**COOPERATIVE FORESTRY RESEARCH UNIT**

**PRE-PROPOSAL**

**PROJECT TITLE:** Secrets in the CTRN: Causal factors of thinning response and transfer to adaptive management regimes in Maine spruce-fir forests

**PRINCIPAL INVESTIGATOR:**

Mike Premer University of Maine 207-581-2863 michael.premer@maine.edu

**CO-PRINCIPAL INVESTIGATORS:**

Shawn Fraver University of Maine 207-581-2842 shawn.fraver@maine.edu

Jay Wason University of Maine 207-581-2889 jay.wason@maine.edu

**ABSTRACT:**

Standdensity management through thinning is a common silvicultural method that has traditionally been utilized for production of commodity timber goods, tree regeneration, and quality improvement. Recently, there has been renewed interest in thinning regimes to mitigate forest health risks, enhance C sequestration and structural complexity, and control competing vegetation. While a rich volume of work from the Commercial Thinning Research Network (CTRN) has examined thinning practices under a variety of treatment timing and intensities, questions remain regarding the interactions of stem and stand response with site conditions (i.e., site productivity). To date, little is known about the edaphic, climatic, and physiologic mechanisms of the duration and magnitude of tree response to thinning in the Northeast region. Therefore, quantifying the site-specific limiting factors to growth is imperative to adaptative management strategies and effective silviculture. In other regions, tree ring stable isotopes have been used to reconstruct tree water use efficiency and disentangle the influential factors of silvicultural treatments, including thinning, and site conditions on stem growth response. However, most efforts have been limited to a single study area and un-replicated across a landscape or region. In parallel, advances in remote sensing derived estimates of water balance through potential evapotranspiration have been demonstrated to provide unbiased, high spatial resolution predictions of thinning treatment response, yet lack a descriptive biological mechanism. Therefore, this project aims to quantify the site and physiological causal mechanisms of operational thinning response through the integration of tree-ring stable isotopes (*δ*13C and *δ*18O) with high spatiotemporal resolution remote sensing estimates of evapotranspiration (20 meter at 1-month intervals) across the CTRN study sites in Maine. Findings from this work can offer insight to the site-limiting factors to site carrying capacity (e.g., Stand Density Index) and thinning response, be used to generate new site-specific density management guidelines, and may serve as a framework for growth model calibration, and future planning.

**PROJECT OBJECTIVES:**

The overall objective of the proposed project is to assess site-specific factors of operational thinning response with new and emerging tools across mixed spruce-fir across Maine. Specific objectives include:

1. Quantify the causal mechanisms of stem growth response (or lack of) to variations in thinning intensity, timing, and site variables through sampling and analysis of tree ring stable isotopes (*δ*13C and *δ*18O) with long-term CTRN datasets
2. Link remote sensing composite estimates of productivity, (e.g., cumulative monthly timesteps of water availability) with thresholds of thinning response across the hydrologic gradient of the CTRN sites
3. Test the accuracy, precision, and compatibility of tree and stand reconstruction through stem increment cores with field measurements to form a framework for future sampling efforts
4. Develop regional spatiotemporal silvicultural thinning guidelines and geospatial tools of estimated treatment response to aid decision support in commercial forest operations

**BACKGROUND:**

Silvicultural thinning is common in the mixed spruce-fir (*P. rubens* and *A. balsamea*) forests of Maine, owing in part to past episodic pest disturbances and land use policies. Traditional stocking targets were established to balance individual tree growth and quality, species dominance, stand volume, and commodity production, while minimizing mortality loss. There has been widespread and renewed interest in thinning to enhance C sequestration rates and wildlife habitat, decrease abiotic disturbance associated mortality (e.g., wind, fire), and mitigate susceptibility to pests, across a variety of landownerships and associated goals. However, questions remain regarding the transferability of stocking guidelines and compatibility with local growing conditions, stand and site response capacity, and long-term objectives. Therefore, a mechanistic understanding of forest growth processes, site dynamics, and response to treatments could improve and support precision silvicultural prescriptions.

It is generally recognized that organic productive capacity and species composition reflect site-specific seasonal variation in precipitation and radiation (site water availability - SWA), attributed to local topography and regional climatic patterns. In forest stands, the onset of tree competition can result in limitation of either water or sunlight through belowground root interactions or aboveground shading effects. Thinning can temporarily alleviate competition and increase growth and C sequestration until the residual trees re-occupy stand growing space. The duration and magnitude of thinning response is dependent upon residual density and SWA. However, it can be difficult to discern the relative impact of limiting factors (water, sunlight) on reduced growth with traditional measurements. The use of tree ring stable isotopes (*δ*13C and *δ*18O) offers a promising solution to identify the limiting factors to tree growth through a temporally referenced composite variable of water use efficiency (*wue* - C assimilated: water lost) (Marshall et al. 2022). This approach has been demonstrated to detect physiologic response and *wue* in conifer thinning studies (Warren et al. 2001, Powers et al. 2010) and fertilization treatments of Douglas-fir (Brooks and Mitchell 2011, Oviedo et al. 2017) in single site experimental units, and recently, regional paired-tree nutrition networks in the Pacific Northwest (Premer et al. 2018). To date, this approach has not been utilized in silvicultural trials of the Northeast region but could be especially useful in a setting with a long-term, replicated silvicultural trial like the CTRN to identify limiting factors to response. In parallel, remote sensing and geoprocessing technology have been utilized to develop high resolution (e.g., 1/5 acre) estimates of SWA in other regions in the form of a water deficit/surplus index as geospatial raster products (Montes et al. 2016; Premer 2020). While computationally intensive, this method utilizes user-defined cumulative monthly time steps to generate simple composite variables of locally calibrated SWA estimators. These tools have been successfully demonstrated as robust predictor variables in studies estimating site index of *Pinus taeda* (Koirala et al. 2021) in the SE, and response to thinning in *Pinus radiata* in Chile (Ojeda et al. 2018), and other applications in Douglas fir plantations across Washington and Oregon. While the NE region is not susceptible to drought or water deficit, excess water can decrease site quality, and optimal SWA for any given tree species varies with functional traits. Given the coupling of tree growth, leaf area, and SWA, this method may provide a framework to map potential thinning response and hydrologic based estimates of productivity in spruce-fir forests. The overall objective is to integrate CTRN plot records with stable ring tree isotopes and high spatiotemporal resolution estimates of evapotranspiration to generate site-specific potential of C sequestration and residual stem growth of spruce-fir stands given variations in thinning regimes and SWA.

**APPROACH:**

This study will utilize trees in thinned and control plots in the CTRN projects across Maine. These sites cover a range of site quality (SI50 = 43-79 ft.), and mean annual precipitation (40-51 in.), and evapotranspiration (5-8 in. water surplus). In a subset of 10 of the remaining 7 CTRN installations, 40 trees (1 per diameter distribution quintile) will be sampled and cored at each Control and 0.3 RD thinning plot of both species (1 red spruce and 1 balsam fir), for a total of 280 tree increment cores. 2 tree cores will be taken at breast height and processed for cross-dating and measurements at the Forest Ecology Laboratory at UMaine. Cores will be measured for radial growth 10 years prior to treatment and 20 years post- thinning. Tree tissue samples of *δ*13C and *δ*18O will be composited by tree of the year immediately pre-harvest, and 4-8-12-16 years after treatment, for a total of 5 samples of stable isotopes per tree. Samples will be prepared at UMaine and processed at the Stable Isotope Laboratory at Northern Illinois University or the Climate Change Institute at the UMaine. Estimates of evapotranspiration and SWA at each treatment plot will be generated with geoprocessing software to estimate incoming radiation and combined with publicly available monthly climate records. SWA estimates will be conducted at a monthly time step from 1990 to 2020 to test the difference of average and cumulative SWA since treatment on radial growth response and stable isotope discrimination. A variety of open-source software will be used for data processing, analytical approaches will use numerous parametric and nonparametric statistical tests.

**ANTICIPATED BENEFITS TO CFRU MEMBERS:**

The project will leverage the CTRN, a unique long-term regional network of experimental thinning plots that spans the mixed spruce-fir forests of Maine. Results can provide previously unavailable information on limiting factors to stand growth response to management that can be directly transferred to application. Findings from this work can be used to update thinning guidelines and generate geospatial decision support tools in spruce-fir systems that are physiologically based and calibrated at a local, site level (e.g., 1/5 acre).

**APPROXIMATE LENGTH OF STUDY:**

Study duration will be approximately 2 years from startup to completion (2023-2025), with possibility of extension through the Center for Advanced Forestry Systems.

**ESTIMATED AMOUNT REQUESTED FROM CFRU:**

For 1 year of MS student support ($35k), 1 summer of field sampling and equipment ($10k) faculty summer salary for Premer, Fraver, and Wason ($26k), and sample preparation and processing costs ($25k) - **$105,600 TOTAL w/overhead included**

**MATCHING FUNDS:**

Year 2 of MS student support ($35k) will be sought by the Center for Advanced Forestry Systems or the Maine Agricultural and Forest Experiment Station (MAFES). Computing equipment (3k) will be provided by funding from MAFES.

**DELIVERABLES:**

Findings from this work will be disseminated to cooperators in the form of technical reports and raster geospatial tools. Site tours (2) and technical transfer workshops (2) will be used to demonstrate operational application and facilitate cooperator engagement with products. This project seeks to directly support a M.S. student, with cost-sharing to support a second M.S. student. Both students will work with faculty guidance to complete the project along and generate original thesis works that can be submitted to peer-reviewed forestry journal articles. This project and associated products can be further used as a framework for additional investigation.

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