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Predicting tree growth from repeat forest surveys using longitudinal models

Repeat surveys of forest trees in permanent plots are key for understanding forest dynamics and the productivity of forests. However, the most common growth models -- based on a single growth interval independent on those around it -- struggle to differentiate between measurement error and true growth, with biologically unlikely negative and very high growth rates a common occurrence. They also fail to incorporate the broader correlation structure from repeat measurement surveys of multiple growth intervals.

To improve estimates of individual growth, we applied a longitudinal hierarchical Bayesian methodology which is able to use a sequence of repeat measures and exploit that relationship beyond a single interval to reduce overall error and account for unrealistic growth. We demonstrate the utility of this approach by fitting two hierarchical models: a constant growth rate and a size-dependent growth rate based on the core of a gamma distribution function, each with individual and species level effects. Fitting these models helps to identify unrealistic size records and provide an alternative estimated size, effectively cleaning the data. Doing so will enable better modelling of lifetime growth trajectories.

We use data from a long-term forest census on Barro Colorado Island to provide robust estimates for variability in growth among individuals and species. Using a sample of 2,000 trees from seven species we are able to demonstrate corrected size estimates for individual life histories, and investigate the distribution of growth rates within a species. Models providing realistic estimates of tree growth over time will improve forestry management, theory about biodiversity, and predictions on the potential for forests to capture and store carbon worldwide.