Estimating Tree Growth Models from Complex Forest Monitoring Data: Appendix B

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Appendix B: Measurement methods and auditing of explanatory variables (tree size, basal area, insolation, elevation, slope, annual water deficit, soil type)

This appendix details measurement methods for both tree diameter and the other covariates, as well as how these data were audited for outliers or checked against other measurements for accuracy.

Biotic factors: Tree size (diameter) and Competition (basal area)

Much of BFRS was logged and then burned to reduce surface fuels between 1900 and 1913 before the land was given to the University of California, Berkeley. A network of inventory plots (0.04 ha) have been periodically sampled since 1976. All trees 11.4 cm DBH and larger in the plot are tagged and measured with a diameter tape to the nearest 0.1 inch (0.254 cm). Smaller trees (minimum size = 0.254 cm in DBH) are tracked in subplots.

Different plots were measured in different years, giving rise to 20 different combinations of start and end years for intervals (see Appendix A). This has resulted in measurements for some trees having years in common and others not. There are three intervals (four censuses) available for most trees. Altogether, the records span 34 years from 1976 to 2010. See Olson and Helms (1996) for more detail on the sampling design.

We audited our data by identifying trees showing potential errors (negative growth, outliers, and inconsistent species identification or survival status). Records with obvious mistakes were corrected (e.g. erroneous species identification) and in some cases, discarded. Outliers above and below three standard deviations were checked against growth chronologies developed from annual tree rings from BFRS (Battles, unpublished data). We discarded records whose growth exceeded the maximum observed from the chronologies using a moving ten-year window (approximately 1 cm/year increase in DBH). Applying this upper bound effectively removed all trees showing a presumably spurious increase in DBH of more than 10% during the interval. We therefore applied a -10% lower bound to match.

A total of 200 out of 5762 records (these numbers include all species) were corrected, and 76 records were removed as outliers for white fir. Other than removing these records, we kept trees showing negative growth in the dataset to avoid biased parameter estimates and because we explicitly modeled observation error.

We calculated total basal area directly from the inventory data for all species for each plot. We did not have individual tree locations and were therefore unable to use neighborhood techniques (Canham et al. 2006) or spatially correlated random effects (Banerjee and Finley 2007, Finley 2011), but this aggregation of basal area by plot and year is a reasonable way to represent the effect of competition on each plot (Lines et al. 2010).

Abiotic factors: insolation, annual water deficit, topographic slope, elevation, and soil type

We represented light availability using yearly insolation values calculated using ArcGIS 9.3 (solar radiation calculator, ESRI (2011)) from a 1/3 arc second digital elevation model from the USGS Seamless Map Database (USGS 2011). These insolation values were checked for consistency against values calculated from a local model using the Gap Light Analyzer (Frazer et al. 1999), parameterized using measurements from a LiCor 2000 Pyranometer (as in York et al. 2003, 2011). Both absolute and relative (solstice/equinox ratios) measurements were consistent.

Moisture availability was represented using annual water deficit, which incorporates both water supply (precipitation) and evaporative potential (temperature) (Willmott et al. 1985). We used data on monthly precipitation and temperature from the Blodgett weather station and day length (calculated from latitude) to estimate annual water deficit from 1963-2010. From these data, we used AET 1.0 (Gavin 2007) to calculate the annual climatic water deficit using the modified Thornthwaite method.

Elevation was measured from a topographic map to the nearest 10 feet (3.05 m). Slope was measured to the nearest % in the field using a clinometer, averaging uphill and downhill measurements. The only categorical covariate included was soil type, which reflects potential nutrient availability. Five soil types are found at Blodgett and all are reflected in the reserve compartments. (Cohasset: Andesite parent rock with high development; Jocal: metasedimentary parent rock; Holland & Holland-Musick: granodiorite parent with intermediate development, Holland-Bighill: granodiorite with little development.) Cohasset soils are typically more productive than the other types.

Soil type, insolation, elevation, and topographical slope were measured at the plot level; we assume that these do not change significantly from year to year. Annual water deficit was calculated for every year, and basal area was calculated for each plot in each year.

For the analysis, all continuous explanatory variables, including tree DBH (size), were centered (mean subtracted) and scaled (divided by standard deviation) before estimation. This standardization was important to improve mixing of the models. For tree sizes, the mean and standard deviation for standardizing were calculated from all measured sizes used in the analysis, and the additional unmeasured (latent) sizes in the model were then defined on this scale. Resulting parameter estimates related to size (DBH) were unscaled (multiplied by standard deviation of size measurements) to provide better interpretability (see Appendix C for algebra on standardizing and unscaling).

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