Updating the Forest Vegetation Simulator with climate response recorded in tree rings

Courtney Giebink, R. Justin DeRose, Mark Castle, John D. Shaw, & Margaret E.K. Evans

THE UNIVERSITY OF ARIZONA®

UA SCIENCE
Laboratory of Tree-Ring Research

Ecology & Evolutionary Biology

FOREST SERVICE
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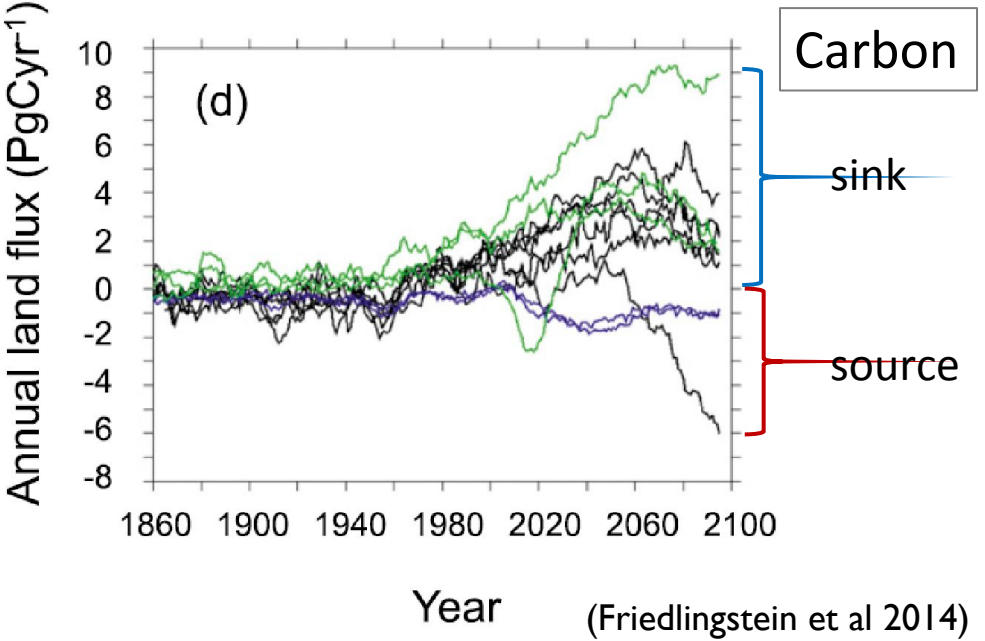
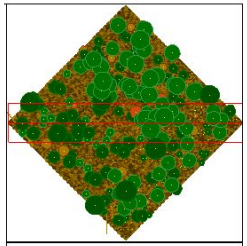
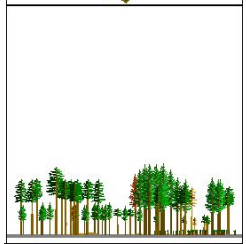
Common goal:
Understanding the future of forests.

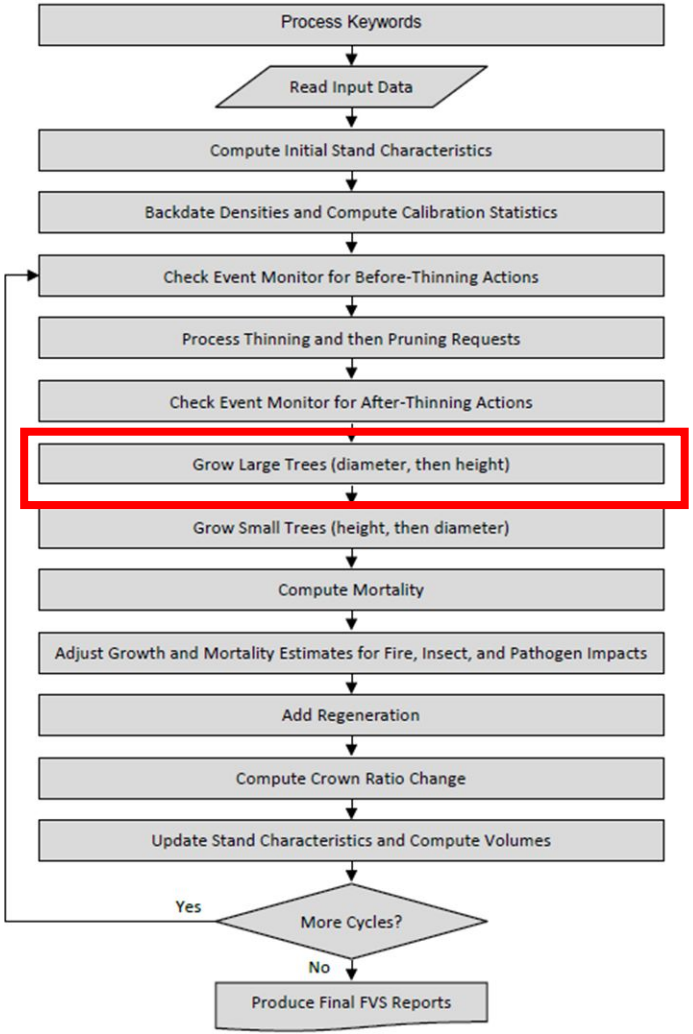


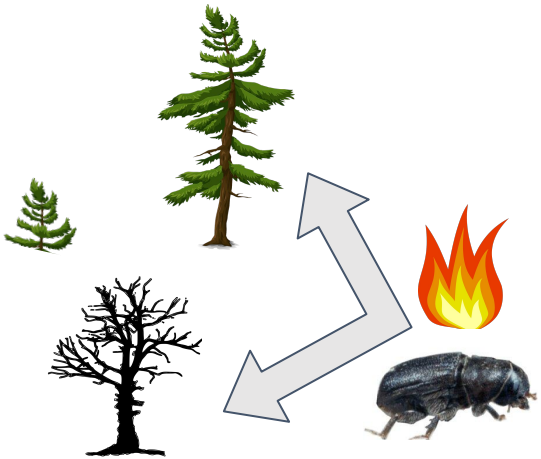
(Friedlingstein et al 2014)

Forest Vegetation Simulator





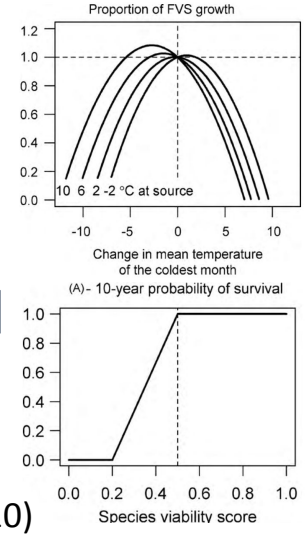




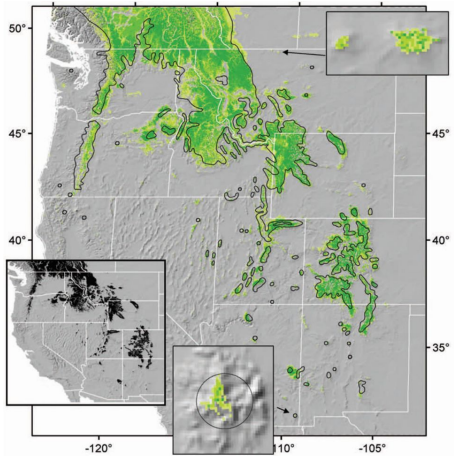
Ring Width = f (Tree, Competition, Site, and **Climate**)

Tree growth

Climate



(Crookston et al. 2010)



(Rehfeldt et al. 2006)

Taking back the increment borer

"This useful little instrument is the invention of the late **Dr. Max Pressler, Professor of Applied Mathematics in the Saxon School of Forestry**...The practical and scientific uses of the instrument are very various…The **effect upon trees of thinning, pruning, or any other arboricultural or silvicultural operation**, can be ascertained by examining the rate of growth a year or two after the trees have been subjected to the new conditions...

...the instrument may be employed for determining the commencement, progress, and conclusion of **growth as affected by species, weather, elevation, exposure**, [etc.]"

(Somerville 1891)

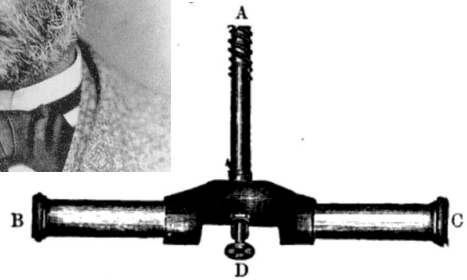
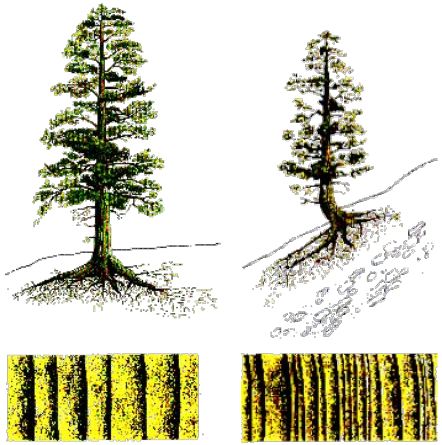


Fig. 6.



Building the Forest Inventory and Analysis Tree-Ring Data Set

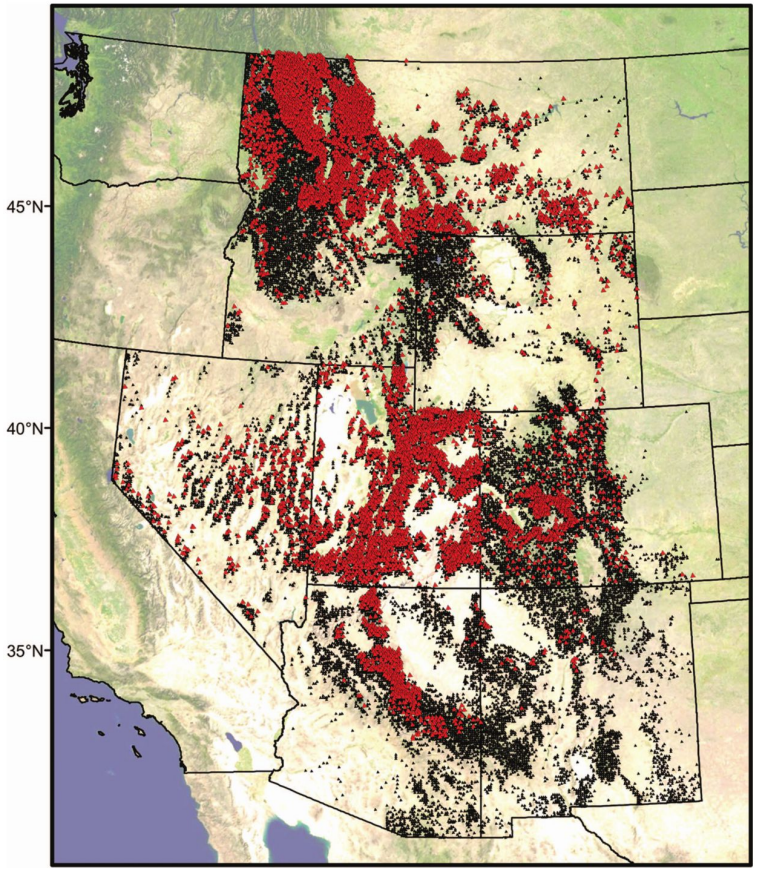
Journal of Forestry
2017 155(4): 283-291

Robert J. DeRose, John D. Shaw, and James N. Long

- Tree-ring data (red)
- FIA plots (black)
  - Metadata

+

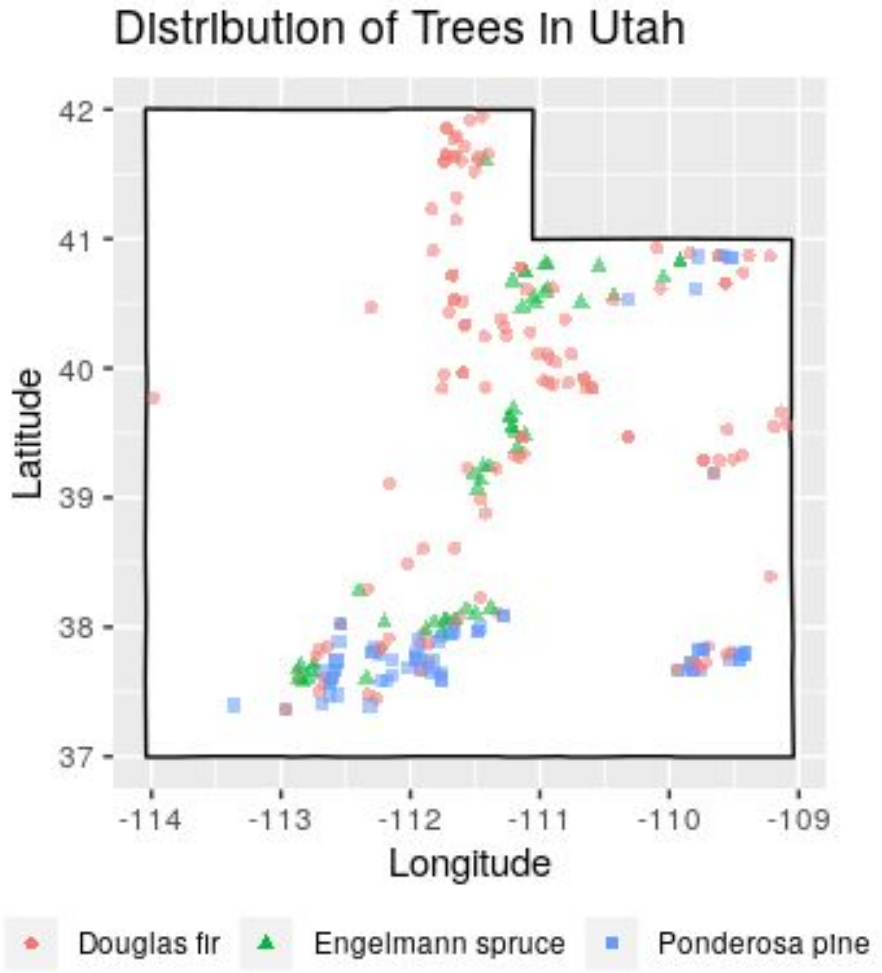
growth = f(tree, competition, site, climate)



DeRose, Shaw and Long 2017

Variant and Species

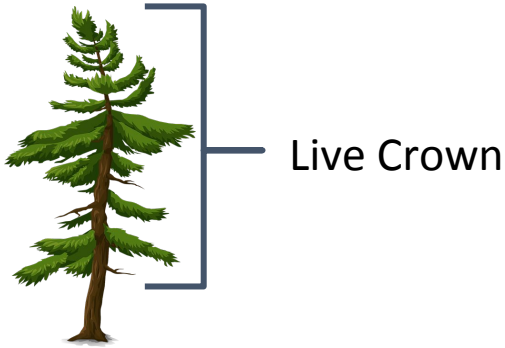
- Utah variant of FVS
- 3 species-specific growth models
  - Douglas fir
  - Ponderosa pine
  - Engelmann spruce



growth = f(tree, competition, site, climate)

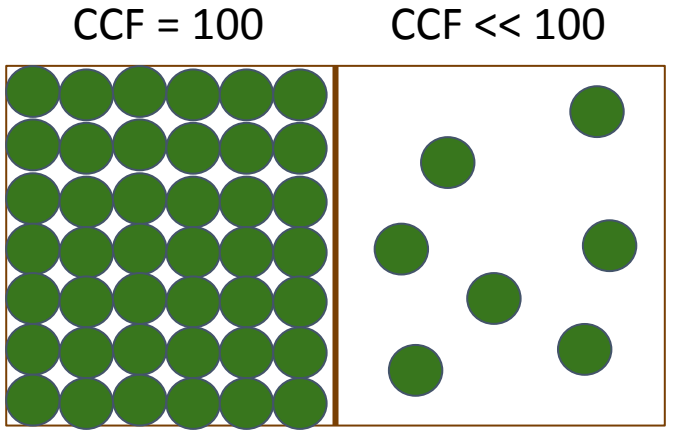
Tree

- ***DBH*** = diameter at breast height
- ***Crown Ratio*** = percentage of a tree's total height that has foliage



Density/competition

- ***BAL*** = basal area of trees larger than subject tree
- ***PCCF*** = subplot crown competition factor
- ***CCF*** = stand crown competition factor



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Tree

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Density/competition

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Site

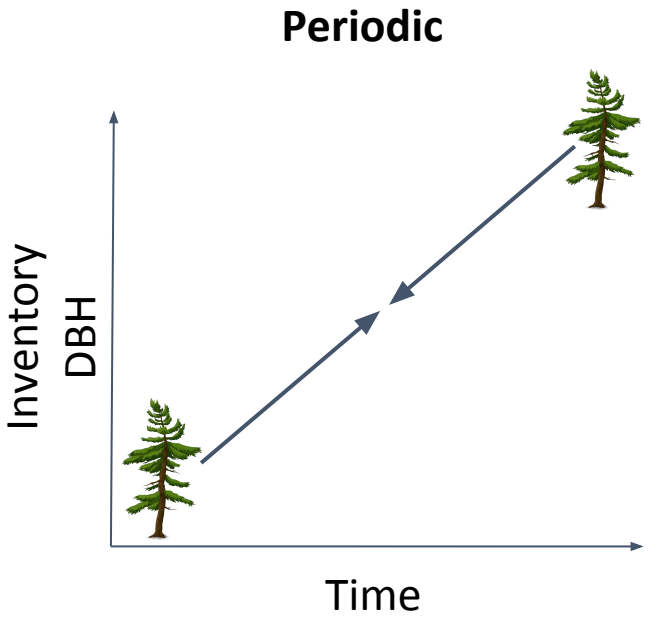
- ***Site index*** = measure of site productivity
- ***Slope*** = degree of incline

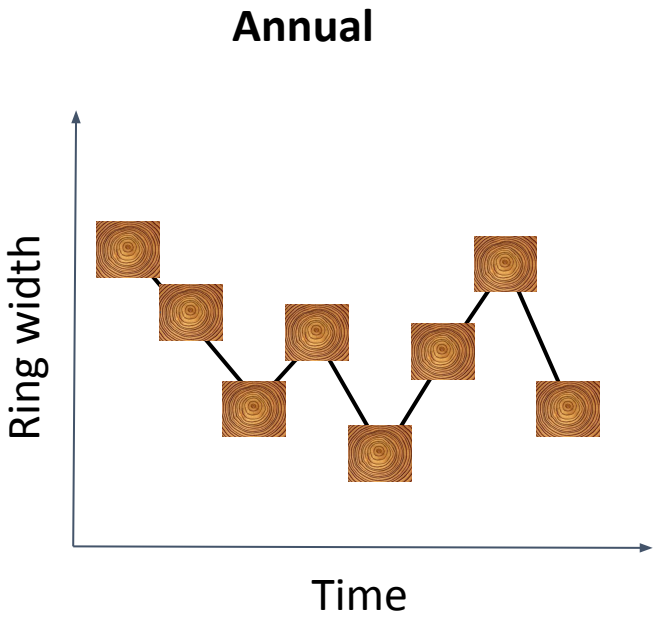
Climate

- ***Precipitation*** = total water year precipitation
- ***Temperature*** = average max monthly temperature

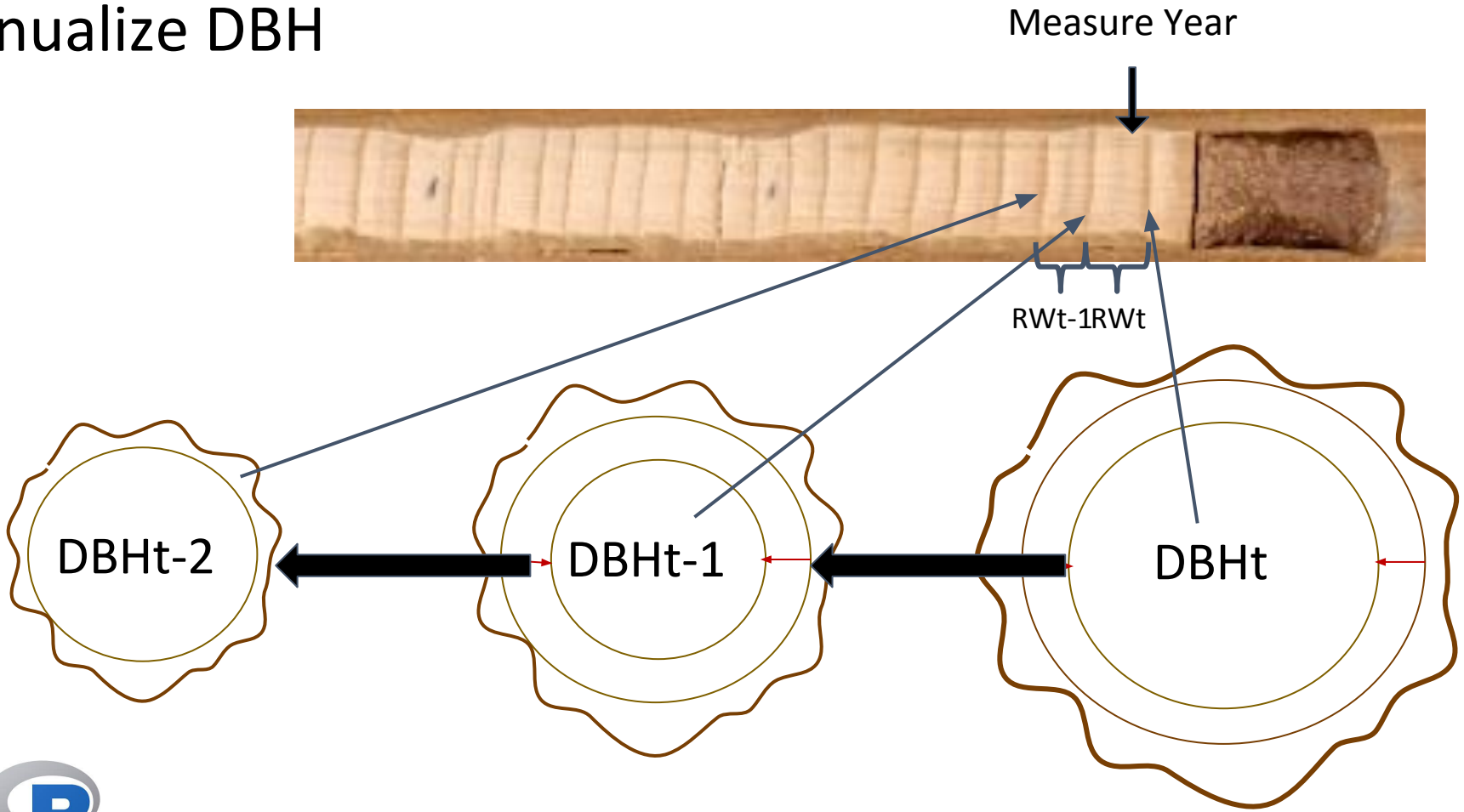
(PRISM Climate Group 2019)

Different temporal scales

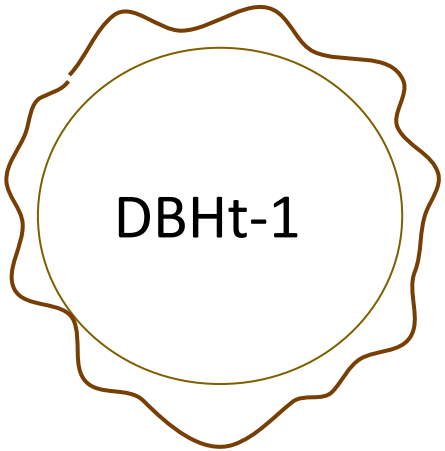




Annualize DBH



Annualize Covariates



CCFt = R1 + (R2 * DBH) + (R3 * DBH^2)

- PCCF
- CCF

BA = 0.005454 * DBH^2

- BAL

SDI = ∑(DBHi/10)^1.6

- Crown Ratio

(Stage 1968, Dixon 1985, & Keyser and Dixon 2018)

Updating the current large-diameter growth model

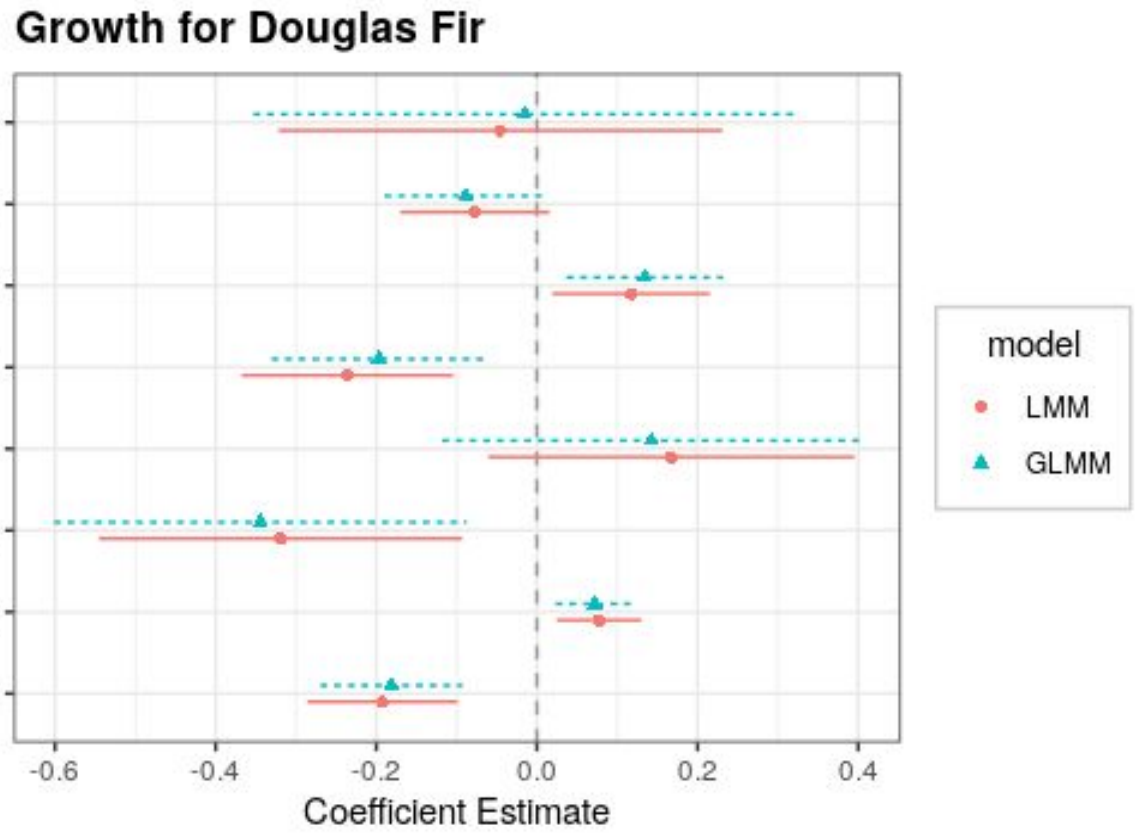
$$\{4.7.1.1\}\quad \ln(DDS) = b_1 + (b_2 * SI) + (b_3 * \sin(ASP - 0.7854) * SL) + (b_4 * \cos(ASP - 0.7854) * SL) + (b_5 * SL) + (b_6 * SL^{\wedge 2}) + (b_7 * \ln(DBH)) + (b_8 * (BAL / 100)) + (b_9 * CR) + (b_{10} * CR^{\wedge 2}) + (b_{11} * DBH^{\wedge 2}) + (b_{12} * PCCF) + (b_{13} * (CCF / 100))$$

- Decadal
- Multiple linear regression
- No climate variables

- Annual
- Mixed effect model
- Climate variables
- Reduce based on collinearity and significance

growth = f(tree, competition, site, climate)

Met?	Expectation
✓	−
	−
	+
✓	−
	+
✓	−
	+
✓	−



growth = f(tree, competition, site, climate)

Met?

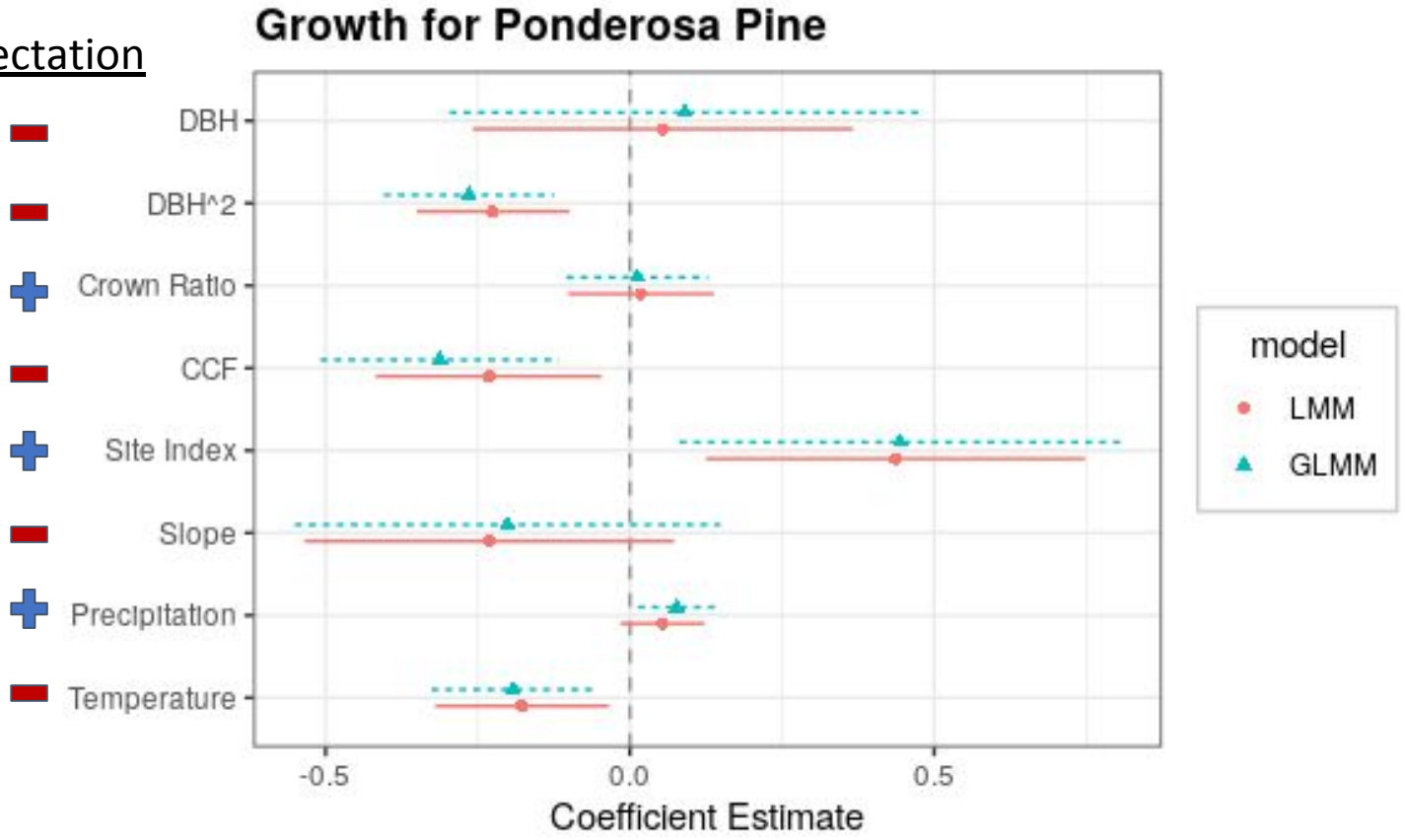
Expectation

✓ ?

✓

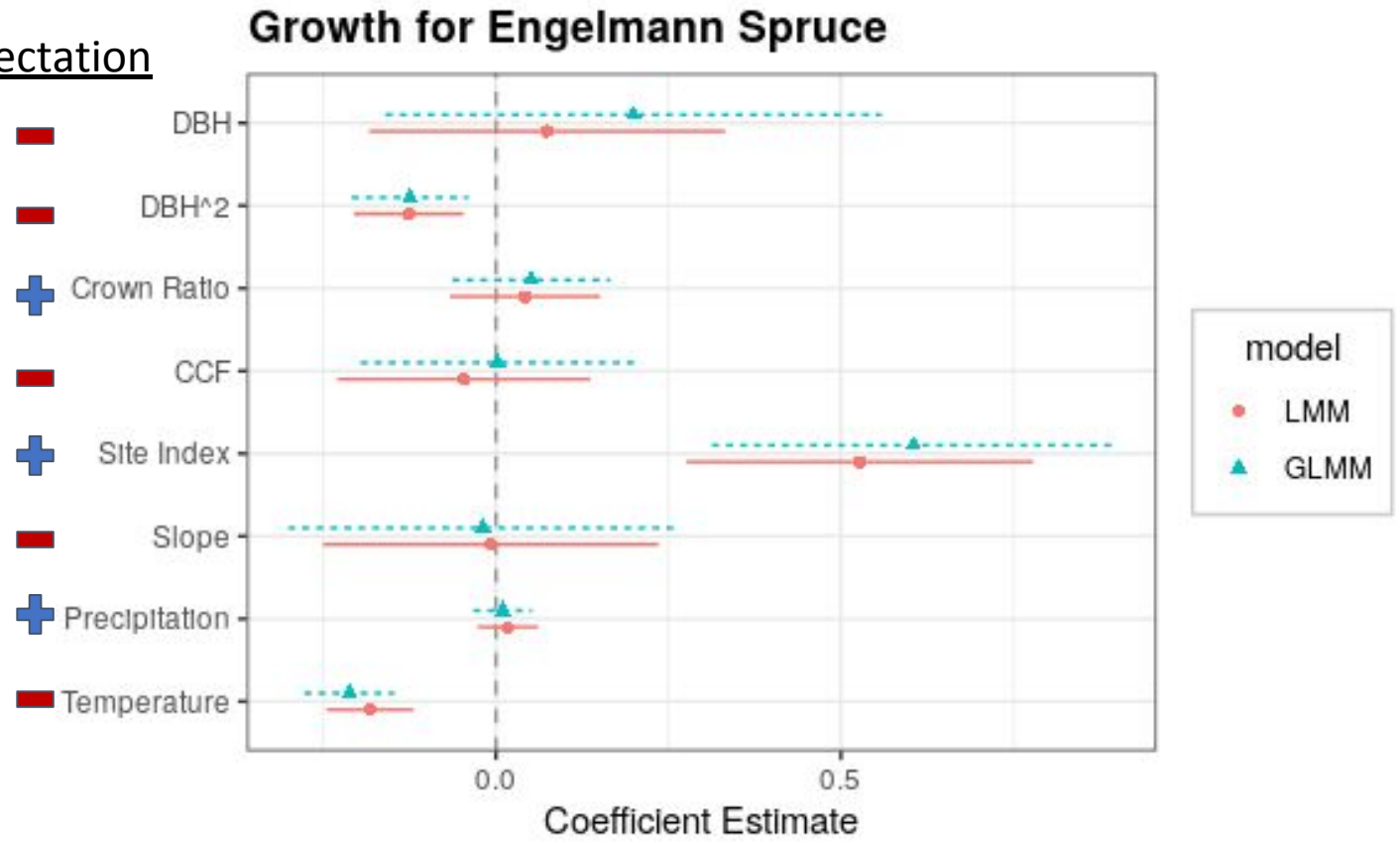
✓

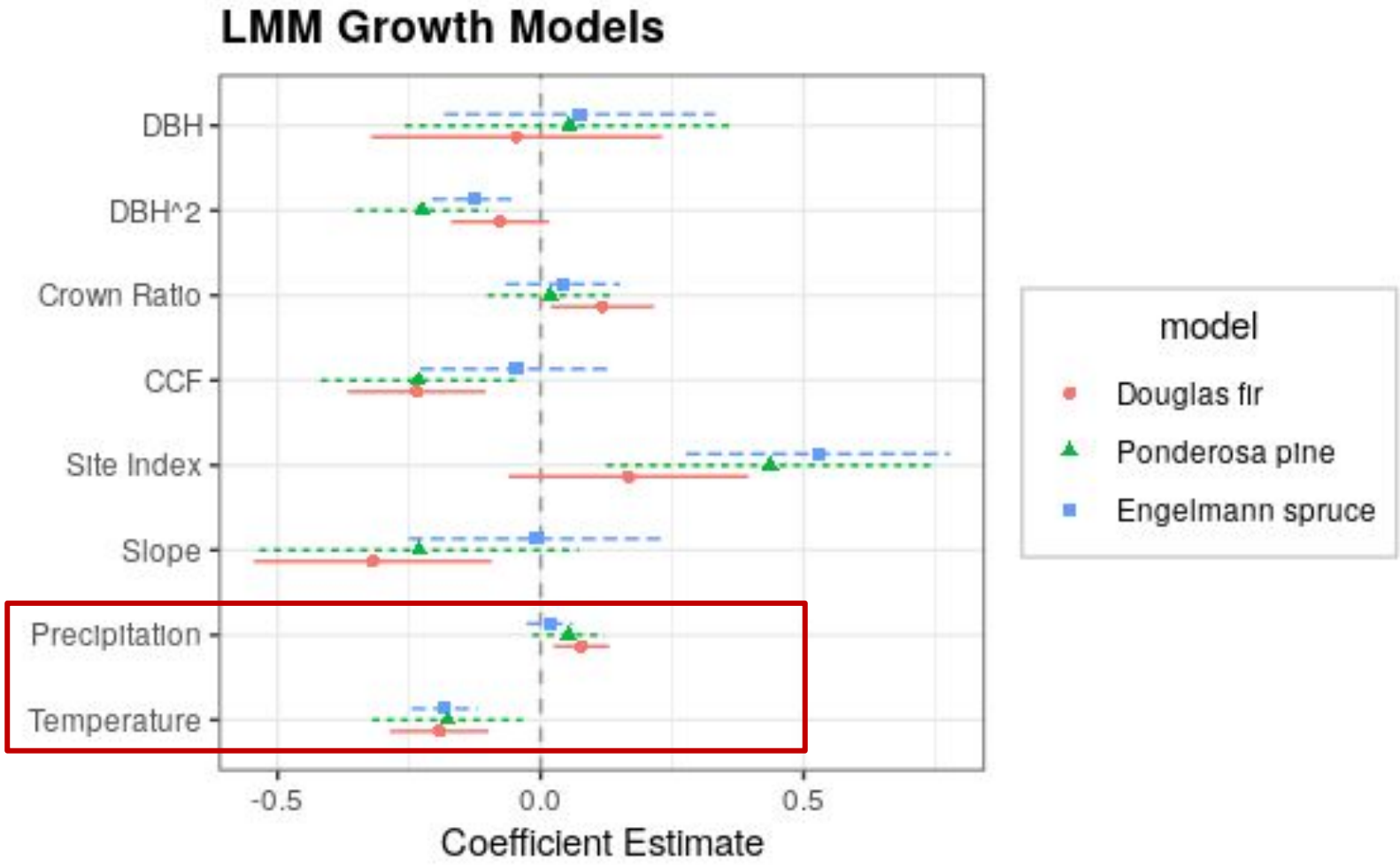
✓



growth = f(tree, competition, site, climate)

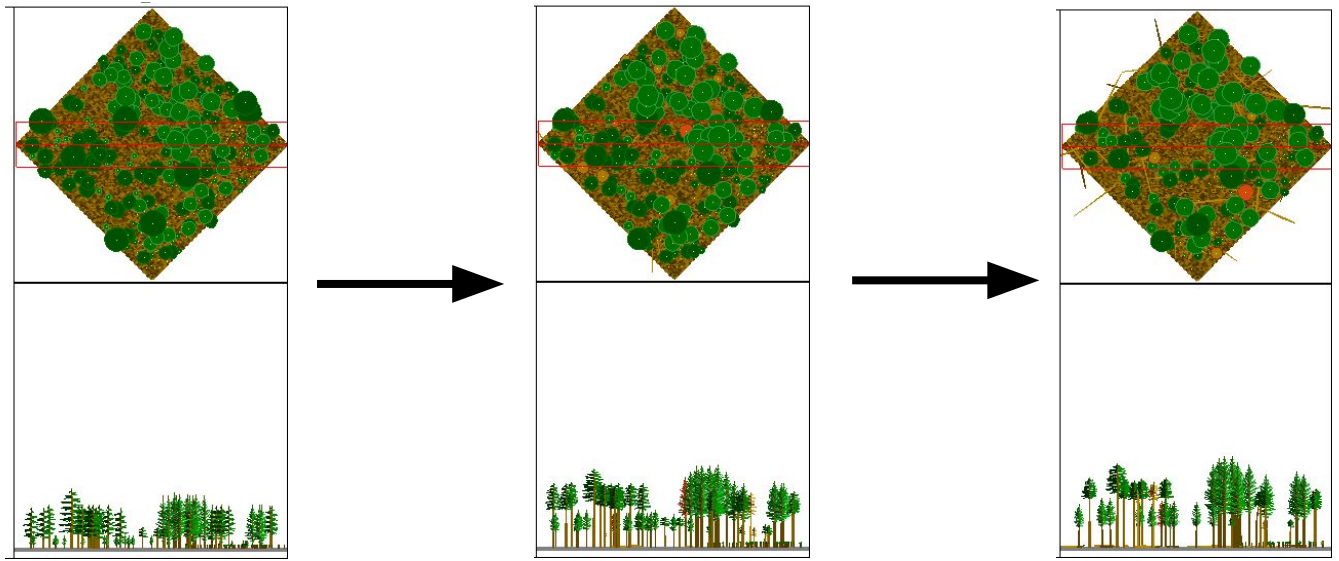
Met?	Expectation
✓ ?	−
?	−
✓ ?	+
✓	−
	+
	−
	+
	−




LMM Growth Models
DBH
DBH^2
Crown Ratio
CCF
Site Index
Slope
Precipitation
Temperature
-0.5
0.0
0.5
Coefficient Estimate
model
Douglas fir
Ponderosa pine
Engelmann spruce

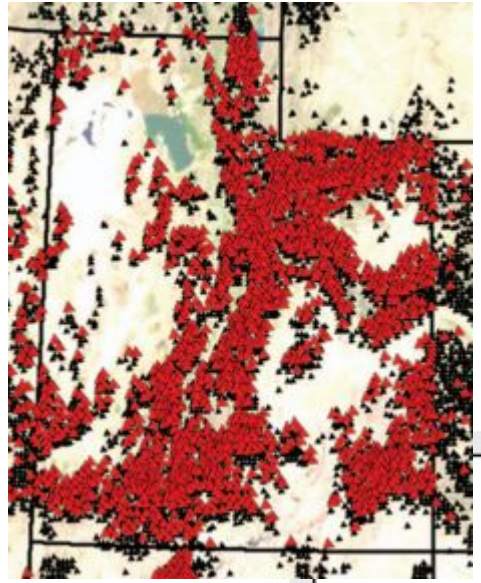
growth = f(tree, competition, site, **climate**)

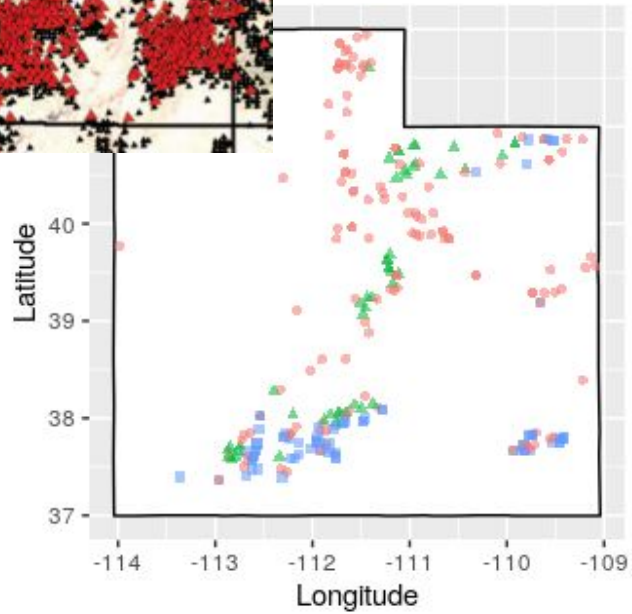
2014 2074 2114



Next Steps...

- Choose final model for each species
- Model validation
- Sensitivity analysis
- Model verification





Thank you!

Evans Lab:
Emily Schultz
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Kelly Heilman

Margaret Evans

Mark Castle

Justin DeRose

John Shaw

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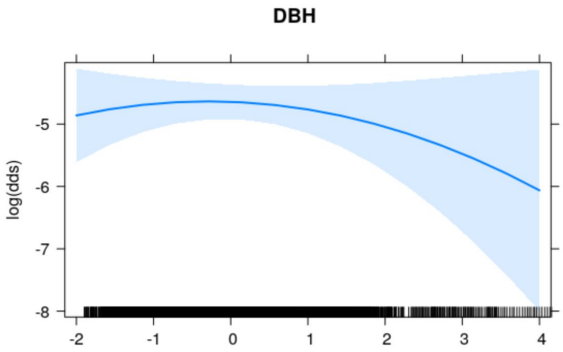
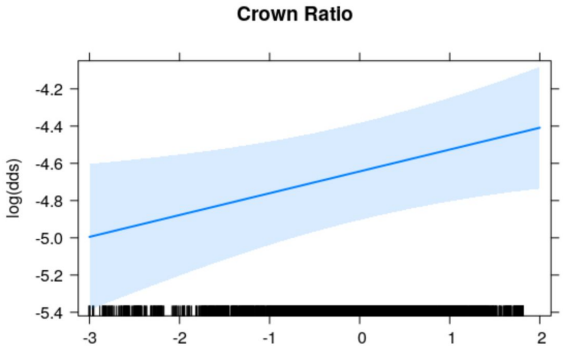
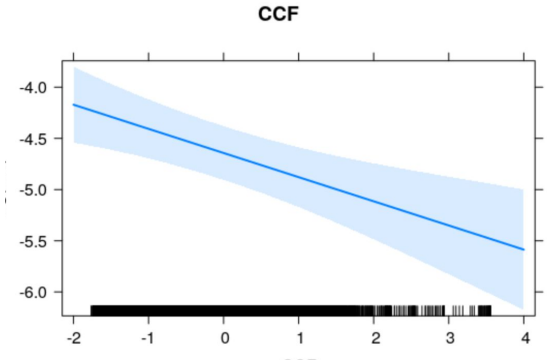
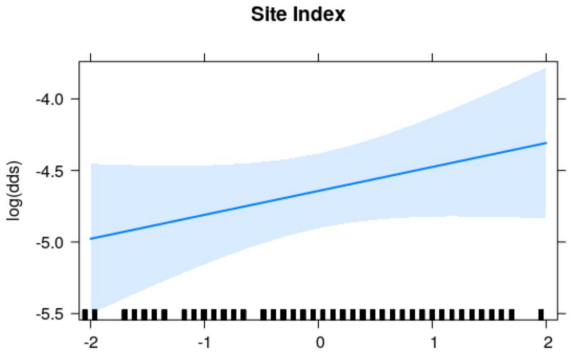
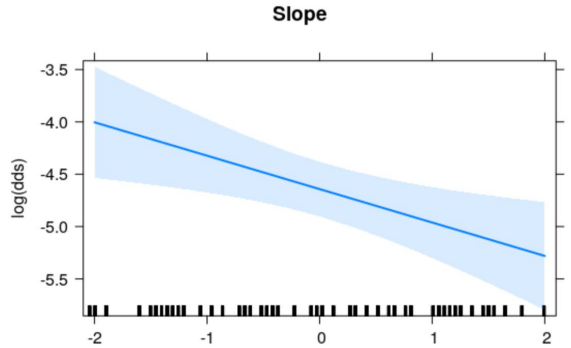
Effects Plots for Douglas fir

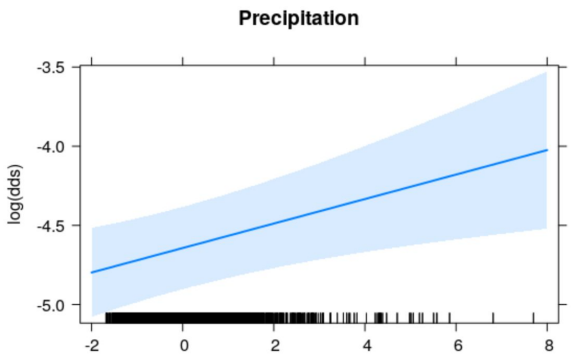


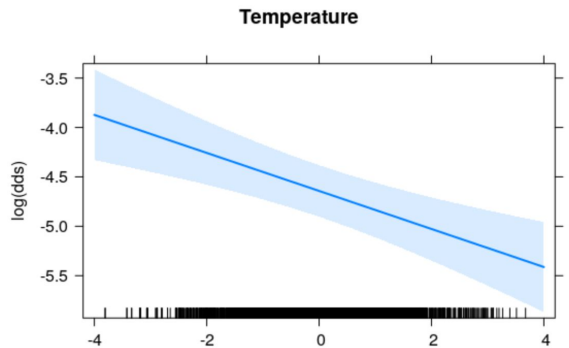




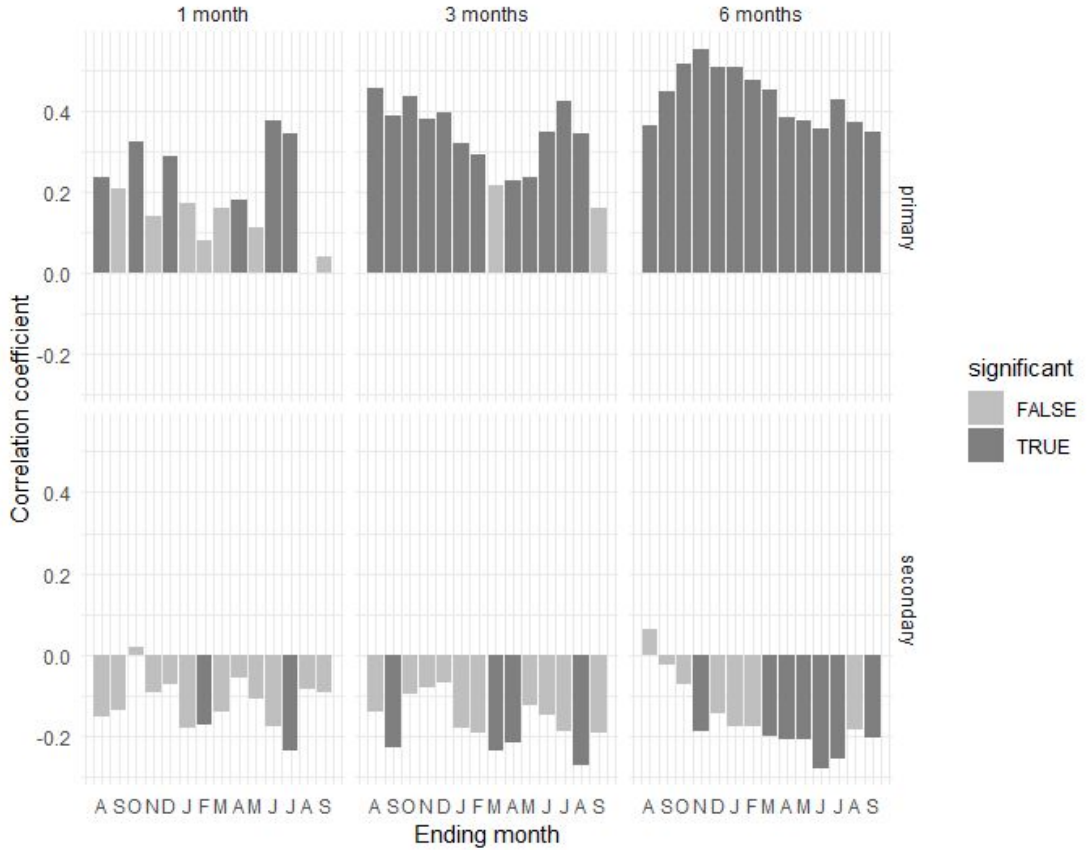


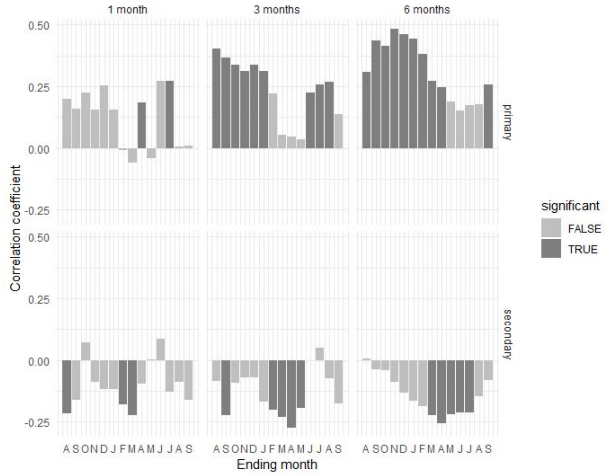


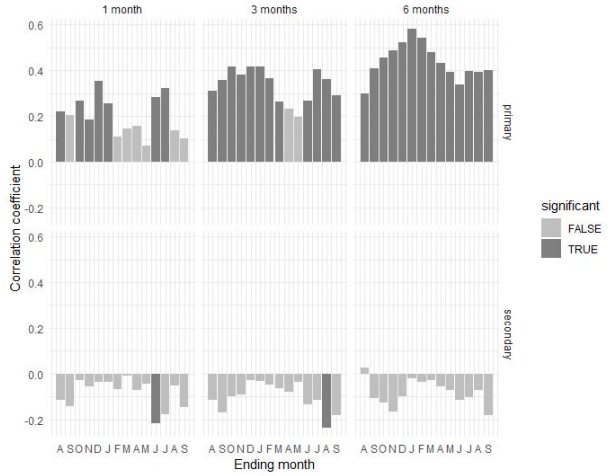




Climate-growth relationships







(Bunn 2008, Zang and Biondi 2015)

Mixed Effect Model

- Non-independent observations
- LMM and GLMM used
  - Linear mixed-effects model (LMM)
  - Generalized linear mixed-effects model (GLMM)
    - Link function