**PROJECT ID:** CAFS.20.82

**YEAR:** 3of 3

**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). 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. Stand thinning has a propensity to alter stand allometry, therefore understanding stand response to it is of great import.  Silvicultural decisions *will be made* whether under more uncertainty or less. Some of the most basic decisions being made (still) are whether to PCT (Pre-Commercially Thin) 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 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 Northeast and/or Southeast as appropriate. |
| **HYPOTHESES or OBJECTIVES:**  There are four (4) specific research objectives this project will pursue:  1) Refit the extant base stand yield model (untreated stands) within the SMC Plantation Yield Calculator (SMC-PYC) given another two full cycles of data collection, improved volume estimates, and updated physiographic region data.  2) Fit a survival model mortality to order to back-calculate planting density and calculate actual PCT intensity, also to derive QMD from TPA and BAA.  3) Incorporate Pre-commercial and Commercial Thinning effects using results of Cross & Turnblom (2020); where a thinning is defined by its timing (PCT = absolute, CT = relative) and intensity (proportion of stems removed).  4) Benchmark fitted model against independent data set, adjust if necessary. |
| **METHODS:**  The base modeling framework selected for the Stand Management Cooperative-Plantation Yield Calculator (SMC-PYC) is the Richards (1959) function 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).  Data available for the Pacific Northwest come from 63 research sites, consisting of 585 plots from PCT'd 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. These data were augmented by in 2022 by RFNRP 207 plots consisting of spacing trials and both non-thinned and thinned regimes.  The first objective is being 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).  The second objective was achieved using spacing trial data (i.e. plant & grow) from SMC Type III installations and RFNRP low site spacing trial plots. At each of the 31 SMC installations, six planting densities were replicated – 100, 200, 300, 440, 680, and 1210 trees per acre. A total of over 1100 plot-measurements were available for fitting a survival model over time. The model used was Schumacher, with parameters estimated as functions of planting density class, annual solar insolation, and site index.  The third objective is accomplished by augmenting the baseline model with silvicultural treatment variables, both pre-commercial thinning and commercial thinning. Pre-commercial thinning effects are to be applied to the current (non-linear) structure using ratios (treated:control) determined from a separate analysis conducted by Cross & Turnblom (2020). This analysis employed a constrained linear response surface. The two disparate model frameworks are brought together by the shared set of control plots to both analyses. The well formatted database has been completed.  In terms of 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 is 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. 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. |
| **MAJOR FINDINGS:**  Though the effects differ a bit by volumetric unit, the emerging climatic variables affecting yield are annual solar insolation; summer degree-days above 18°C; spring, autumn, winter Hogg’s climate moisture index, autumn precipitation, minimum autumn temperature, spring relative humidity, and end of the frost-free period. (... continued)  A good fitted survival model has parameters with quasi-biological interpretations (site index, solar insolation), but some do not have a strict biological foundation; chief need is to differentiate between planting densities.  Refined planting density estimates (survival @ 3y) remains a key to differentiating between treatment yields.  Updated baseline models (those without climate effects variables) are quite useful for comparison with the previous fits and were instrumental in debugging our newly coded FORTRAN Nelder-Mead optimalization algorithm. |
| **DELIVERABLES:**  Basal area, QMD, and volumetric yield ratios for stands thinned pre-commercially [partially completed]  Survival model for untreated Douglas-fir in PNW region [near completion]  Re-fits for basal area (BAA), volumetric models (CVT, CV4, CV6, BF4, BF6) [completing]  Public presentations of findings at CAFS annual IAB meeting and regional research meetings [both in process]  User interface to yield model available to SMC membership (SMC-PYC v.2)  Working Paper to be delivered to SMC membership detailing data, methods, and results. |
| **MEMBER COMPANY BENEFITS:**  Standardized framework for stand modeling  Improved financial analyses and comparisons of silvicultural treatments (PCT, CT, FERT) |