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

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Common goal: Understanding the future of forests.
Forest Vegetation Simulator

1. Process Keywords
2. Read Input Data
3. Compute Initial Stand Characteristics
4. Backdate Densities and Compute Calibration Statistics
5. Check Event Monitor for Before-Thinning Actions
6. Process Thinning and then Pruning Requests
7. Check Event Monitor for After-Thinning Actions
8. **Grow Large Trees (diameter, then height)**
9. Grow Small Trees (height, then diameter)
10. Compute Mortality
11. Adjust Growth and Mortality Estimates for Fire, Insect, and Pathogen Impacts
12. Add Regeneration
13. Compute Crown Ratio Change
14. Update Stand Characteristics and Compute Volumes
15. Yes: More Cycles?
16. No: Produce Final FVS Reports
Tree growth = f (Tree, Competition, Site, and Climate)

Ring Width = f (Tree, Competition, Site, and 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)
Building the Forest Inventory and Analysis
Tree-Ring Data Set

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

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

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

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

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

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

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

(PRISM Climate Group 2019)
Different temporal scales

Periodic

Annual

Inventory
DBH

Ring width

Time

Time
Annualize DBH

Measure Year

DBH_{t-2} \rightarrow DBH_{t-1} \rightarrow DBH_t

RW_{t-1} \rightarrow RW_t
Annualize Covariates

\[ CCF_t = R1 + (R2 \times DBH) + (R3 \times DBH^2) \]

- PCCF
- CCF

\[ BA = 0.005454 \times DBH^2 \]

- BAL

\[ SDI = \sum (DBHi/10)^{1.6} \]

- Crown Ratio

(Stage 1968, Dixon 1985, & Keyser and Dixon 2018)
Updating the current large-diameter growth model

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

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

Met?  Expectation

✓  ?
✓  ✓  ✓  ✓
growth = f(tree, competition, site, climate)
growth = f(tree, competition, site, climate)
Next Steps...

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

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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