NSF I/UCRC Center for Advanced Forestry Systems

Year 4 Phase III Progress Report 2023

Meg Fergusson & Aaron Weiskittel
CAFS3 Lead Site, University of Maine
Center for Research on Sustainable Forests

National Science Foundation
NSF Grant IIP-1915078

Vision

To actively support the US forest industry by solving problems with targeted, applied, and collaborative research coordinated across multiple universities.

Mission

To optimize genetic and cultural systems to produce high-quality raw forest materials for new and existing products by conducting collaborative research that transcends traditional species and disciplinary boundaries.

Objectives

Serve as national organization for R&D relevant to the forest industry

Coordinate and perform national research activities across multiple sites that align with the prioritized needs of forest industry

Document and communicate key research outcomes to relevant stakeholders

Provide a long-term strategic vision for research needs of forest industry

Convene leading scientists from academia and industry who are prepared to address new/unforeseen challenges to the forest industry, such as changing markets

Create national networking opportunities for universities and forest industry

The University of Maine became the lead site for CAFS in 2016. The CAFS program is led by Dr. Aaron Weiskittel, Director of UMaine's Center for Research on Sustainable Forests.

crsf.umaine.edu/forest-research/cafs

CAFS Lead Site Director's Report

The National Science Foundation's Center for Advanced Forestry Systems (CAFS) is now another year closer to its successful graduation as an Industry-University Cooperative Research Center (IUCRC). This past year also represents my fifth year as CAFS Director and I would like to thank the University of Maine as well as CRSF's Meg Fergusson for continued support for us serving as the CAFS Lead Site since 2018. CAFS has been a significant part of my professional career since I joined the University of Maine in 2008, and has allowed me to engage with both researchers and forest industry representatives from across the US. I continue to remain committed to providing that same opportunity for others, particularly as both universities and forest industry transition to the post-pandemic world of 2023.

Our third in-person Phase III Industry Advisory Board (IAB) meeting held in June in Louisville, KY, was strongly attended by the membership, along with numerous program-supported graduate students. These events are a true highlight for me, providing a great opportunity to see the progress being made with the various research projects, the dynamic interactions between meeting participants, and getting to experience a new forest type with its own unique challenges. In addition to the numerous graduate students and post-docs who joined us, this year two faculty members from one of our START supplemental grants at the University of Maine at Fort Kent were able to present some of their research involving 2-year technical school students. Presentations were also given by REUs and INTERN supplemental grant recipients, which highlight the diversity of research that is happening in CAFS.

I am again delighted to highlight the many key accomplishments and outcomes from CAFS Year 4 in this center annual report. A striking statistic is that the CAFS' robust research portfolio now encompasses 26 projects, which is one fewer than our peak of 27 during Phase II (2013), despite having a lower number of participating university sites in Phase III. Even more important from my perspective, nearly 70% of these projects involve multiple university sites, versus generally less than 20% of projects in Phases I and II. This makes evident the highly collaborative nature of the membership and the importance of cross-regional efforts, both critical for the long-term sustainability of CAFS. The original intent of CAFS was to build synergies and effective partnerships across universities and industry both internal and external to the regions involved; I believe we have now realized this vision and have a solid foundation for future efforts related to CAFS.

From all perspectives, industry and university participation remains strong. Our IAB Executive Committee is re-energized by the current momentum and is busy exploring future sustainability plans. Strong progress has been made on the technology roadmap and a few new projects are being planned to address current gaps. Faculty participation has continued to increase with most of the research funding being used to support graduate students or post-docs. We now have several IAB-approved research projects led by early-career faculty, which was a critical part of my own career and very excited to see their involvement and fresh ideas. Given the coming year is our last with NSF funding, a strong push has been made to leverage the supplemental funding opportunities with several REU, INTERN, and START requests currently in the works, which continue to diversity and strengthen CAFS value-add to our IAB.

Next June we will head to Madison Wisconsin to explore yet another new forest type and see future advances in forest products and their implications for current forest management. Of course, we could not make all these advances and accomplishments without the strong dedication and involvement of all, which I appreciate and find so rewarding. I am very proud of what we have done and delivered.

As always, I look forward to the continued collaborations and evolution of this organization, particularly as we work towards full graduation of the IUCRC program after 15 years of existence.

Aaron Weiskittel

Director, Center for Advanced Forestry Systems
Director, University of Maine

Forests are vital to the world's economic, ecological, and social health.

Forests provide numerous ecosystem services, particularly sustainably managed forests.

Economic Opportunities exist to meet increasing demand for wood products from an increasing global population, rising living standards, greenhouse gas policies, bioenergy, and advances in green building technologies.

Meetings

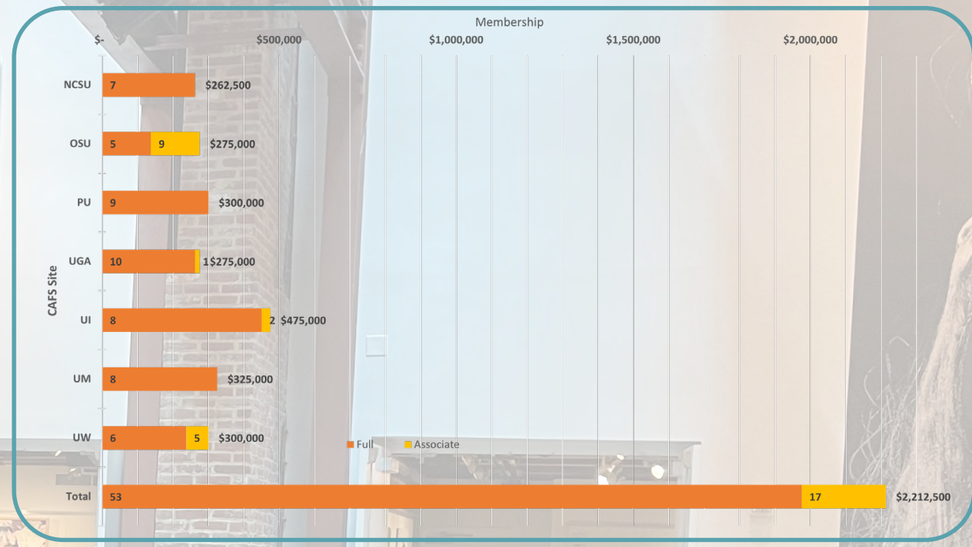
As Covid-19 restrictions continued to lift, UMaine selected Louisville, KY, for its in-person internal advisory board (IAB) meeting in June 2023. The event showcased project progress updates and stakeholder interaction. Nearly 50 site directors, industry representatives, and researchers attended the IAB and field tour.

Research

conducted by CAFS increases the competitiveness of forest products industries and forest landowners by solving problems at multiple temporal and spatial scales, and by determining fundamental solutions that transcend traditional tree species, regional, and disciplinary boundaries. Industrial members benefit by becoming knowledgeable about a wider range of technological capabilities. In addition, technology transfer between CAFS scientists and member personnel fosters rapid implementation of new technologies.

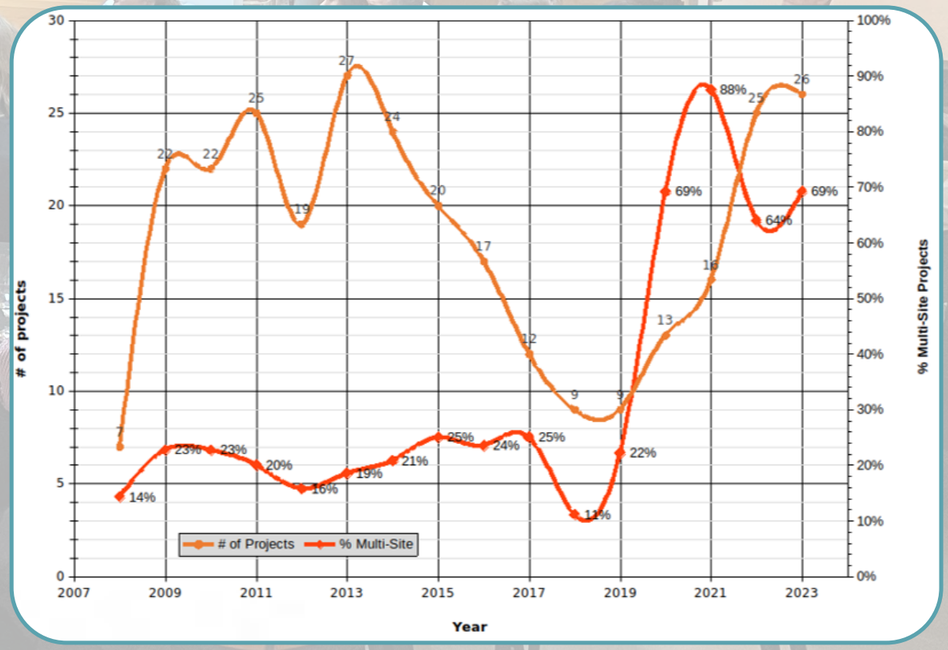
FY23 Budget

$2.2M in contributions across 7 sites and 84 primary and secondary IAB members



CAFS Research Portfolio

Greater than 70% of projects are now multi-site

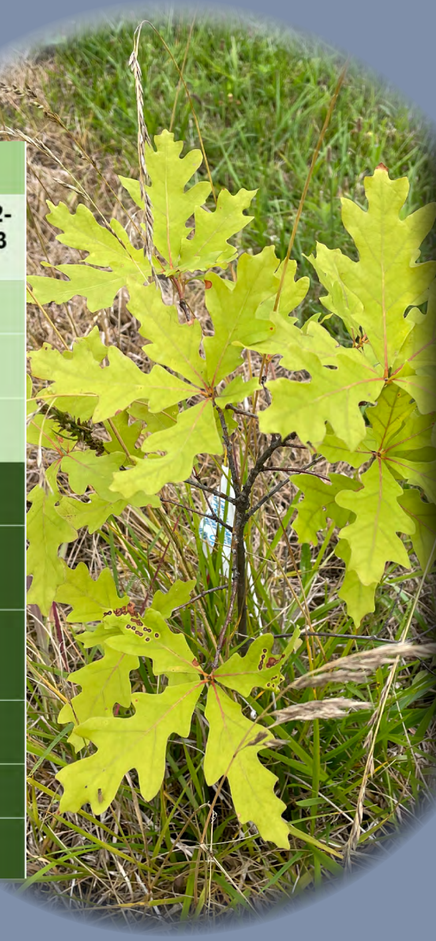


Phase 3 Technology Roadmap

	2019	2020	2021	2022	2023	Outcomes
All CAFS Sites	■	■	■	■	■	IAB Meetings, evaluation, undergraduate education, publications, attendance at national meetings, securing of additional research support
Theme 1: Forest Modeling & Decision-Support Tools Primary IAB Partners: American Forest Management, Green Diamond, Campbell Global						Provide IAB members with improved tools that allow better and more precise forest management and planning
Project 1: Assessing and mapping regional variation in potential site productivity Lead Partners: NCSU, UI, UGA, UW, PU	■	■	■			Better understand how potential site productivity differs across the key forest regions in the US, the most influential factors, and produce high-resolution maps for IAB members to aid planning
Project 2: Assessing and mapping regional variation in site carrying capacity Lead Partners: UI, UM, OSU, VT, UGA, UW	■	■	■			Derive consistent estimates of maximum stand density index, evaluate most influential factors, and provide high-resolution maps to aid management
Project 3: Evaluation and refinement of regional GY models Partners: UM, VT, UGA, OSU, PU			■	■	■	Using the outcomes from Projects 1 and 2, evaluate regional growth and yield behavior and refine as possible
Theme 2: Effective Use of Remote Sensing Technologies Primary IAB Partners: JD Irving, Rayonier, Weyerhaeuser						Evaluate and leverage emerging remote sensing technologies to improve planning
Project 4: Mapping species composition and past disturbance using optical sensors Partners: UI, UM, UGA	■	■	■			Optimal sensors like Landsat and Sentinnel-2 offer the ability to annual map species composition and past disturbance, but have yet to be tests across the US
Project 5: Improving efficiency and accuracy of Enhanced Forest Inventories derived from LiDAR Partners: UW, OSU, UGA, UM	■	■	■	■	■	LiDAR is becoming increasingly used to produce Enhanced Forest Inventories, but uncertainties on ground data, necessary metrics, and modeling method remain.
Project 6: Using hyperspectral imaging to evaluate forest health risk Partners: VT, NCSU, OSU, UM			■	■	■	Forest health risks are extensive and difficult to detect. Hyperspectral imaging from terrestrial and/or airborne sensors can help detection and quantification
Theme 3: Improved Silvicultural Practices Primary IAB Partners: Hancock Forest Management, International Forest Company, Molpus Timberlands Management						Forest managers have a variety of silvicultural regimes to select from, but it is often unclear on selecting the best practices for each site
Project 7: Quantifying long-term gains using advanced genetics Lead Partners: PU, UGA, OSU, NCSU	■	■	■			Tree genetics has seen significant advances in recent years due to better breeding practices and cloning, but a synthesis of the long-term potential effects of these practices across multiple species has yet to be presented
Project 8: Modeling forest response to early stand treatments Lead Partners: UW, UI, NCSU, VT	■	■	■			Vegetation management is critical to successful rotations, but its prediction is complicated by a variety of factors such as the type and extent of competing vegetation. Leveraging long-term datasets, the outcomes of contrasting treatments would be assessed and modeled.
Project 9: Identifying type and level of response to forest fertilization Lead Partners: UW, UI, NCSU, PU			■	■	■	Forest fertilization is a widely used silvicultural practice that is difficult to predict. Using long-term and newly available data, methods to improve predictions of forest responsiveness would be evaluated.
Project-wide activities informed by Research Plan	Incorporation of advanced and emerging technologies Delivery of multi-platform, decision-support tools Harmonization, and synthesis of available regional datasets to generalize trends Multi-disciplinary, knowledge to action, and stakeholder-drive framework					

Phase 3 Milestone Timeline

Milestone	Fiscal Year				
	18-19	19-20	20-21	21-22	22-23
Apply for & secure NSF Phase III funding	■				
Approve bylaws, strategic plan, & technology roadmap	■				
Initiate research projects identified on technology roadmap	■	■	■		
Revise and refine bylaws, strategic plan, & technology roadmap		■	■	■	■
Secure additional partners including industry, academia, and non-profit sectors.	■	■	■	■	■
Integrate center research and education activities that effectively train and benefit undergraduate and graduate students	■	■	■	■	■
Survey, document, and prioritize industry member research needs	■	■	■	■	■
Plan and host biannual meetings	■	■	■	■	■
Annually report progress, outcomes, and finances	■	■	■	■	■



2023 IAB Attendance Summary

	June 2023 IAB Meeting				November 2023 IAB Meeting			
	N of Member Firms Attending	N of Member Representatives Attending	N of Faculty Attending	N of Students Attending	N of Member Firms Attending	N of Member Representatives Attending	N of Faculty Attending	N of Students Attending
University of Maine	8	8	4	-	5	9	3	-
University of Idaho	5	5	3	3	3	4	2	3
University of Washington	5	5	2	-	4	8	3	-
NC State University	6	6	2	-	4	7	2	-
Oregon State University	6	6	2	3	5	11	4	2
Purdue University	3	3	2	1	1	1	4	2
University of Georgia	8	8	1	1	6	9	2	1

Highlights

Key Considerations

- Entering final year of NSF support before officially graduating from the IUCRC program
- Member and researcher collaboration and engagement remain high
- Need to strategically shift focus on long-term sustainability
- Continued incorporation of advanced & emerging technologies
- Synthesis of regional datasets
- Desired outcomes from continued program support: synergistic partnerships, improved coordination across the forest sector, increased investment in forests (R&D)
- CAFS has effectively demonstrated the ability and importance of multi-site, cross-regional collaboration

Meetings

- In-person IAB held in Louisville, KY, in June 2023
- 46 industry members and researchers attended in person; additional 12 joined remotely
- Reminder of NSF supplemental funding opportunities (see INTERN and START projects in this report)
- Held in conjunction with the National Council for Air and Stream Improvement (NCASI) Biometrics Working Group
- Virtual IAB held November 2023; 64 industry members and researchers attended, including 2 former IAB Executive Committee chairs.
  - 95% of the surveyed CAFS IAB members were supportive of future sustainability as an IUCRC with current structure following graduation
  - 74% of the surveyed CAFS IAB members believed the CAFS technology roadmap reflected IAB needs very well, while nearly 90% thought it reflected IAB needs moderately well or better
  - 100% of the surveyed CAFS IAB members supported future more targeted and specific RFPs for the IUCRC

Field Tour Highlights

- White Oak Genetics & Tree Improvement Program
  Phase 1: White Oak acorn collection from sites across US; Phase 2: Progeny testing & repository at Maker's Mark; Phase 3; Seed orchard production
- White Oak Genome Tree (used to sequence DNA of White Oak)
- Barrel aging & cooperage at Maker's Mark Distillery

NCASI Affiliation

- 28% of CAFS members are also NCASI members
- Provide synergistic partnerships and leverage key resources and expertise
- Improve coordination across the sector

Ongoing Projects (*indicates multi-site projects)

Lead Site	PI	Project/Title	Status 2023
UW	Turnblom et al.	16.69 Stand and tree responses to late rotation fertilization	Continuing
UI*	Kimsey et al.	19.75 Assessing & mapping regional variation in site carrying capacity across the primary forest types in the US	Continuing
NCSU/UGA*	Cook et al.	19.76 Assessing & mapping regional variation in site productivity across the primary forest types in the US	Continuing
UI*	Nelson/Jacobs/Gonzalez	20.78 Intraspecific hydraulic responses of commercial tree seedlings to nursery drought conditioning	Continuing
UM	Legaard/ Weiskittel	20.79 Multi-regional evaluation of new machine learning algorithms for mapping tree species distribution and abundance	Continuing
PU*	Couture/Jacobs	20.80 Using hyperspectral imaging to evaluate forest health risk	Continuing
OSU*	Hatten	20.81 Resilience of soil organic matter to harvesting: A global study of long-term soil productivity experiments	Continuing
UW*	Turnblom and Cross	20.82 Stand response to thinning: Enhancing response prediction through modeling	Continuing
UW	Cross and Turnblom	20.83 Using predictive analytics to decompose site index	Ending
UW	Littke	20.84 Physiologic response to commercial fertilization programs in Pacific Northwest forest plantations	Continuing
OSU*	Gonzalez	21.85 Variation in productivity, wood quality and soil carbon of nine conifer species across a gradient in water deficit	Continuing
NCSU*	Trlica	21.87 Linking leaf area index and remote sensing across different forest types	Continuing
UGA*	Dahlen et al.	21.88 Quantifying silvicultural treatment effect on lumber quantity and quality in loblolly pine	Continuing
UGA	Dahlen et al.	21.89 Quantifying carbon sequestration as a function of silvicultural treatment in loblolly pine	Continuing
NCSU*	Cook et al.	21.91 NCSU START: NSCU, Montgomery Community College, Wayne Community College	Continuing
UM*	Weiskittel et al.	21.92 UMaine START: UM & UMaine at Fort Kent	Continuing
UI	Coleman	22.95 UI INTERN: Improving tree seedling survival with defense-enhancing endophytes	Ending
NCSU	Pala	22.98 CAFS Interactive Mapping Platform (CAFSIMP)	Continuing
UGA*	Bullock et al.	22.99 Effects of dominant tree height definition on loblolly pine growth & yield model outputs	Continuing
UM*	Premer et al.	23.100 Use of carbon isotopes for assessing site-specific response to thinning	New
UI	Kimsey et al.	23.101 Site-stand dynamics & pine beetle mortality in Ponderosa pine ecosystems	New
UI	Nelson et al.	23.102 Enhancing resistance to fungal pathogens in commercial tree seedlings	New
OSU*	Mainwaring	23.103 Determination of crown morphological traits using laser scanning in Douglas-fir and loblolly pine genetics trials	New
OSU*	Hailemariam et al.	23.104 Interplay between sampling design and small area estimation to improve forestland inventory	New

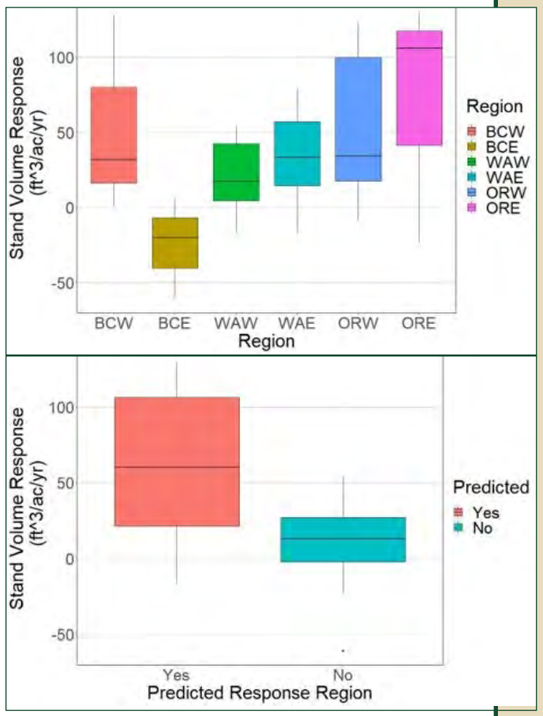
Stand and Tree Responses to Late-Rotation Fertilization

Eric Turnblom, Kim Littke, Jason Cross, Mason Patterson, and Rob Harrison (UW)

The study is designed to estimate a regional nitrogen fertilization response (RRE) for Douglas-fir on late-rotation stands from paired-plots in randomly located late-rotation stands within four distinct regions of Washington and Oregon and two regions in British Columbia. This study will provide a much-needed examination of the economics involved with late-rotation fertilization.

Annual Progress

- Greatest tree and stand volume response in BC West and Oregon West and East regions.
- Modeled volume response in Late-rotation and Paired-tree studies.
- Modeled volume response in Late-rotation and Paired-tree studies
- Predicted response regions contained significantly greater tree and stand response



Current Progress: Stand Volume Response.

Future Plans

- 20 installations will be measured for six-year response in Winter 2023.
- Four new installations will be established by Spring 2024.
- Manuscript in preparation describing relationships between PRS nutrient adsorption, soil and site productivity, and 4-year fertilizer response.

Member Company Benefits

- Soil, tree, and PRS probe nutrient data collected across the coastal Pacific Northwest.
- Inclusion of response data into growth models.
- Greater understanding of nutrient availability in predicting fertilizer response.
- Examination into the economics of late-rotation fertilization.

Project Highlights

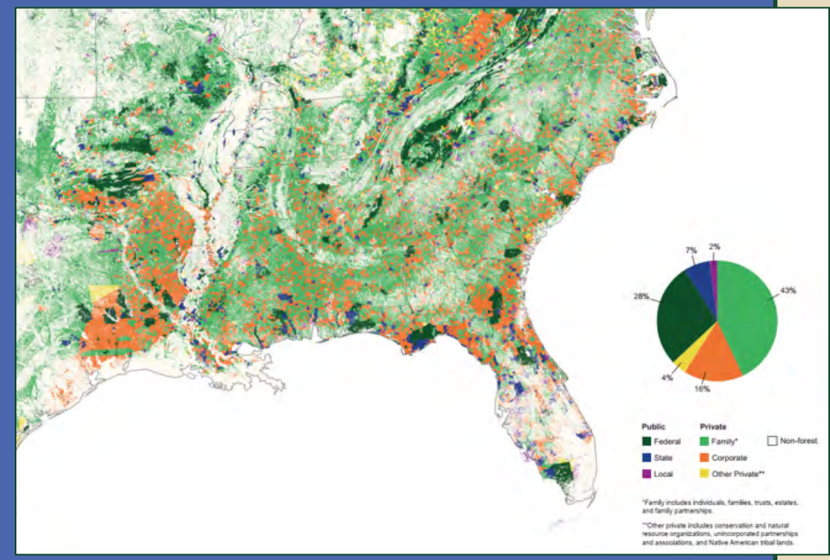
Assessing & Mapping Regional Variation in Site Productivity

Rachel Cook (NCSU), Cristian Montes (UGA), Aaron Weiskittel (UM), Jeff Hatten (OSU), Mark Coleman (UI), Doug Jacobs (Purdue), Mark Kimsey (UI), Doug Maguire (OSU), Kim Littke (UW)

This project features cross-site collaboration and sharing of remotely sensed and empirical field data for spatial modeling of potential site productivity. The objective is to develop a consistent and biologically-meaningful metric of potential site productivity that can be related to a combination of environmental and edaphic factors and mapped across the various regions. Depth-to-water table has been linked to: Tree growth and height, Basal area, Foliar nitrogen, Needle length. Management factors that influence depth-to-water table: harvesting, bedding, thinning, prescribed fire.

Annual Progress

- Mapping response based on continues variables.
- Classification based on site productivity optimization of trees 'SPOT' codes.
- Site index improving 0.5 ft per year.
- Site index fertilizer response shows geology matters within NRCS soil series .
- Uncertainty in stand projections determined and modeled as well, showing uneven uncertainty values across the southeast U.S.



FIA plots by SPOT for "base" SI (natural v. planted) 1,562 unique codes.

Future Plans

- More data! USGS LiDAR for member plantations & FIA data.
- Incorporate LAI map into productivity modeling.

Member Company Benefits

- Improved metrics for assessing site productivity.
- Development of simplified soil classification system for forest management.
- Incorporate LAI to enhance predictive response.
- Improve confidence of response and therefore return on investment.

2023 CAFS Phase 3 Progress Report

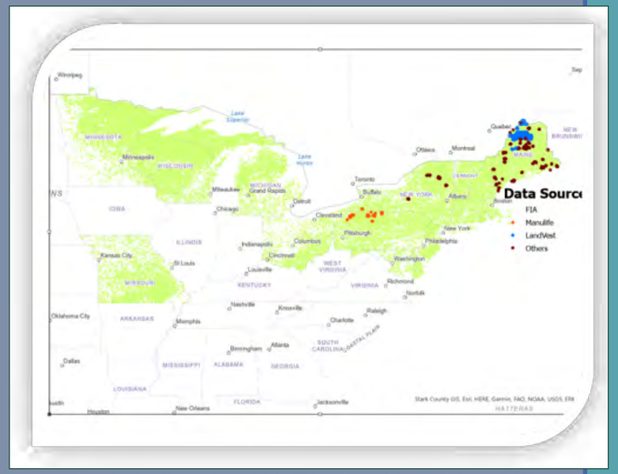
Assessing & Mapping Regional Variation in Site Carrying Capacity Across the Primary Forest Types in the US

Mark Kimsey (UI), Aaron Weiskittel (UM), Rachel Cook (NCSU), Cristian Montes (UGA), Doug Mainwaring (OSU), Eric Turnblom (UW)

Maximum site carrying capacity determines the number of individuals of a certain size per unit of area that a defined stand can support and maintain. The objective of this research project is to 1) synthesize a nationwide forest measurements database from publicly available data and from CAFS members, 2) standardizing maximum carrying capacity modeling, and 3) provide regionally relevant, national forest carrying capacity models.

Annual Progress

- Northwest regional SDImax models are being shared satisfactorily (Web apps and raster's).
- Data is prepared for SDImax modeling. Currently, we are analyzing and reviewing existing regional models to standardize Maximum Carrying Capacity modeling.
- The SDImax model build for loblolly pine in the southern United States, is sensitive to site, stand, and silvicultural treatments, and it is validated by local experts.



Northern Region SDImax Data: FIA 34,759; Industry & Research Data ~5,000

Future Plans

- Meeting with SDImax model researchers in the northern region to learn about crucial covariates for modeling.
- SDImax modeling for commercial species in northern region.
- Generating a GeoTiff for the loblolly pine SDImax model in southern region.
- Exploring SDImax modeling for other species based on data availability and member interest in southern region.
- Enhance and standardize SDImax models by incorporating additional data received/ expecting from members in the Pacific Northwest.

Member Company Benefits

- A GTR creating a pine management guide flexible to climate, species composition, site type, and method of measurement (lidar vs traditional stand exam).
- Consistent methodology/platform for identifying and managing forest density across multi-regional land holdings.

Project Highlights

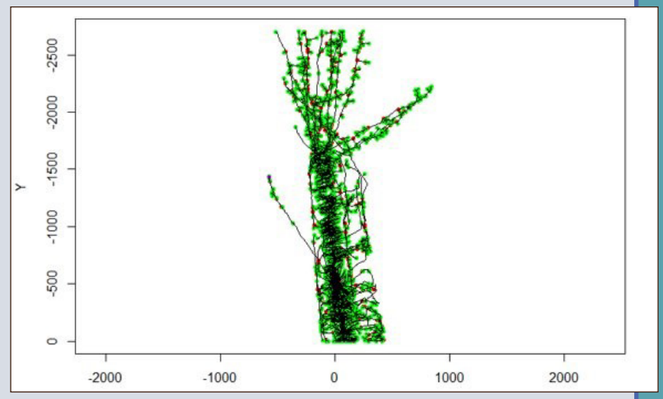
Intraspecific Hydraulic Responses of Commercial Tree Seedlings to Nursery Drought Conditioning

Andrew Nelson (UI), Douglass Jacobs (Purdue), Carlos Gonzalez-Benecke (OSU),

Multi-institution project to examine drought-related physiological parameters (e.g., stem and root hydraulics, resistance to cavitation) and root morphological traits of various genotypes of western larch, black walnut, and coastal Douglas-fir from diverse maternal tree climates across each species' native range.

Annual Progress

- Estimating Black Walnut root diameters by sampling 3D point cloud at various points along root skeleton.
- Crop out most of the points in the root plug for architectural analysis
- Segments of the root skeleton are divided into slices.
- Point cloud is sampled for each slice, and circle fitting is used to estimate radius/diameter.
- Our results suggest the presence of a drought memory, in that early drought stress modified seedling responses to subsequent drought events.



3-D point cloud: This Black Walnut skeleton has 3000+ segments

Future Plans

- Improve the method of measuring circle-fitting error for root diameter.
- Estimate root volume.
- Validate 3D models by comparing it to 2D scans of the same root systems.
- Further develop the architectural analysis on egressing roots.
- Preparing manuscripts on simulated drought physiological response and outplanting performance.

Member Company Benefits

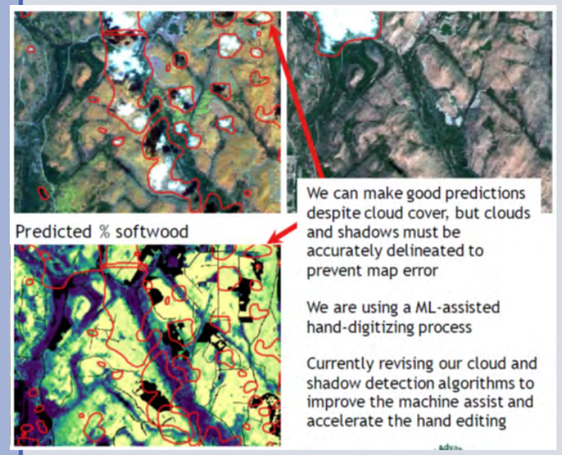
- Results may help reduce reforestation costs associated with replanting failed plantations by tailoring phenotypes to match a broad range of site conditions across three major forestry regions of the US.
- The X-ray computed tomography technology will provide new opportunities to generate data on dynamic responses of root systems to nursery treatments,root plasticity, genetic and cultural improvement of root architecture, & seedling quality for current environmental challenges.

2023 CAFS Phase 3 Progress Report

Multi-Regional Evaluation of New Machine Learning Algorithms for Mapping Tree Species Distribution and Abundance

Kasey Legaard, Aaron Weiskittel, Ken Bundy, Erin Simons-Legaard (UM)

For the past several decades, machine learning (ML) algorithms have been adopted and refined to improve forest map accuracy. However, several decades of data and algorithm development in satellite remote sensing have not yielded robust solutions for eliminating systematic map error. This research specifically targets this problem using a ML method that is capable of minimizing both total and systematic error in satellite-derived maps. This mapping approach combines the strength of Support Vector Machines (SVMs) to model complex, nonlinear relationships based on limited training data, a common condition in forestry applications, with the adaptability of a multi-objective Genetic Algorithm (GA).



Annual Progress

Species & Forest Type Mapping

- Species and forest type mapping workflows tested and finalized across approx. 5 million acres.
- Currently processing data for statewide coverage.
- Plan to integrate with NOAA C-CAP data this winter, and deliver final land cover products in spring 2024.

State of Maine Biomass Mapping

- Preliminary aboveground live biomass from NAIP point cloud metrics and Sentinel-2 bands, northwest Maine
- Processing 2021 NAIP point cloud statewide, at 10-meter resolution, using software developed in-house

Future Plans

- Expand processing to test sites in the NW, SE, and Upper Midwest.
- orking to establish pilot studies with both public and private organizations within Maine to evaluate species predictions and derivative forest type or composition maps.
- Complete statewide processing in parallel with modeling.

Member Company Benefits

- Continued development and proof of concept of low-cost forest mapping methods using multi-objective ML and automated geospatial processing.

Project Highlights

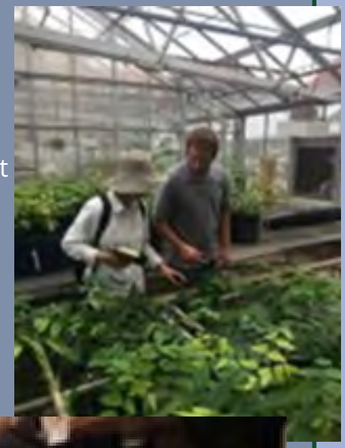
Using Hyperspectral Imaging to Evaluate Forest Health Risk

John Couture, Sylvia Park, Melba Crawford, Matthew Ginzel, Brady Hardiman, Douglass Jacobs (Purdue)
Aaron Weiskittel, Parinaz Rahimzadeh, Peter Nelson (UM)
Cristian Montes, Caterina Villari, Kamal Gandhi (UGA)

Forest systems face a diverse array of stressors of a scale and complexity previously unobserved. Incorporating digital approaches into forest monitoring and management has potential to mediate the negative impact of stressors on forests. Hyperspectral data is capable of rapidly generating tree biochemical and physiological status, especially in response to stress.

Annual Progress

- Leaf functional traits predicted from spectral data provide detailed information on shifts in tree health status.
- Standardized analyses, spectral measurements, and robust statistical modeling allow us to build trait models to retrieve relevant foliar traits for stress monitoring.
- The inclusion of short infrared wavelength ranges (1300–2400 nm) was essential in enhancing the prediction of all six leaf traits using PLSR.

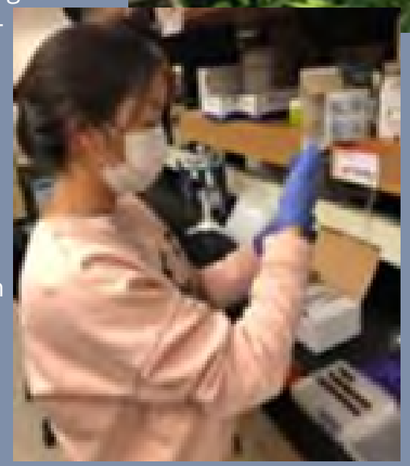


Future Plans

- Integrate multiple layers of stress-specific information using leaf trait predictions and hyperspectral phenotyping for stress-specific decision tree algorithms.
- Two approaches, hyperspectral phenotyping and leaf trait predictions, provide multiple layers of stress-specific information.

Member Company Benefits

- Outcomes that can directly inform potential management decisions involving forest plantation management through more efficient and specific characterization of tree health using remote sensing data.
- This project will be at a national-scale and will be relevant for all industry members.



Stress response measurements

2023 CAFS Phase 3 Progress Report

Resilience of Soil Organic Matter to Harvesting: A Global Study of Long-term Soil Productivity Experiments

Jeff Hatten (OSU), Stephanie Winters (OSU), Kim Littke (UW)

Soil organic carbon (SOC) quantity and quality are linked to important soil functions including nutrient mineralization, aggregate stability, trafficability, and water retention and hydrologic processes. In turn, these soil functions are correlated with a wide range of ecosystem properties that are relevant to forest managers. This project will aim to elucidate the mechanisms that impart resilience to forest SOC after extreme disturbances across a wide range of soils and forest types.

Annual Progress

- Preliminary results suggest that younger labile carbon is mineralized.
- Retaining surface residues maintains labile carbon pools in the mineral soil.
  - The response of soils appears to be regulated by mineralogy.
  - Soil carbon resilience is being derived from retained harvest residues and competing vegetation.

Future Plans

- Lab work and data analysis.
- ID fingerprint of organo-minerals.
- Characterize mineralogy.

Member Company Benefits

- Understand which sites need special care to preserve soil carbon pools.

Project Highlights

Stand Response to Thinning: Enhancing Response Prediction through Modeling

Eric C. Turnblom (UW), Jason C. Cross (UW), Aaron Weiskittel (UM), Cristian Montes (Rayonier), Bronson Bullock (UGA)

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. With this project we propose to build on previous research 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.

Annual Progress

- Fitting the first version of the base (untreated) stand model, some biogeohydroclimatic zones produced significantly different yields.
- The same physiographic regions that have been shown to affect site index, have also been shown to affect yield.
- Refined planting density estimates (survival @ 3y) key to differentiating between treatment yields.
- PCT data sets/data frames built.

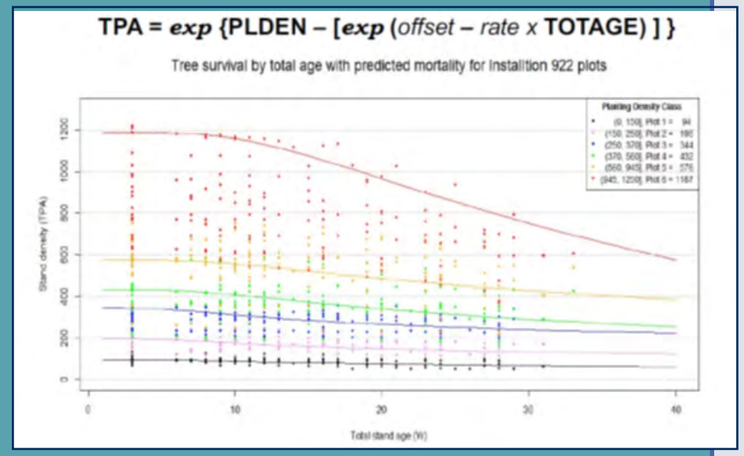
Future Plans

- Simultaneous fitting of trees per acre and basal area to derive quadratic mean diameter
- Extend PYC v2.0 models to incorporate PCT effects, then thinning. Version 2.0: base equations; version 2.1: 2.0+ PCT effect; version 202: 2.1+ CT effect
- Keep opportunities for cross-region collaboration open.

Member Company Benefits

- Standardized framework for stand modeling.
- Improved financial analyses and comparisons of silvicultural treatments (PCT, CT, FERT).

Mortality prediction using Gompertz equation



2023 CAFS Phase 3 Progress Report

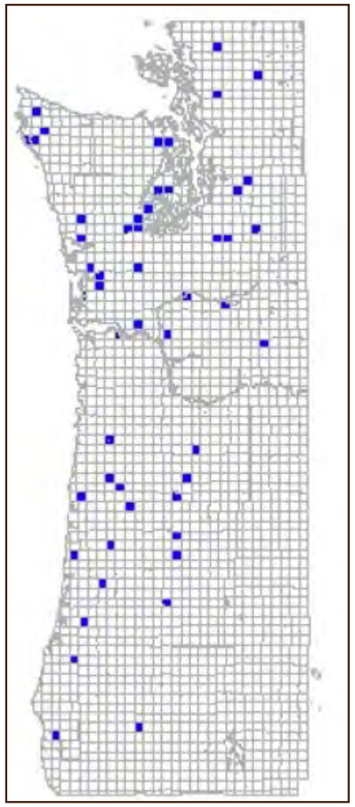
Using Predictive Analytics to Decompose Site Index

Jason Cross and Eric Turnblum (UW)

Site Index is an input in various growth and yield models, whose outputs support millions of dollars' worth of silvicultural decisions that include planting, pre-commercial thinning, and fertilization. Increased quantities of atmospheric carbon dioxide are contributing to changes in the observed ranges of factors once thought to be fixed when index values were conceived. Accounting for the effects of climate change requires investigation into the decomposition of site index into its additive subcomponents. The objective of this project is to verify and validate (elements of) growth & yield models, and improve their parameterization.

Annual Progress

- Automated machine-learning methods for variable selection worked – most remained significant in the model; supplanted by other variables.
- Nelder-mead fitting procedure coded in FORTRAN was reliable, showed performance improvements over R-implementation. Still a computing-intensive process.
- Working on integration of model into SMC's Plantation Yield Calculator.



Future Plans

- Observed relationship between rate and shape parameters indicate a uniqueness and independence to shape. Relationship is robust across age, location, spacing, and natural vs. planted. The largest shape values are fitted on the older, dense stands.
- Tool (Excel spreadsheet+FORTRAN) for determining relative importance of variables within a dataset; can be used for other growth & yield modeling efforts.
- Tool (FORTRAN program) for fitting non-linear model where parameters are linear function of any number of variables.
- Outward-facing web application to predict top-height using a point-and-click mapping program, requiring planting density as an input, alternately accepting age and trees per acre. Range limited to western Oregon and Washington.

Member Company Benefits

- Extended utility for existing growth & yield models.
- Improved accuracy of naive predictions during land acquisition/disposition.

Project Highlights

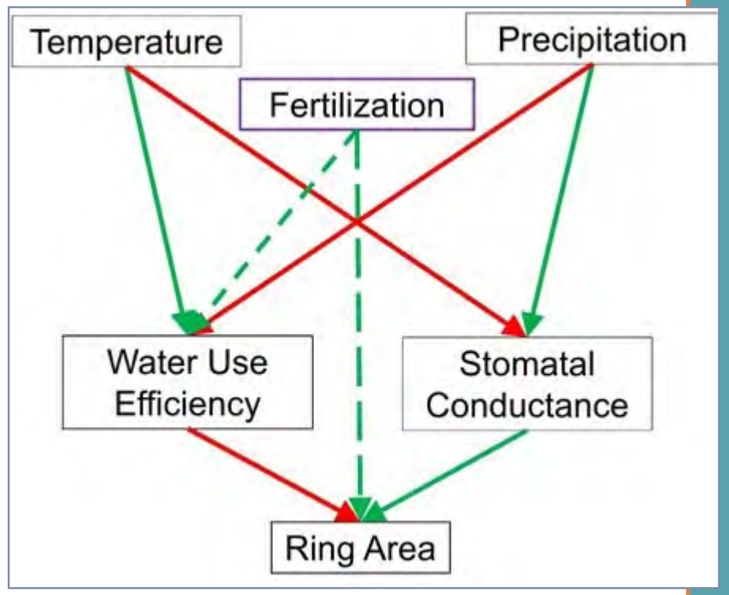
Physiologic Response to Commercial Fertilization Programs in Pacific Northwest Forest Plantations

Eric Turnblom and Kim Littke (UW), Michael Premer (Rayonier)

Forest productivity is commonly limited by site nutrient availability, and deficiencies can result in extended rotations, forest health issues, and ultimately, unrealized volume gain. While fertilization is perhaps one of the most commonly applied silvicultural practices, little is known about the optimal timing and prioritization of lands for nutrient amendments. The goal of this project is to assess the role of silvicultural treatments on terrestrial C sequestration and commodity production across the Pacific Northwest Region of North America and synthesize these findings into management guidelines.

Annual Progress

- 30 installations measured:
  - » Responsive installations (4+ years) grew more from 2-6 years than temporary response (0-2 years) and non-responding installations.
  - » Temporary response installations showed a short-term growth response.
  - » Majority of growth response was in years 1-3 of earlywood.
  - » Latewood growth stayed high for 4 years post-fertilization then decreased in years 5 and 6.
- 29 of 30 installations:
  - » Responsive installations increased earlywood WUE in years 1-4 over non-responsive installations.
  - » There were no differences in dO18 between response types.



Future Plans

- Analyze remaining installation for C and O isotopes.
- Three peer-reviewed publications that reflect each project objective.

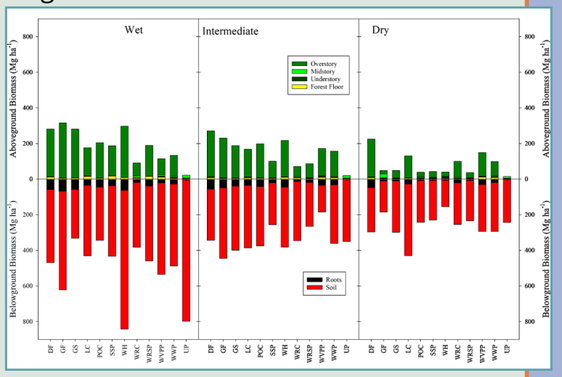
Member Company Benefits

- Recommendations for silviculture under future climate scenarios.
- Improved silvicultural recommendations for Douglas-fir plantations based on physiologic response.

Variation in Productivity, Wood Quality and Soil Carbon of Nine Conifer Species Across a Gradient in Water Deficit

Carlos Gonzalez (OSU), Kim Littke (UW), Jeff Hatten (OSU), Doug Mainwaring (OSU), Maxwell Wightman (OSU), Aaron Weiskittel (UM), Emily Von Blon (OSU)

Climate change is expected to increase average temperatures and shift precipitation regimes, contributing to more severe and widespread disturbances. Higher evapotranspiration demands and the potential increase in water deficit can be detrimental to the growth and survival of tree species in the PNW. Understanding how commercially and ecologically valuable species are sensitive to climate can help to guide species selection and management decisions to enhance stand resistance and resilience to projected climate changes.



Annual Progress

- NPP: Measured diameter and height of all crop trees, understory vegetation (cover, height), and midstory (DBH) in all plots.
- NPP: Measured forest floor (mass) and collected additional soil samples in unplanted plots at all sites.
- NPP: Collected and processed litterfall at all plots throughout the year.
- Diameter growth phenology: Measured dendrometer bands at all plots 4 times throughout year 2023.
- Measurements will ultimately provide more in-depth and long-term results on crop tree and ecosystem growth response to contrasting climate conditions and allows us to capture the effects of inter and intra-annual climate variability.

Future Plans

- ✦ Measure Midstory (DBH) of 1 plot; collect 2 soil samples at each of the remaining plots.
- ✦ Measure dendrometer bands and collect litterfall.
- ✦ Incorporate all information collected in this study into 3-PG forest growth model.

Member Company Benefits

- ✦ Better understanding of the sensitivity of 10 commercially and ecologically valuable species in the PNW in terms of productivity and wood properties, to water deficit and climate variability.
- ✦ Understanding the growth-climate relationship for many alternative species, as well as its impact on wood quality, will help management decisions on species selection for reforestation purposes.
- ✦ Contribute to the enhancement of stand productivity, which can improve resistance and resilience to projected climate changes while serving as a mitigation tactic through increased carbon sequestration.

Project Highlights

Leaf Area Index Estimates to Inform Midrotation Treatments

Modified from "A Neural Network Approach to Generating Leaf Area Index Estimates Using the Sentinel-2 Satellite Record"

Rachel L. Cook (NCSU), Andrew Trlica (NCSU), Aaron Weiskittel (UM), Mark Kimsey (UI), Cristian Montes (UGA), Alicia Peduzzi (UGA)

This project seeks to expand the capability and accessibility of our ongoing modeling work in predicting timber plantation canopy leaf-area index (LAI) using freely available global-coverage satellite data. Leveraging the work completed to date, we seek funding to 1) expand the species range covered by the model, 2) develop a user friendly interface so the results can be accessed and used by the non-specialist, 3) build capacity to predict and map deciduous understory presence, and finally 4) to build a national-scale site potential productivity baseline map for future silvicultural response modeling.

Annual Progress

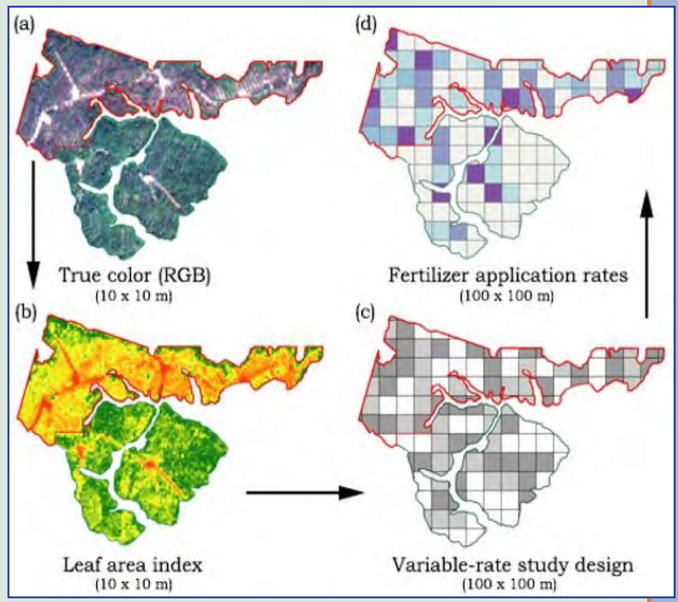
- Deciduous understory: Some success in detecting/calibrating understory; reasonable detection of herbicide release.
- NC: Field measurements + time series of Sentinel-2 LAI and understory metrics.

Future Plans

- ✦ Complete analysis of effects of fertilizer rate, prescription style (LAI vs. random), herbicide.
- ✦ Responses in volume, basal area, height, and LAI.
- ✦ UAV/Aerial LiDAR: further refinement of the Sentinel-2 understory method.

Member Company Benefits

- ✦ Accurate, flexible, accessible tool for LAI estimation can inform forestry decisions.
- ✦ Canopy LAI is critical for stand and substand-level management.
- ✦ Understory LAI is critical for vegetation control.



2023 CAFS Phase 3 Progress Report

Quantifying Silvicultural Treatment Effect on Lumber Quantity and Quality in Loblolly Pine

Joe Dahlen, Anjila Lamichhane, Cristian Montes, & Bronson Bullock (UGA), Corey Green (VT), Tom Eberhardt (USFS)

Even though over 18 billion board feet of southern pine lumber are produced each year from the U.S. south, information on silvicultural treatment impacts on lumber quantity and lumber is very limited. This is because forest through mill studies are difficult to conduct and thus rarely done. This study will investigate the impact of silvicultural treatment on the lumber quantity and quality from loblolly pine from the Forest Modeling Research Cooperative's Regionwide Intensively Managed (IMP) study. The study has 3 treatments, a control treatment with no thinning or pruning, a light thinning treatment where 1/3 of the trees have been removed, and a heavy thinning treatment where 2/3 of the trees were removed and the first log was pruned. Treatments applied when trees reached 40-46 ft.

Annual Progress

- 120 trees felled.
- Logs & resulting lumber tracked (treatment, stand, tree, log, position within log) thru sawmill.
- All lumber pieces accounted for; some lumber destroyed during milling process.
- Delays: lumber imaging systems needs calibration and software tweaks.
- Automated analysis robust for modulus of elasticity.

Future Plans

- Install new encoder on universal testing machine.
- Non-destructive evaluation.
- Destructively test to failure via ASTM standards.

Destructive testing after imaging.

Member Company Benefits

- Lumber quality and quantity information as a result of silviculture from a designed experiment.
- Evaluation on the impacts of 2 thinning regimes relative to no thinning.

Project Highlights

Quantifying Carbon Sequestration as a Function of Silvicultural Treatment in Loblolly Pine

Joe Dahlen, Tilak Neupane, Sameen Raut, Nawa Raj Pokhrel, Cristian Montes, & Dan Markewitz (UGA), Tom Eberhardt (USFS)

There is a growing interest in quantifying carbon sequestered from managed forests. Information is available on silvicultural treatment effects on stem volume for loblolly pine, however information is limited on the carbon sequestered as a function of silvicultural treatment. Original plan to investigate carbon sequestered in the main bole of loblolly pine from the CAPPS study did not work out. Instead, trees from the Intensively Managed Plantation thinning trial will be sampled from 5 of the study sites. The stem volume will be measured, and disks collected at multiple height levels. The amount of carbon sequestered from each tree will be measured annually from the disks such that the total carbon found in the main bole can be quantified annually. The data from the individual trees will be scaled to the plot level.

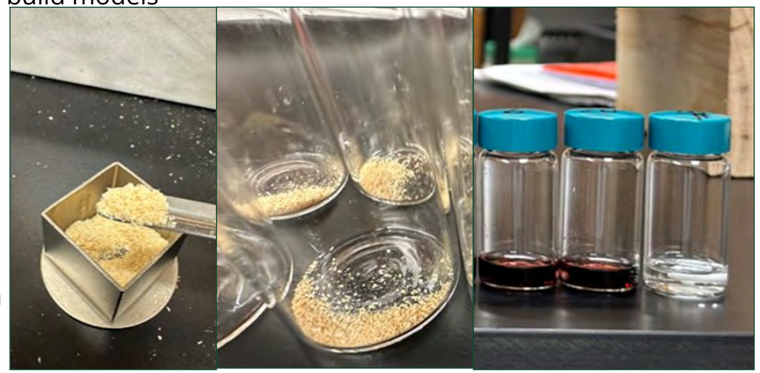
Annual Progress

- Supplementaal reference data with NIR.
- Work progressing to develop extractives, lignin (and cellulose), and carbon % models for loblolly pine.
- Extractives % = dry weight of samples before and after Soxhlet extraction.

Future Plans

- Lignin methodology finalized – samples being run.
- ~90% done with the cellulose methodology.
- Measure carbon %.
- Align NIR data with ring level X-ray densitometry data.
- Predict ring level values and build models

Grind samples being processed to find Lignin %



Member Company Benefits

- Information on carbon stored as a function of silvicultural treatment in loblolly pine.
- Provide preliminary results on the use of a rapid field tool to estimate carbon stored at a stand level when combined with biometric information.

2023 CAFS Phase 3 Progress Report

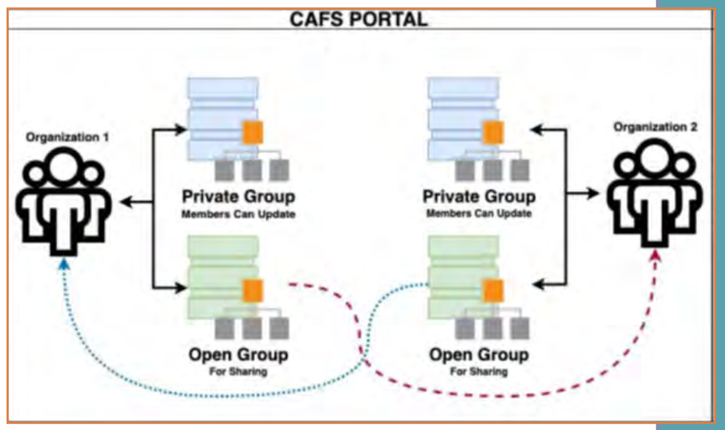
Center for Advanced Forestry Systems Interactive Mapping Platform (CAFS IMP)

Okan Pala and Adem Kurtipek (NCSU)

Our goal is to create a user-friendly internet mapping platform (CASF IMP). Initially, we will work with three CAFS sites to incorporate the layers of interest to the platform The interactive mapping platform we develop will be used to visualize the data extent, location, format as well as data custodian's information for further communication. We are using ArcGIS Online (AGOL) platform for data sharing and collaboration. Through this platform, site coordinators and technicians can have direct access to their data through a password-controlled environment managed by AGOL. They will be able to access, visualize, download, and upload data. Moreover, the users will be able to update their data on the fly without having to download and upload the layers.

Annual Progress

- Evaluation of interactive mapping platforms
  - » Experience Builder: Newer technology-less pre-developed tools
  - » WebApp Builder: Older technology-more pre-developed tools.
- Portal Interface: Single interface for info and latest data layers.
- Portal data sharing protocol: open groups for sharing, private groups for collaboration/testing within organizations.



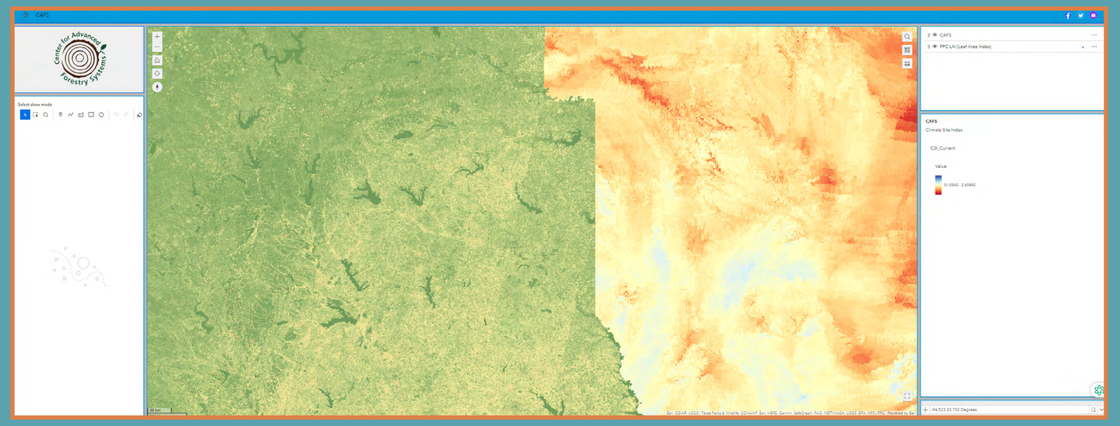
Future Plans

- ✦ Complete evaluation & training/transfer phases.
- ✦ Finalize the technology selection: Experience Builder v. WebApp Builder.
- ✦ Implement secure folder sharing from the portal with an industry partner.
- ✦ Implement new features on the WebApp (raster analysis, direct data export, additional functionality based on need).

Member Company Benefits

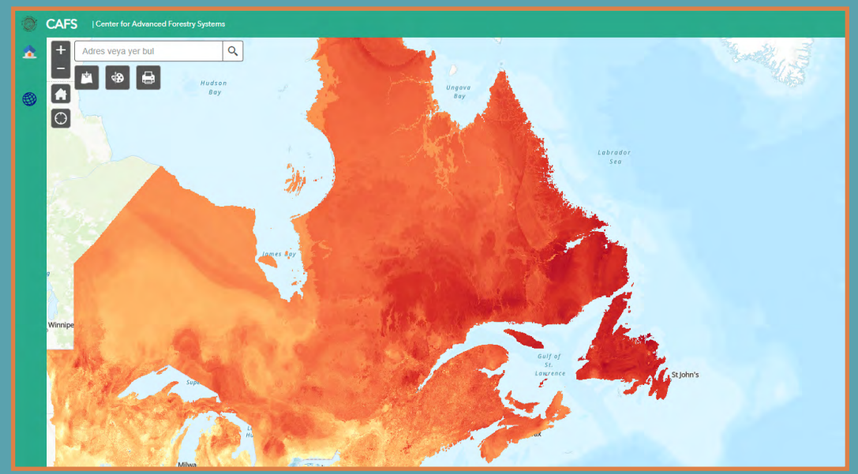
- ✦ Ultimately, CAFS IMP can be used to communicate and visualize the site data with ease, increase collaboration among CAFS sites and provide ease for data finding, and

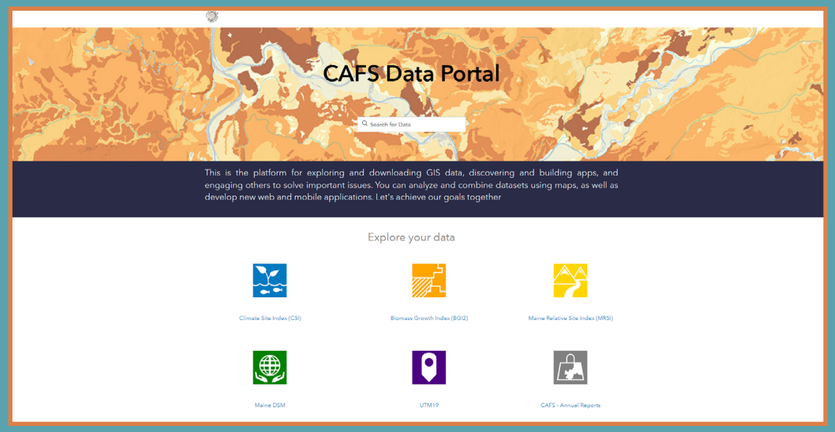
Project Highlights



Above: Screen shot of Experience Builder: Interactive mapping platfrom options 1

Right: Screen shot of WebApp Builder: Interactive mapping platform option 2





CAFS Portal Interface: Info & latest data layers

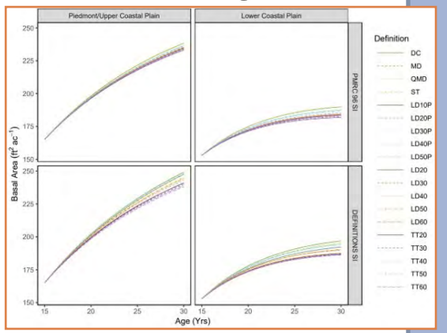
The Effects of Dominant Tree Height Definition on Loblolly Pine Growth and Yield Model Outputs in the Southeast U.S.

Bronson Bullock, Caddis Fulford, Cristian Montes (UGA), Rachel Cook (NSCU), Temesgen Hailemariam (OSU), Eric Turnblom (UW), Aaron Weiskittel (UMaine)

The project will examine the implications derived from different dominant tree height definition usages on growth and yield models. This will also include highlighting any statistical significances between different dominant height definitions and silvicultural treatments (e.g., thinning), stand conditions (e.g., density), and physiographic regions. Additionally, the project will investigate how Net Present Value (NPV) estimations may vary based on dominant tree height definition.

Annual Progress

- There is no single designated definition for dominant tree height in the southeast US (or internationally). Examined the variables 'dominant height' and 'site index' on growth & yield model outputs.
- 19 definitions evaluated:
  - Dominant & Codominant crown classes (DC)
  - DBH > Mean Diameter (MD)
  - DBH > Quadratic Mean Diameter (QMD)
  - Best Sawtimber potential class (ST)
  - 10-50% Largest DBH (LD**P)20-60 Largest DBH TPA (LD**)
  - 20-60 Tallest TPA (TT**)
- Growth and yield model outputs guide silvicultural management and timberland investment decisions.



Future Plans

- Evaluate the impacts on projected green weight & merchantable product classes.
- Repeat simulations with thinning (90, 70, & 50 ft^2 ac^{-1}) and thinning+fertilization.
- Rank definitions based on fit statistics and characteristics.
- Assess the impact on rotation age for maximizing economic returns between the best definition(s) and worst(s).

Member Company Benefits

- A greater understanding of the impacts of dominant tree height definitions on growth and yield model outputs for loblolly pine plantations.
- Highlight potential influence on financial investment decisions as a result of the variability between different dominant tree height definitions.

Project Highlights

2023 Project Starts

Density Management Strategies for Enhancing Carbon Sequestration in U.S. Working Forests

Mike Premer (UMaine), Eric Turnblom (UW), Kim Littke (UW), Rachel Cook (NCSU), Andrew Nelson (UI), Bronson Bullock (UGA)

The role of forest ecosystems as a natural climate solution, specifically C sequestration and storage, has been widely recognized across the forested regions of North America. Working forests offer potential for C sequestration-oriented management as these settings are already intensively managed for commodity products, and, in turn, long-term C storage. This project aims to assess the role of silvicultural treatments, specifically stand density management, on terrestrial C sequestration and forest growth utilizing existing research networks and to synthesize these findings into management guidelines and basis of future research.

Annual Progress

- Grad student recruited and active.
- Initial round of sampling in Maine complete: 2/6 Maine sites sampled.
- Water deficit products generated for the region at 20 m resolution.

Future Plans

- Tree rings will be processed at Forest Ecology Lab at UMaine.
- Completion of field sampling of remaining sites.
- Ring isotope processing will be conducted at Columbia University.
- Extend to the PNW and SE.

Member Company Benefits

- Synthesize the quantification and assessment of observed correlations between stand structure, edaphic variables, and thinning physiologic response into regional silvicultural recommendations for working forests.
- Improve silvicultural recommendations for density management for major conifer species across the U.S.

Site-Stand Dynamics and Pine Beetle Mortality in Ponderosa Pine Ecosystems: Implications for Density Management

Mark Kimsey Jr., Haley Andeson, Steve Cook (UI)

The goal of this project is to develop a companion ponderosa pine SDImax model that is sensitive to stressors that precipitate pine beetle (WPB, MPB) mortality outbreaks. These stressors may or may not coincide with traditional density management thresholds that are associated with density dependent related mortality. It is critical to develop a more granular understanding of which site and stand variable combinations contribute to pine beetle outbreaks across spatial and temporal scales. Spatially and temporally explicit models that identify at risk pine ecosystems will enable targeted and timely treatment prescriptions for creating resilient forests.

Annual Progress

- Data acquistion for western pine beetle model.

Dataset	Relevant Information
USFS Insect and Disease Detection Surveys	Outbreak year, spatial footprint, outbreak size, presence of other insect/disease agents within outbreak footprint
GSSURGO	Available Water, Soil Organic Carbon, Lithology, Depth to Restrictive Layer
ClimateNA	Mean annuals (Temperature, Precipitation), 30-year normals (Temperature, Precipitation)
Various sources	Elevation, slope, aspect, latitude, Topographic Wetness Index, Heat load
USFS LiDAR Products	SDI, Basal Area

Future Plans

- Western Pine Beetle: Identification of size/density thresholds for mountain/western pine beetle; Determination if and at what point in stand development climatic conditions induce pine beetle outbreaks; Determination if climate change indicates shifts in pine carrying capacity as a function of site type and species composition; A western/mountain pine beetle management guide.
- Southern Pine Beetle: Collect available pine beetle outbreak data; Utilize available remotely sensed imagery (GEE) to correlate site/stand factors at 30-meter pixel scale (temperature, precipitation, NDVI; Utilize in situ plot data to correlate to site/stand factors at stand scale (density, species composition).

Member Company Benefits

- Potential time and cost savings by reducing large-scale mortality from pine beetle epidemics, and more resilient forest stands. Density threshold modifiers for existing SDImax models that incorporate pine beetle epidemic risk factors.

Project Highlights

Enhancing Resistance to Fungal Pathogens in Commercial Tree Species

George Newcombe and Abby Ferson-Mitchell (UI)

During a CAFS-NSF funded internship in 2022, a study was conducted testing endophytic treatments on susceptible seed of three tree species: western white pine (WWP), Port-Orford-cedar, and Hawaiian koa, all commercially valuable species and of concern for restoration efforts due to devastation caused by pathogens. Three endophytic treatments were put to the test against the respective pathogen system (i.e., white pine blister rust; cedar root disease; koa vascular wilt); in the case of WWP, two Bacillus treatments stood out as having a significant reduction in disease severity. In this new study we plant to retest the repeatability of the significant findings, and expand the project by including commercially planted 'resistant' varieties (e.g., WWP Bingham F2 lot). WWP Bingham F2 lot has demonstrated between 70-80% survival in some stands and about 33% or less in other stands due to white pine blister rust. The overall goal of this study will be to enhance survival and reduce disease severity in 'resistant' and susceptible varieties to improve out-planting success as seedlings are still often the preferred method to stand establishment over natural regeneration.

Annual Progress

- Seed treatments and sowing for WWP and Port-Orford cedar.
- Pathogen inoculations for WWP.
- Data collection Koa.

Future Plans

- Koa: Innoculate koa seedlings with bacterial endophytes; sow germinated seedlings into FOXY inoculated soil; begin collecting daily mortality data.
- WWP: Begin disease severity scoring: bacterial treatment v. water control; susceptible seed v. resistant seed sources; high spore density v. low spore density.
- Port-Orford cedar: inoculate with pathogen, testing 3 factors: bacterial treatment v. water control; susceptible seed v. resistant seed sources; homogenization risk with inoculation method.

Member Company Benefits

- Results could be used to improve survival of out-planted resistant varieties in different ecoregions, reducing the cost and effort for reforestation following a failed plantation in areas impacted by low-medium-high pathogen loads.
- The results may also be used to improve survival of genetic families that lack genes for resistance but have other desirable traits for commercial use (e.g., hardiness, timber quality, fast growth).
- Results may also be used to inform tree improvement programs.

2023 CAFS Phase 3 Progress Report

Determination of Crown Morphological Traits Using Laser Scanning in Douglas-fir and Loblolly Pine Genetics Trials

Doug Mainwaring (OSU), Sukhyun Joo (OSU), Rachel Cook (NCSU), David Carter (VT)

Intensive sampling of genetically selected trees has identified specific heritable crown attributes associated with enhanced individual tree growth, including short branch lengths, high leaf area density per unit crown length, and narrow crowns. The objective of this project is to collect laser-scanned data from pure-family plantations to develop an algorithm for identifying specific crown characteristics associated with enhanced growth, and to apply these protocols within progeny test trials to identify candidate families for additional ground-based measurements. All measurements will be used to produce multipliers/modifiers to account for specific crown characteristics within growth and yield models.

Annual Progress

- Collect drone-based 450 ppm laser scans of pure family blocks at three western Oregon sites containing improved stock.
- Analyze point cloud, develop algorithm for identifying traits of interest.
- Measure pure family blocks of interest at three sites, collecting data on dbh, height, HCB, and two crown widths on each tree.

6'x6' production of laser scans and orthomosaics

Future Plans

- Link tree-level estimates from point cloud to individual trees
- Complete tree measurements
- Assess ideotype-level differences in max crown width/largest crown width
- Test for crown trait-adjustments to pertinent G&Y equations: diameter increment, height to crown base, and crown recession
- Simulate pure-ideotype plantings and assess the implications

Member Company Benefits

- First iteration of growth model adjustments to account for genetic differences in crown traits.
- Ability to test for the benefits of growing Douglas-fir in ideotype plantings.
- An algorithm for aerial detection of crown traits within progeny tests, realized gain trials, and plantations.

Project Highlights

The Interplay Between Sampling Design and Small Area Estimation to Improve Forestland Inventory

Temesgen Hailemariam (OSU), Aaron Weiskittel and Mike Premer (UM), Rachel Cook (NCSU), Phil Radtke and Corey Green (VT)

One of the challenges often faced in forestland inventory/valuation is estimating gross and net merchantable volume for smaller areas of interest consisting of delineated stands within a larger forested population or ownership. This project has three sets of objectives: (1) examine variable selection methods for developing small-area estimation models that link inventory plots and remotely sensed data for timberland inventory; (2) examine the performance of selected sampling designs and sample sizes for applying SAE models. In that, we seek to examine the use of small-area estimators to either reduce sample size when precision is given or improve precision when the sample size is fixed; and (3) allocate sample size to subpopulation, including optimal allocation of samples in small domains.

Annual Progress

- PhD student recruited.
- Data collected in Western Oregon
  - » Individual inventory plot summarizations, stand summarizations and polygons
  - » Sentinel data, including mean reflectance values and additional variables derived from sentinel data sets
- Began literature review and identify variable selection/reduction methods for estimating stand volume and site index from climate, terrain, and remotely sensed data.
- Examine different number and combinations of variables and reduce the number of variables before selecting a final set of variables.

Future Plans

- Complete literature review and data compilation for other key regions.
- Develop sampling protocols to link remotely sensed data and ground data/attributes to reduce uncertainty and improve the quality of small-area estimates for timberland inventory.
- Translate some of the theories in small-area estimation to practices.

Member Company Benefits

- Member companies borrow strength from the freely available remotely sensed and ground data and reduce the costs of data acquisitions. They will benefit by reducing the cost of establishing ground plots and improving the estimation and prediction of selected stand variables, including gross and net merchantable volume.

2023 CAFS Phase 3 Progress Report

NSF Supplemental Funding Programs

A number of the CAFS sites have successfully applied for supplemental funding from NSF to help advance the readiness of the STEM workforce to acquire core professional competencies and skills that will support careers in any sector of the U.S. economy. Details of these projects are provided in the following pages.

INTERN
Non-Academic Research Internships for Graduate Students

INTERN grants provide supplemental funding for graduate students to gain knowledge, skills and experiences that will augment their preparation for a successful long-term career through an internship in a non-academic setting. It provides an opportunity for grad students to pursue new activities aimed at acquiring professional development experience that will enhance their preparation for multiple career pathways after graduation.

START
Skills Training in Advanced Research & Technology

Funding supports students, faculty and faculty/student teams from 2-year institutions of higher education in gaining experience working on state-of-the-art, industrially driven IUCRC research projects at IUCRC sites. The program benefits may include alumni and peer support; paid, credit-based internships; and forest research experiences at CAFS university sites.

INTERN: Tree Dominance from Remotely Sensed Data

Mark Kimsey and Noel Daugherty (UI)

This project, which began in 2022, will obtain multiple, high point-density datasets from photogrammetric and LiDAR remote sensing acquisitions across a variety of site and stand conditions, all paired with GPS stem-mapped forest plots, relative to three different US regions: Pacific Northwest, Northern Rocky Mountains, and Southeast. The goal is to evaluate differences in remote sensing platforms to detect and accurately measure tree crown metrics and their relationship to tree dominance, and to evaluate the accuracy of remote sensing platforms to detect change in tree and stand growth over short temporal periods and varying site productivity types.

INTERN Research Experience

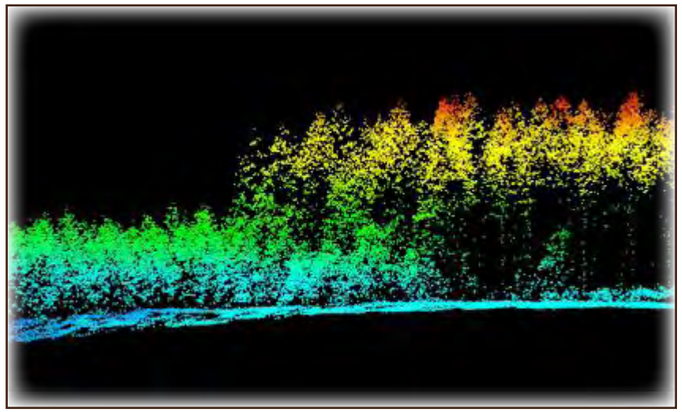
- Field and high density field collection to create a remotely sensed dominant tree list.
- Data processing, analysis & reporting.
- Compare traditional and remotely sensed tree lists.

Future Plans

- Assess implementation of growth and yield models with multitemporal remotely sensed data.
- Assess the accessibility and ease-of-use of remotely sensed forest areas and the programs used to derive forest inventory metrics

Member Company Benefits

- Potential for implementation of growth and yield models with multitemporal remotely sensed data.
- More accessible remotely sensed forest inventory metrics.



LiDAR remote sensing generates a digital 'point cloud' that visualizes tree cover and the elevation details of the bare earth. USDA Forest Service photo.

2023 CAFS Phase 3 Progress Report

START: Internship & Field Experience Program

Rachel Cook and Andrew Trlica (NCSU)
Dylan Hurley, Montgomery Community College
Jim Brodie, Wayne Community College

Partnership with Montgomery Community College and Wayne Community College to offer paid internships/field experience with CAFS member company and CAFS research experience at NC State. Focus on GIS and remote sensing, with an emphasis on first-hand experiences. Goal is to create pipeline to the NC State forestry program that might lead to graduate school studies or employment with CAFS industry members.

Internship Experiences

- MCC student Drew Martin, internship with North Carolina Forest Service working on using Survey123 to digitize NCFS field data for best management practices.
- MCC student Eli Kelly, internship with Manulife, Remote sensing analysis: midrotation response to vegetation control x variable rate fertilization.
- WCC student Mallory Leblanc, internship with Weyerhaueser, Comparable site selection using GIS and coastal prediction models for future application.
- WCC student Michael Farmer, internships with NC State & Manulife, NC ground data: Midrotation fertilizer rate x herbicide.




Project Highlights

START: University of Maine & University of Maine at Fort Kent

Aaron Weiskittel and Nicole Rogers (UM)
Ned Rubert-Nason and Neil Thompson, University of Maine Fort Kent

Partnership with University of Maine Fort Kent's 2-year technical college to support a two-year project working toward a better understanding of commercial tree responses to stress. Working with faculty from UM and UMFK, internships will encompass lab sampling and field work, including using hyperspectral imaging to assess tree health, determining the effects of microclimate on forest health and regeneration, and estimation of wood moisture content. CAFS funded three student interns, and indirectly supported 10+ undergraduates since 2021. CAFS also sponsored travel by 2 UMFK faculty to attend the 2023 conference in Louisville, KY.


Experiences

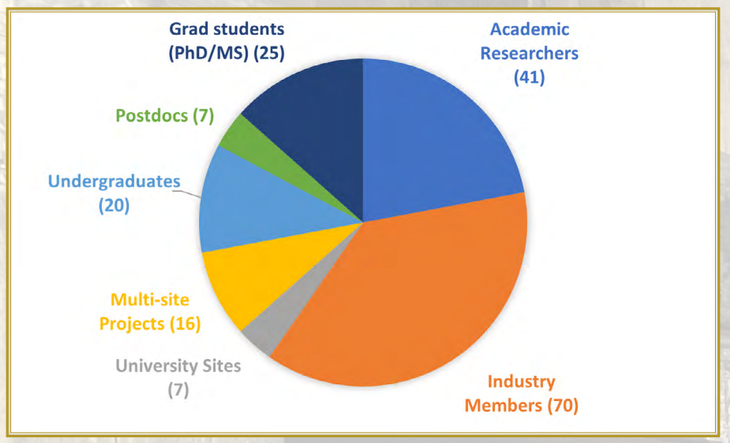
- Develop computational model for health assessment of *Populus* and *Picea* trees from hyperspectral images. All field data collected, >90% of lab analyses complete, Geospatial analysis and predictive model creation underway. *Skills:* Tree measurement, specimen collection, phytochemical analysis.
- Identify climactic variables that influence tree health and regeneration. All climate monitoring stations installed & operating; FIG plots established & surveyed; pilot sites established for studying cedar tree decline. *Skills:* Climate monitoring equipment installation, FIG surveys, physiological and phytochemical measurements, tree health assessment.
- Develop computational model for using NIR spectroscopy to rapidly estimate wood moisture content. ~50 wood core samples collected, scanned and analyzed for moisture content; predictive algorithm developed; scientific paper in preparation. *Skills:* Operate portable NIR spectrometer, tree coring, gravimetric analysis.
- *Transferrable skills:* Communication, innovation, critical thinking, and leadership

Future Plans

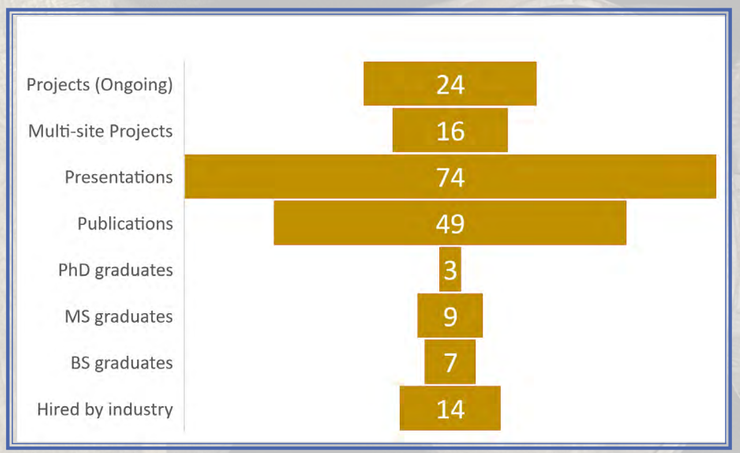
- Finish laboratory analysis & data curation.
- Continue data collection and establish long-term database.
- Investigate causes of cedar decline.
- Fund undergraduate learning network.

2023 CAFS Phase 3 Progress Report

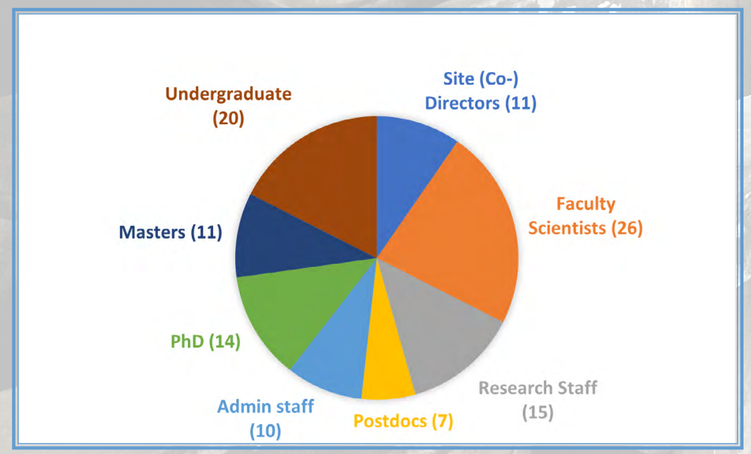
CAFS Snapshot



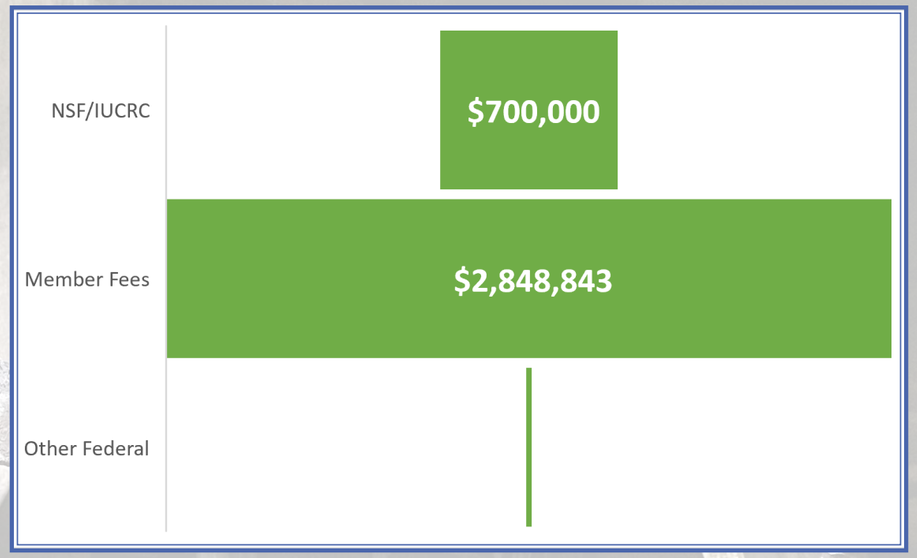
Outcomes



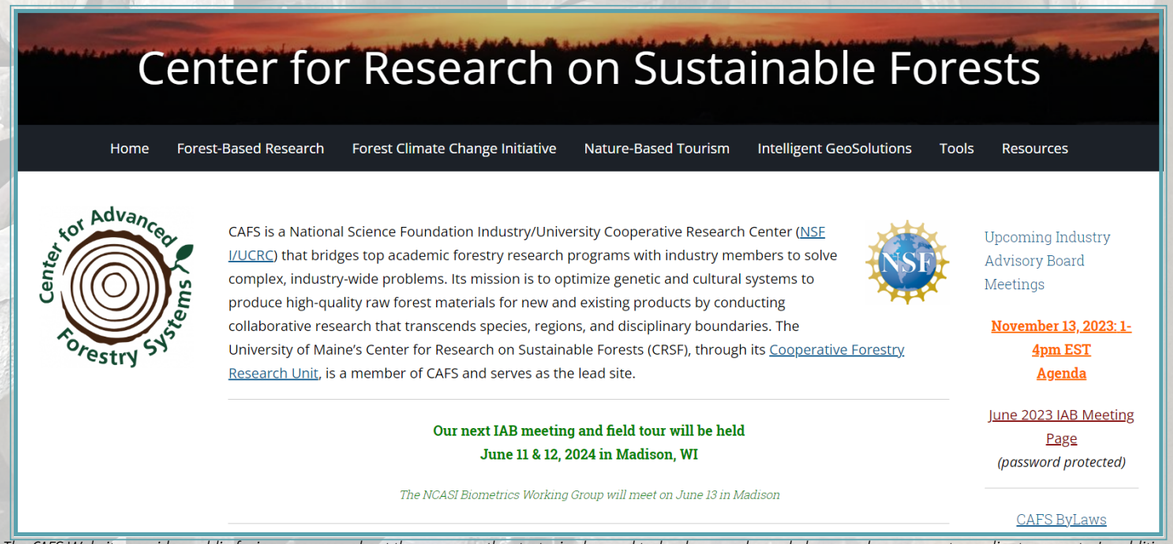
Research Personnel



CAFS FUNDING SOURCES



crsf.umaine.edu/forest-research/cafs/



The CAFS Website provides public-facing resources about the program, the strategic plan and technology roadmap, bylaws, and assessment coordinator reports. In addition, password-protected meeting pages provide a vital resource for industry members and researchers to access project updates and internal advisory board materials.

Center for Advanced Forestry Systems

November 16, 2022

This letter serves as certification that the Center for Advanced Forestry Systems' Industrial Advisory Board approves the National Council for Air and Stream Improvement, Inc. (NCASI) as an in-kind secondary member of the IUCRC Phase 3 effort.
NCASI provides external financial assistance, helps to prioritize industry research needs, and provides a strong linkage to other nationwide industry-supported research efforts.

Dale Hogg
Co-Chair
CAFS IAB Executive Committee
Green Diamond Resources

Tom Trembath
Co-Chair
CAFS IAB Executive Committee
Forest Investment Associates

Aaron Weiskittel, Director
crsf@maine.edu
crsf.umaine.edu
207.581.3794

CAFS Phase III projects address national and regional technological challenges with research questions aimed at specific multiple spatial and temporal scales, including molecular, cellular, individual-tree, stand, and ecosystem levels.


Center for Advanced
Forestry Systems