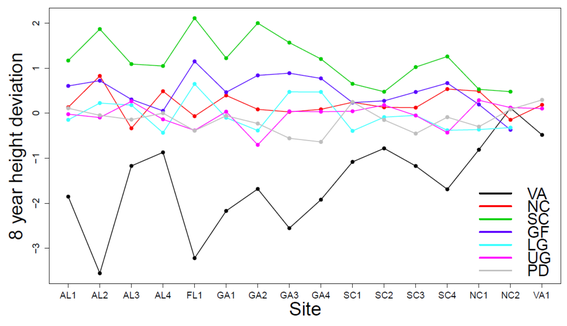


***Fig. 4**: Deviation of seed source height means from site means. VA seed source performed poorly compared to other seed sources, particularly at the southern sites.*



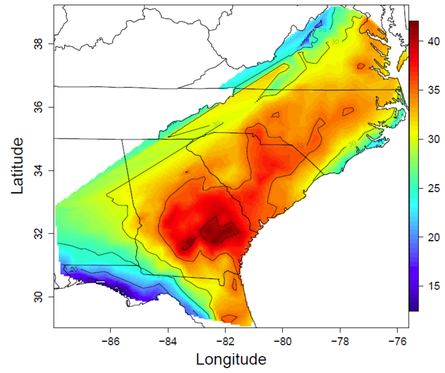
Models fit and coefficient estimates

Variable	OLS	RIDGE	LASSO
PPT_s	-47.02	-47.07	-47.34
PPT_s^2	50.66	50.72	51.06
$TMIN_s$	-19.78	-17.17	0.00
$TMIN_s \times TMIN_p$	0.53	0.53	0.54
$TMAX_s$	98.81	94.89	69.97
$TMAX_s^2$	-104.41	-100.61	-75.77
$TMAX_p$	-6.57	-6.60	-6.12
$TMAX_s \times TMAX_p$	10.77	10.81	10.05
$PPT_s \times TMIN_s$	-36.34	-36.47	-37.28
$PPT_p \times TMIN_p$	-3.09	-3.09	-3.06
$TMIN_s \times TMAX_s$	54.71	52.30	36.43
$TMIN_p \times TMAX_s$	3.60	3.60	3.57
$LONG_p^2/LAT_p^2$	-0.44	-0.44	-0.44

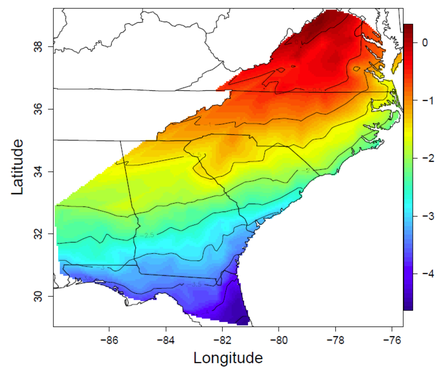
Applications

To illustrate a possible application of the presented model, an hypothetical climate scenario was created from historical data, assuming a 5% decrease in precipitation, 2% increase in maximum temperatures, and an increase of 2 ^{0}C in minimum temperatures.

Predicted height of coastal SC seed source across the Southeast. Notice that coastal SC seed source is expected to perform well across the Southeast but highest growths is expected to be in southern GA.



Predicted performance of VA seeds source (deviation from site means). The blue color in southern GA and northern FL suggest that this source should not be planted southern NC.



Conclusions

Climatic variables can be used to model future performance of pine seed sources for a given planting site under future climate scenarios.

Acknowledgements

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