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YEAR: 1 of

PROJECT TITLE: Stand response to thinning: Enhancing response prediction through modeling

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PROJECT DESCRIPTION:

Forecasting yield is a primary objective of forest managers, who often use more than one tool for making predictions; stand level models are used for longer-term planning, while individual level models are often used for closer-to-harvest forecasts when needed. Stand level models may capture inter-tree synergies (e.g., below ground associations or 'cooperation') better than individual level models due to their aggregation of effects, and in some instances, stand allometry and other stand structural attributes are found to be closely linked to site index / stand productivity (Gehringer 2001, Pittman and Turnblom 2003). Some researchers have demonstrated that stand allometry as it is expressed through the Height:DBH relationship is closely associated with stand production, or yield (McLintock and Bickford 1957, Vanclay and Henry 1988). Turnblom and Burk (2000) found that the level (or height) of the self-thinning line was more closely related to the evolution of stand allometry than to inherent site quality, at least as measured by Site Index. Stand thinning has a propensity to alter stand allometry, therefore understanding stand response to it is of paramount importance.

Silvicultural decisions *will be made* whether under more uncertainty or less. Some of the most basic decisions being made (still) are whether to PCT or not, or whether to commercially thin or not, or both. Thus, having a firm grasp of what no thinning looks like (on different sites) is of critical importance (see objective 1); for example, describing how a PCT or a commercial thinning compares to no thinning, and how to account for thinning effects in the process (see objective 2).

This project extends the results of Bose, et al. (2018) and Cross and Turnblom (2020), using them in forming a predictive yield model, in which a set of stand attributes can be input to deliver yields of various volumetric units at future points in time as direct output. The project builds on an extant baseline (untreated) stand yield model developed using data from the Pacific Northwest Douglas-fir forest type collected by the Stand Management Cooperative (Chappell 1988). The results of this initial effort in the PNW can be expanded to the remaining two forest types in Bose, et al. (2018) as appropriate.

HYPOTHESES or OBJECTIVES:

There are four (4) specific research objectives this project will pursue:

1) Refit (update) the extant base stand yield model (untreated stands) within the SMC Plantation Yield Calculator (SMC-PYC) given another two full cycles of data collection,
2) Incorporate Pre-commercial and Commercial Thinning effects using results of Bose, et al (2018) and Cross & Turnblom (2020),
3) Benchmark fitted model against independent data set, adjust if necessary,

4) Expand technology to other commercial forest types, as appropriate.

METHODS:

The base modeling framework selected for the Stand Management Cooperative-Plantation Yield Calculator (SMC-PYC) is the Richards (1959) function, due to its well recognized flexibility and utility in matching / describing stand yield, both in treated and untreated stands, and for its quasi-biologically interpretable parameters. The primary (driving) model variables are region and framework independent: Potential site productivity estimates and site carrying capacity. Other variables considered are stand density, species (species mixture), elevation, latitude / longitude, and other physiographic-hydromorphic-climatic attributes. Primary model outputs are trees per acre (TPA), basal area / acre (BAA), quadratic mean DBH (QMD), cubic foot volumes (including top, to 4" and 6" top, i.e., CVT, CV4, CV6, respectively), and board foot volumes (to 4" and 6" tops).

The first objective will be accomplished using the methods previously established for version 1.0 of the PYC (Turnblom et al. 2020), which uses a standard algorithm for implementing weighted least squares to identify system parameters, coupled with a bootstrapping step to examine parameter distributions for eliminating those that are statistically not significant (0.05 error rate). This objective is well timed, as two additional measurement cycles have been completed since version 1.0 of the SMC-PYC. Data available for the Pacific Northwest come from 63 research sites, consisting of 585 plots including no treatment controls, PCT only (varying timing and intensity), commercial thinning only (varying timing and intensity), and both combined, measured from two to nine times using a measurement interval of either two or four years.

For the second objective, the baseline model will be augmented with silvicultural treatment variables, both pre-commercial thinning and commercial thinning. A cursory literature search has revealed several possible model augmentation structures (Pienaar & Renny 1995, Huuskonen and Hynynen 2006, Kuehne et al. 2016). A more extensive literature search will be conducted, and the best method or blend of model augmentation strategies will be selected / merged. The treatment augmented model will be refit and reduced to produce the updated version of the SMC-PYC.

Third, the model produced under the 2nd objective will be benchmarked using a quasi-independent data set. Two strategies (Jackknifing and cross-validation) will be employed to gain a full understanding of model behavior under different stand and site conditions. Dependent on the outcome of benchmarking, a model refinement step may take place, and the refined model re-benchmarked, as needed.

Objective 4 will be fulfilled by enhancing existing relationships between scientists and personnel at the relevant CAFS sites and/or developing new ones, as needed, to be conducted in parallel with the execution of the previous objectives. Data sharing agreements will be developed and put in place as needed.

MAJOR FINDINGS:

- The same physiographic regions that have been shown to affect site index (CAFS 20.83), have also been shown to affect yield.
- Refined planting density estimates (survival @ 3y) key to differentiating between treatment yields.
- Predictors for mortality need not have biological foundation; need only differentiate between planting densities.

DELIVERABLES:

A Master's Thesis was completed: Hawes, B. *In Press.* Mortality Modeling in Douglas-fir Plantations in the Pacific Northwest. MS Thesis. School of Environmental and Forest Sciences, University of Washington, Seattle, WA 98195. At the end of the coming year, our planned PNW Region DF / WH Stand Survival / Mortality models will be fit and finalized over the entire data set. The BA and QMD yield models will be fit in addition to TPA (survival) for comparing the two "triplet" fits. The best of (QMD | TPA, BA) or (TPA | BA, QMD) will the be chosen. All volumetric attribute models will then be re-fit (CVT, CV4, CV6, BF4, BF6), thus completing the base model of the PYC (Plantation Yield Calculator) ver. 2 for dissemination. Public presentation(s) of findings at CAFS Annual IAB Meeting and Regional research meetings will be made. Preliminary results of tested treatment augmentation strategies, including confidently directed plan for fitting a 'treated' model using 'the best' or 'best blend' of treatment augmentation strategies.

MEMBER COMPANY BENEFITS:

- A standardized framework for stand modeling
- Easier future calibrations of growth and yield prediction models given framework for model updates
- Improved financial analyses and comparisons of silvicultural treatments (PCT, CT, FERT)