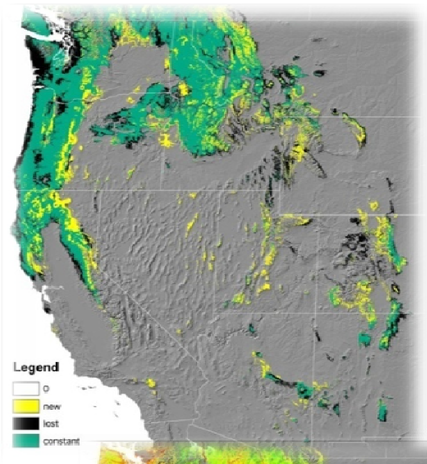
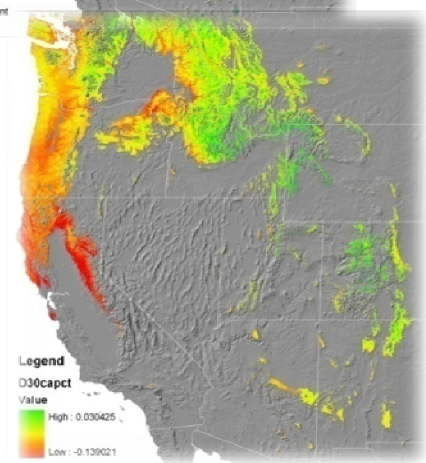




Modeling growth responses to climate change of interior Douglas-fir populations:

a novel analysis of provenance tests data

by Laura P. Leites and Gerald E. Rehfeldt

Involved in this project:
L. Leites, A. Robinson, G. Rehfeldt, J. Marshall, N. Crookston

Goals:

- To present a new approach to the analysis of provenance tests data,
- To discuss the resulting information in the context of climate change effects on the trailing-edge populations.

Outline

- Introduction
- Methods
- Results
- Discussion with bonus: Rehfeldt & Crookston's bioclimate model.

Introduction

Objectives:

- To assess the potential growth response of interior Douglas-fir populations to climate change with scarce available data.

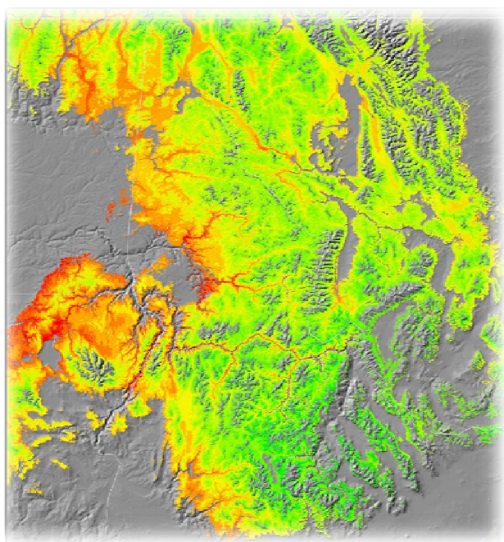
Starting points:

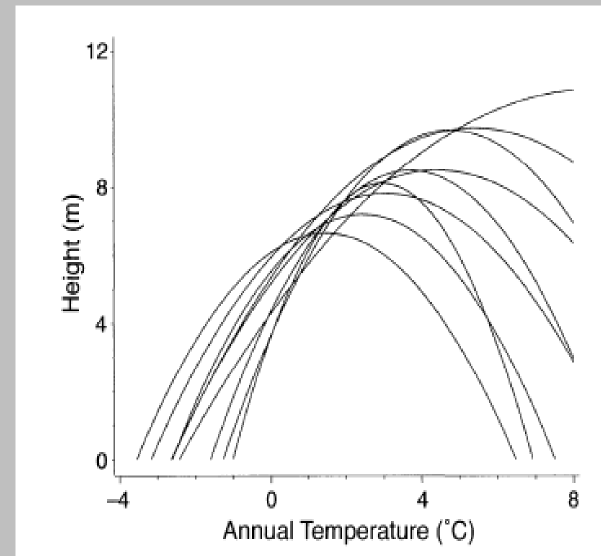
Data: provenances tested in common gardens

Previous studies: Species-level response
Population-level response

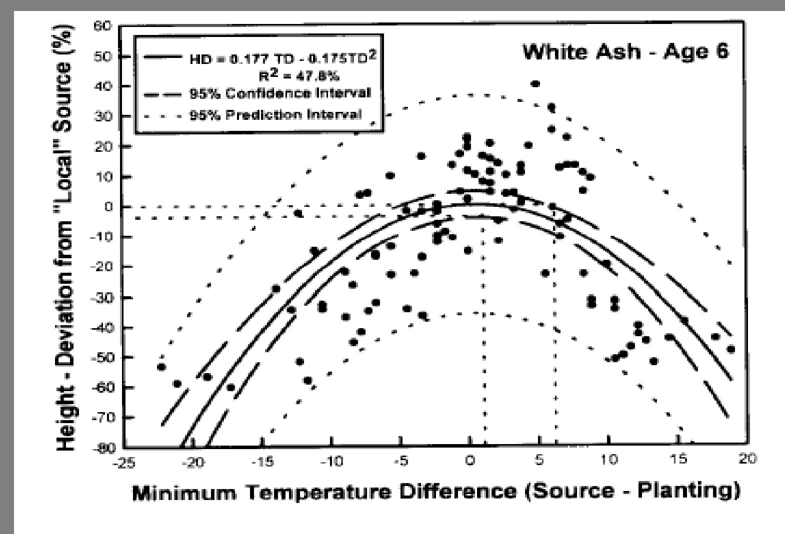
Introduction

- Species-level response?
- Population-level response?
- Both





Rehfeldt et al.1999. Genetics responses to climate in *Pinus contorta*: niche breath, climate change, and reforestation. Ecological Monographs 69(3): 375-407.



Carter.1996. Provenance tests as indicators of growth response to climate change in 10 north temperate tree species. CJFR.26:1089-1095.

Methods - Data

- Wind-pollinated cones were collected from 228 seed sources (hereafter populations).
- Four geographic regions :
  1. North Idaho and Northeast Washington (region 1)
  2. Western Montana (region 2)
  3. Central Idaho (region 3)
  4. Montana and Idaho near the Continental Divide (region 4).
- Populations grouped by regions where tested in 4 studies, each in a different time period.
- 17 populations were planted in more than 1 study.

Methods - Data

- Each study comprised <u>3-4 test locations</u>.
- Each location comprised 1 to 8 planting sites.
- Planting sites had different treatments. Only those with no treatments were used in this analysis: 1 or 2 per location.
- Planting sites comprised 2-3 blocks.
- Populations were planted in row plots of 10-12 seedlings.

Methods - Data

- 3-year population height (HT) was recorded.
- Climatic normals for the period 1961-1990, 18 climate variables.
- Transfer distances (trds): difference between a given climate variable value at the test location and at the population's seed source location.
- 3 to 4 HT- trds pairs per population.

Methods - Analysis

The model - two interdependent areas of focus:

1. Building a model that would address our objective.

2. Applying a statistical tool that would provide the most information and accommodate the hierarchy of the data.

Methods - Analysis

Why a linear mixed-effects model?

a. Quadratic response of growth on climate transfer distance.

b. Draw information from all populations: broad range of transfer distances at the species-level.

c. Keep population-level specificity.

d. Select the effects of interest for predicting new data.

e. Organize unexplained variation and define effects for which we will not know their values when predicting for new data.

Methods – Fixed effects selection:

1) Species-level response:

- 18 climate trds variables were evaluated with a simple linear model of quadratic form: $HT = b_0 + b_1 * trds + b_2 * trds^2 + e$

2) Adding population-level information

- 18 climate at seed source variables were evaluated.
- We used Spearman's correlation rank to select those with the highest linear correlation between HT and the climate variable.

Methods - Analysis

Fixed-effects:

1. One of the 4 trds variables.
2. One of the 3 climate at seed source variables only as a linear effect.
3. A trds*climate at seed source interaction term.

Random-effects:

Study x (Location/ site / block) x (Region / population)

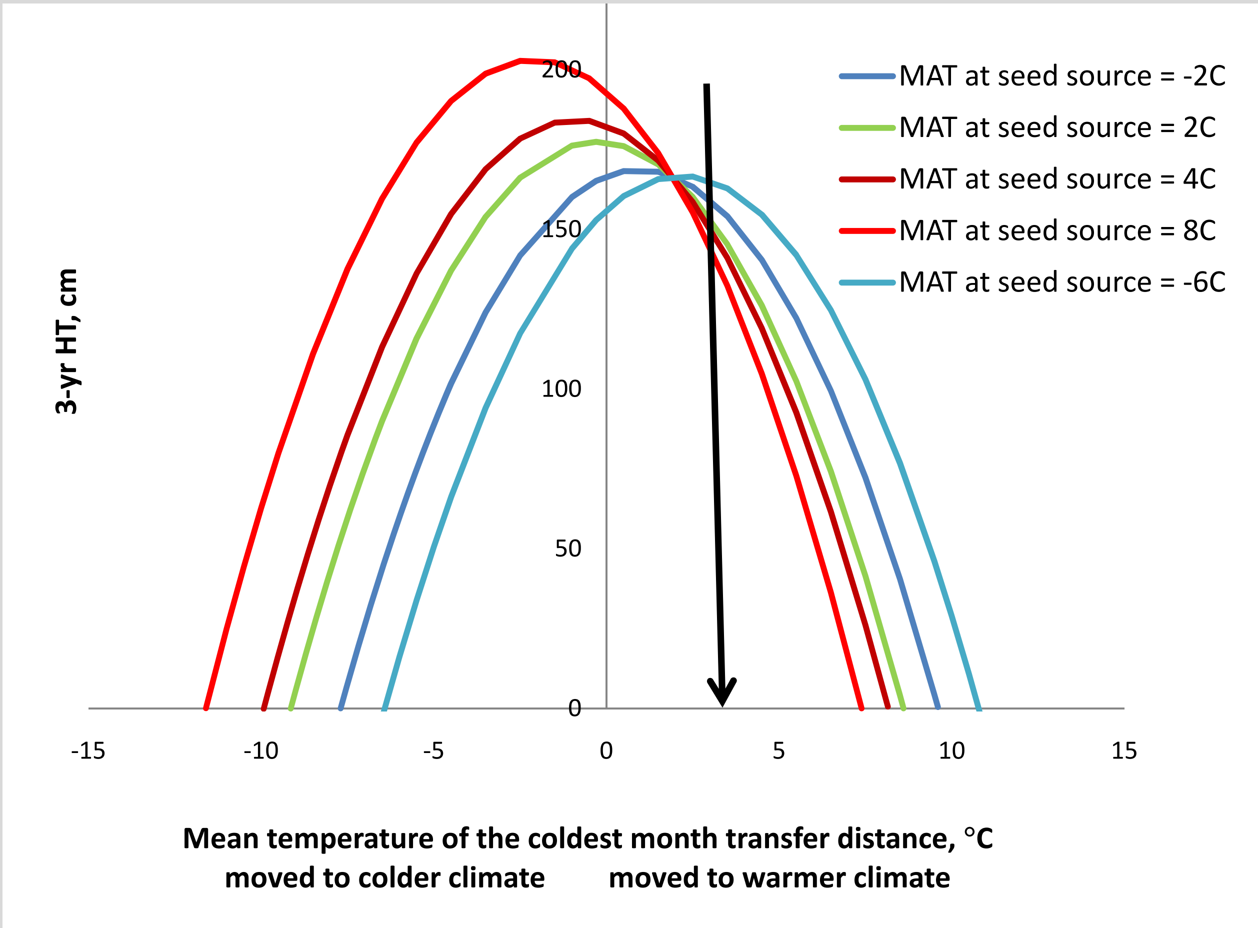
Methods - Analysis

$$y_{j(i(k(lmq)))} = \left(b_0 + u_{1m} + u_{2j(q)} + u_{3i(k(l))} + u_{4k(l)} + u_{5l} + u_{6q}\right) + \left(b_1 + u_{7j}\right)x_{1j(l)} + \left(b_2 + u_{8j}\right)x_{1j(l)}^2 + b_3 x_{2j} + b_4\left(x_{1j(l)} * x_{2j}\right) + \epsilon_{j(i(k(lmq)))}$$

- y = 3-yr height for the j^{th} population in the i^{th} block the k^{th} planting in the l^{th} test site in the m^{th} study and q^{th} geographic region;
- x_1= climate transfer distance for the j^{th} population in the l^{th} test site;
- i = block index;
- j = population index;
- k = planting index;
- l = test site index;
- m = study index;
- q = geographic region index;
- b_0, b_1, and b_2 are parameters;
- u_1 and u_8 are random-effects

Results

HT = 172 + 2.65*MTCM. TRDS - 2.25*MTCM.TRDS^2 + 1.55*MAT.SeedSource - 1.38*MTCM. TRDS*MAT.SeedSource + ϵ



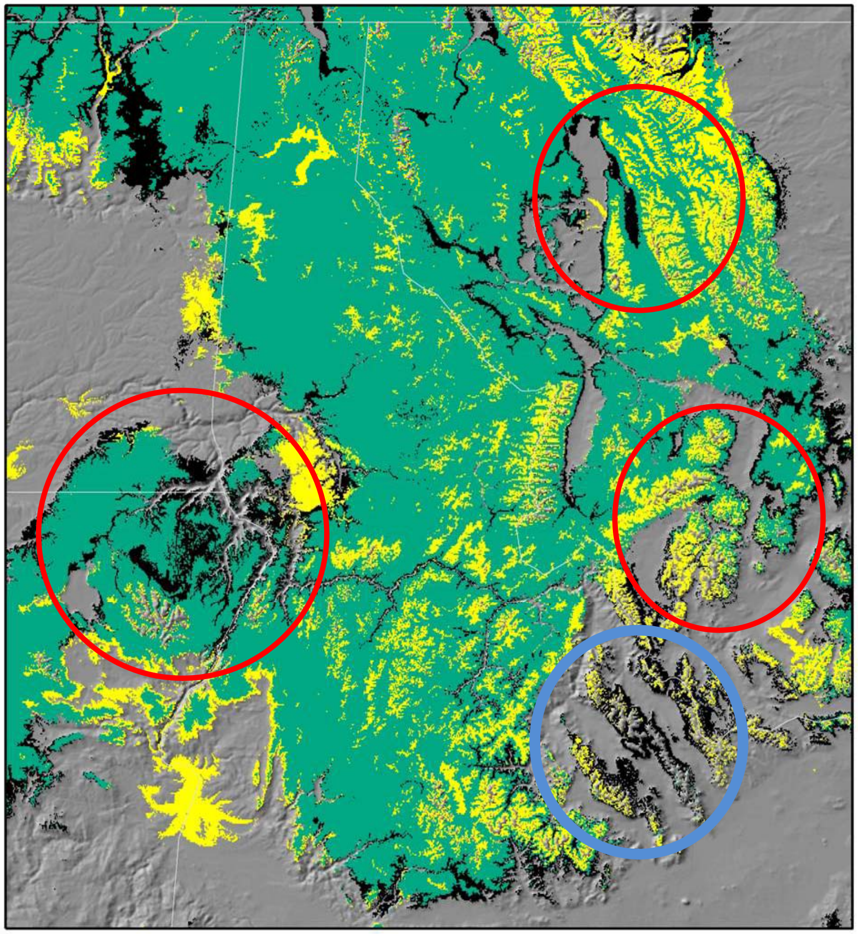
Discussion

Bonus: *Rehfeldt & Crookston's bioclimate model for Douglas-fir.*

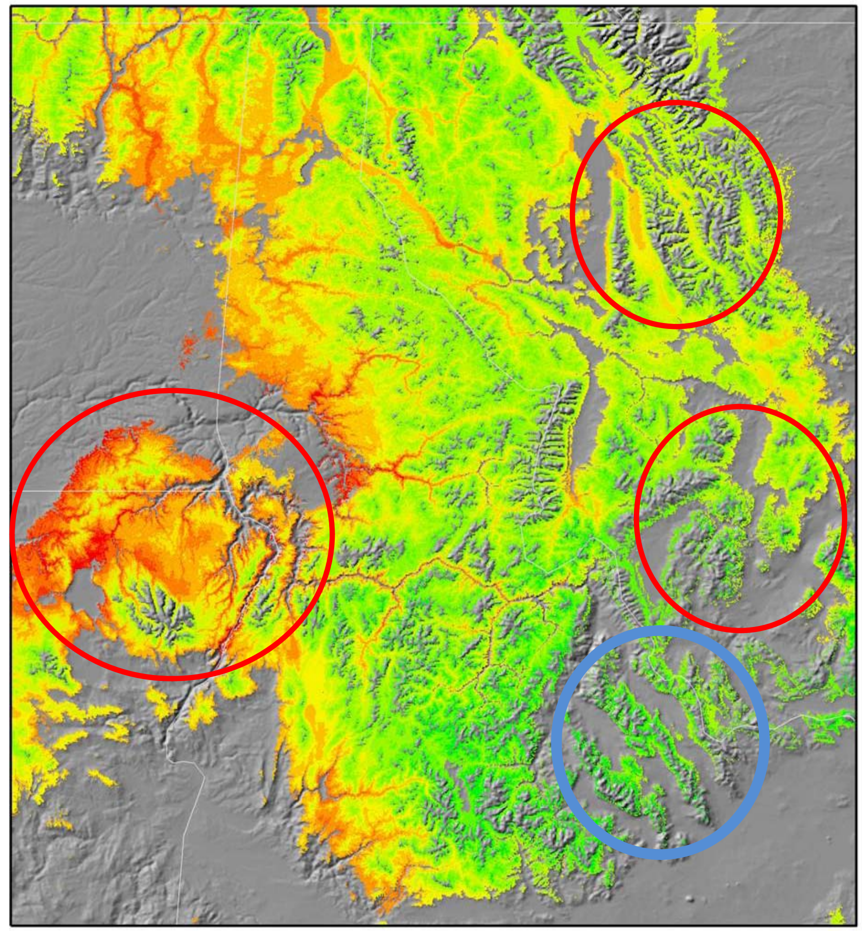
- Objective: determination of Douglas-fir climate profile .
- Data:
  - 18 climate variables,
  - FIA plots: 18,000 plots with Douglas-fir, 100,000 plots without Douglas-fir
- Method: random forests multiple-regression tree.
- Prediction of occurrence of a species under current and future climate.
- Suitability of a site for a given species to be present.

Discussion –
Climate 2030, Canadian GCM, A2 scenario

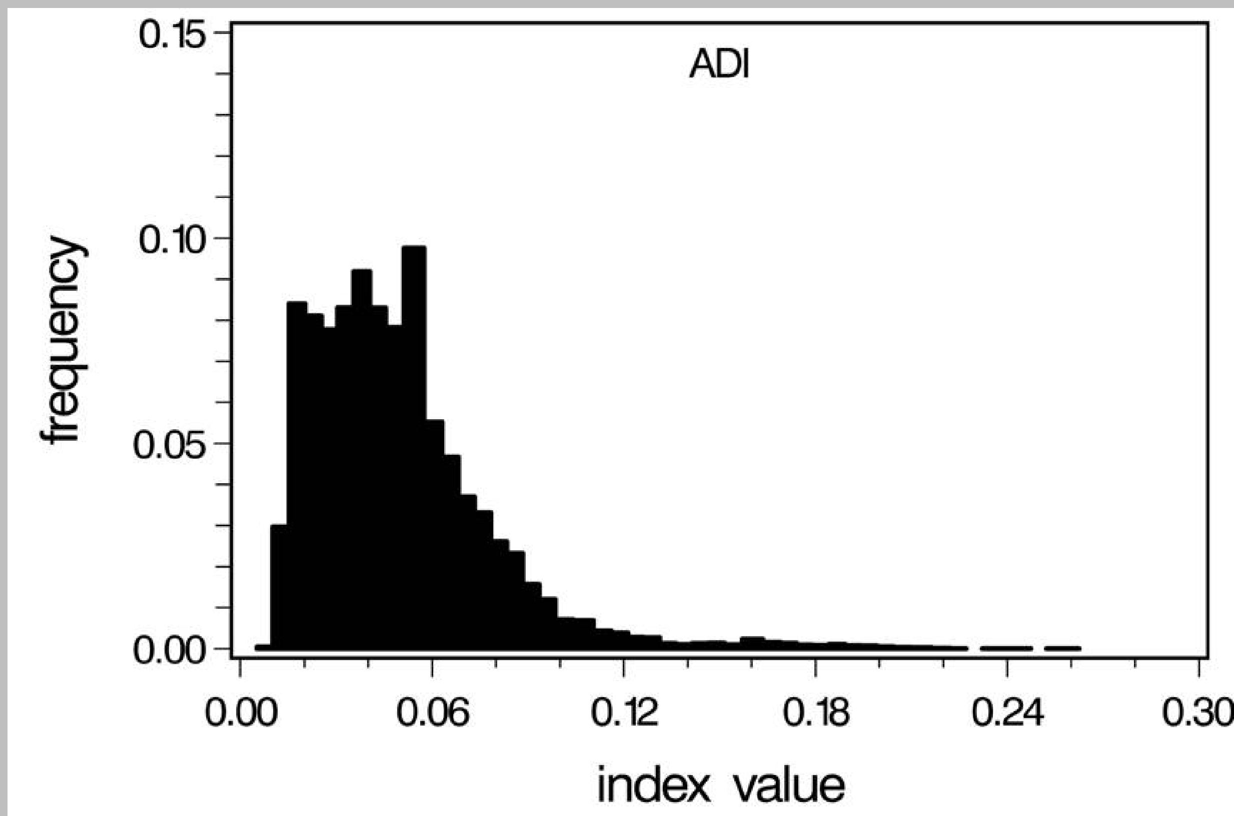
Species-level information



Population-level information



Discussion



ADI = annual dryness index = (sqrt(DegreeDays>5C))/MeanAnnual Precipitation

Final thoughts:

Strengths of the analytical approach:

- Use of historic data:
  - generation of a broad range of transfer distances while accounting for the within-group correlations.
  - species- and population-level response.
- Model readily applicable to populations within the geographic area.

Aspects that need improvement:

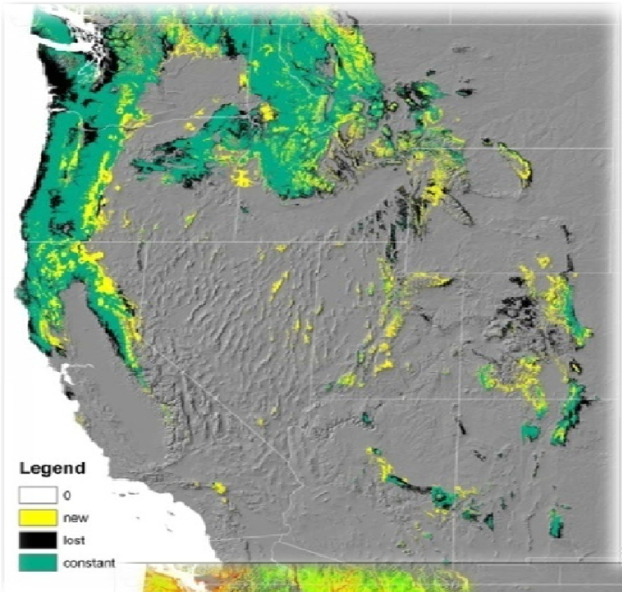
- Large proportion of total variation accounted for by random effects.
- Incorporation of a site productivity measure as a fixed-effect.
- Use of climate data specific for the test years.

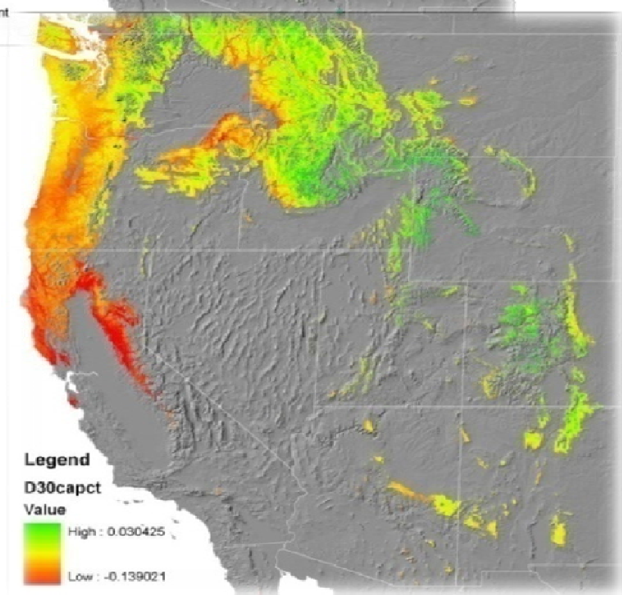
Final thoughts:

Biological implications for interior Douglas-fir:

If climate change scenario and predictions hold.

- Decrease in growth for most populations, mainly those at the xeric-edge.
- Suitability of current xeric-edge environments for DF presence will decrease driven mostly by an increase in dryness.



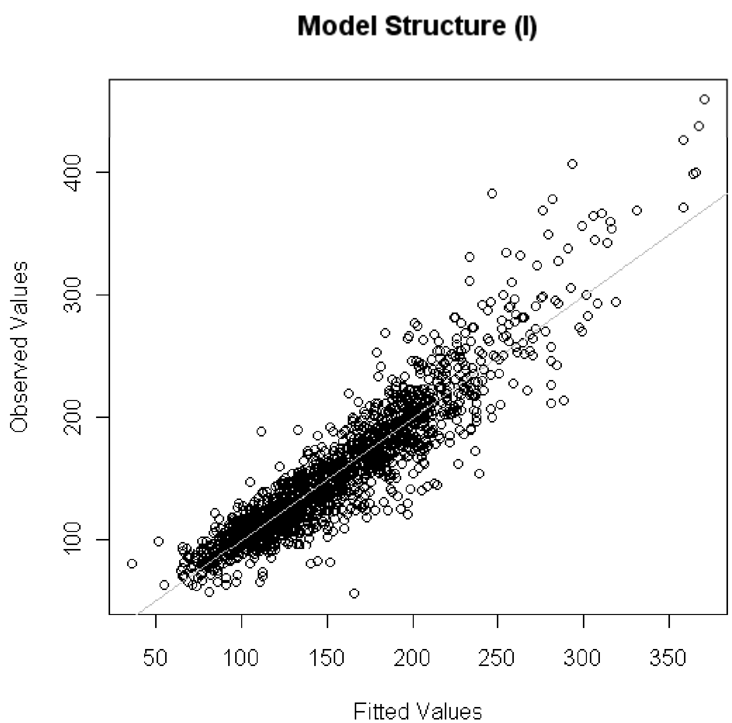


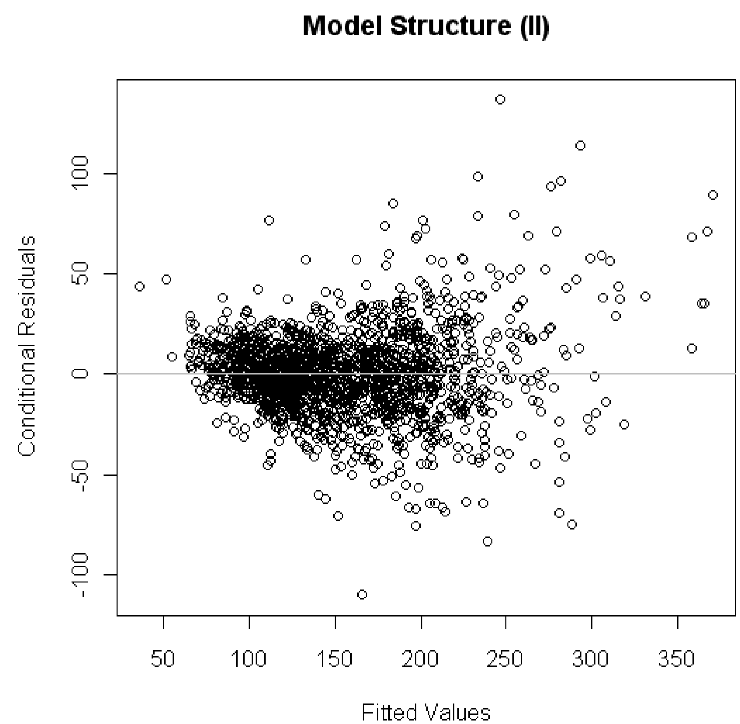
Thanks!

Questions?

Additional slides

Model fit: diagnostic plots





Model summary:

Parameter	Parameter estimate	Confidence intervals (α = 0.95)	
		lower	upper
b0 (intercept)	172.70	78.05	267.34
b1 (MTCM)	1.545	-5.84	8.93
b2 ($MTCM^2$)	-2.253	-2.92	-1.59
b3 (MAT)	2.646	-2.67	7.96
b4 (MTCM*MAT)	-1.379	-2.49	-0.27
SD (u1, study)	55.17		
SD (u2, population)	19.47		
SD (u3, block)	9.97		
SD(u4, planting)	18.03		
SD(u5, test location)	63.42		
SD(u6, region)	38.59		
SD(u7, population linear)	5.49		
SD(u8, population quadratic)	0.56		
SD (Є)	23.94		
Cor(u2, u7)	0.95		
Cor(u2, u8)	-0.14		
Cor(u7, u8)	-0.44		