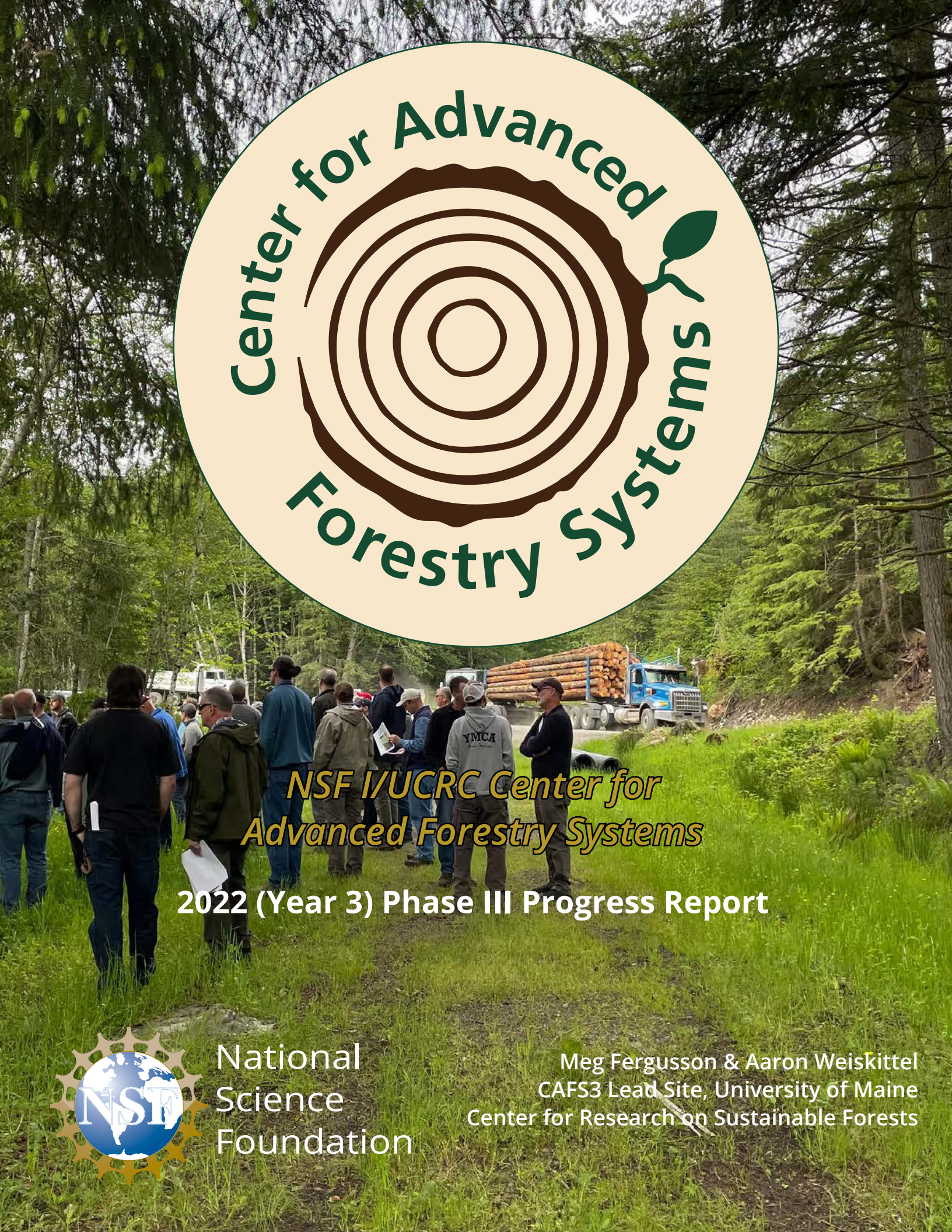


NSF I/UCRC Center for Advanced Forestry Systems

2022 (Year 3) Phase III Progress Report

National Science Foundation

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

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

Over the past year, the National Science Foundation's Center for Advanced Forestry Systems (CAFS) crossed the midway point on Phase 3 and I believe our current strong momentum will propel us towards eventual successful graduation as an Industry-University Cooperative Research Center (IUCRC). This past year also represents my fourth year as CAFS Director and I would like to express appreciation for the University of Maine's continued support for our serving as CAFS Lead Site since 2018, which has placed additional administrative burdens on this small yet growing cooperative. Ever since I arrived to the University of Maine in 2008, CAFS has provided an important opportunity for me to engage with both researchers and forest industry representatives across the US. I am committed to providing that same opportunity for others, particularly as both universities and the forest industry transition to the post-pandemic world of 2023.

This year we were able to get back to business as usual with our first in-person Industry Advisory Board (IAB) meeting since June 2019. It was a delight to be back in the Pacific Northwest and we could not have picked a better spot than the beautiful Salish Lodge, which is situated right next to the infamous Snoqualmie Falls and inspiring surrounding forests of towering Douglas-fir. Both the indoor and outdoor portions of the IAB meeting were very productive. The meetings were well attended, attendees were delighted to reconnect after endless virtual meetings, and we welcomed several new faces. Although the virtual world made organizing and hosting large meetings like the CAFS IAB relatively easy, there are certain limitations that made meaningful interactions and open discussions difficult. Plus, it is important for both CAFS researchers and industry members to see the different challenges each region actually faces on the ground. Additionally, we very much appreciate the University of Washington, Washington Department of Natural Resources, and Manulife Global for their great help on putting on an engaging field tour.

The current research happening within CAFS is exciting, highly collaborative, and forward thinking, particularly as new and powerful technologies continue to emerge. As I reflect on the midpoint of this award, our IAB-approved research projects continue to grow yet they all still embrace and address critical knowledge gaps or needs identified in the technology/research roadmap that was developed in 2019. In a recent meeting with the CAFS IAB Executive Committee, we noted particular research areas like remote sensing and small area estimation that they would like to see addressed through collaborative research projects in the remaining two years of Phase 3. This feedback and knowledge will help prioritize future collaboration and projects to ensure successful outcomes that can help launch CAFS following NSF's support. This is a true team effort and continuing to create the opportunity for effective industry-university collaboration is critical.

Due to CAFS' long history with NSF and high number of both university sites as well as IAB members, the NSF Office Inspector General recently selected us as one of the first IUCRC to receive a formal intensive audit, which officially started in September 2022 and is expected to continue into early 2023. Given the general complexity of IUCRCs and NSF's high expectations for them, this audit process has been a rather enduring ordeal yet we have been able to provide all the required documentation and justification for Phase 3. This has also been a great opportunity to reflect on how CAFS has operated and find better ways of doing things, which we hope to effectively implement in 2023. The experience has also made me truly grateful for the wonderful support staff that CAFS continues to benefit from, particularly our current Communications and Coordinator, Meg Fergusson. I could not have accomplished half of what we have set out to do in Phase 3 without her continued support and hard work.

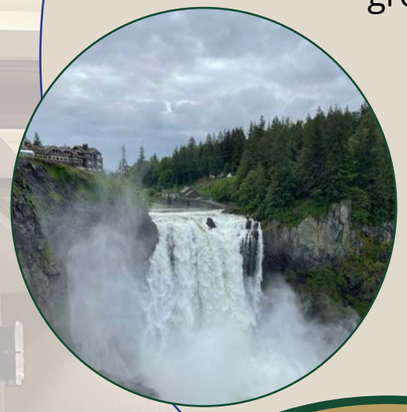
I am delighted to highlight the many key accomplishments and outcomes from CAFS' Phase 3 in this center annual report. I look forward to the continued collaborations and evolution of this organization.

Aaron Weiskittel
Director, Center for Advanced Forestry Systems
Director, University of Maine Center for Research on Sustainable Forests

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

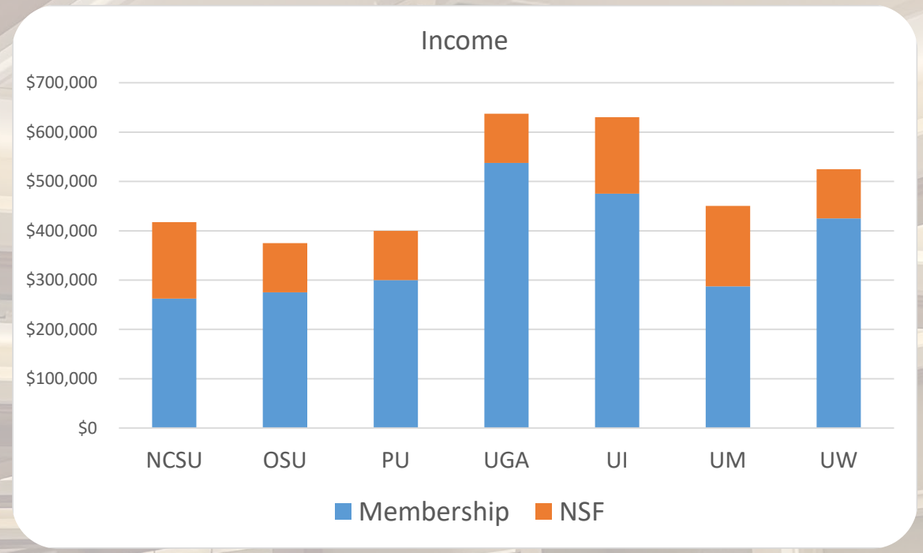
After 2 years of delays due to Covid-19 restrictions, UMaine reconvened the in-person internal advisory board (IAB) meeting format in June 2022 for project progress updates and stakeholder interaction. Nearly 60 site directors, industry representatives, and researchers attended the IAB and field tour held in WA this past year.

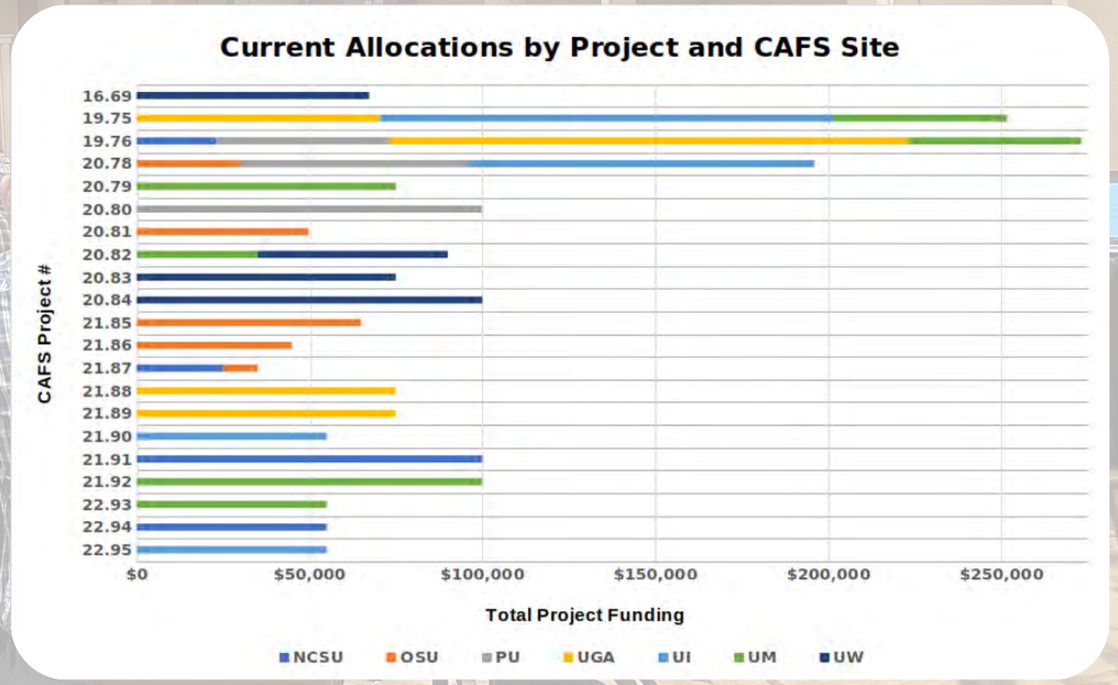
Research

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.

FY22 Budget

$2.5M in contributions across 7 sites and 84 primary and secondary IAB members



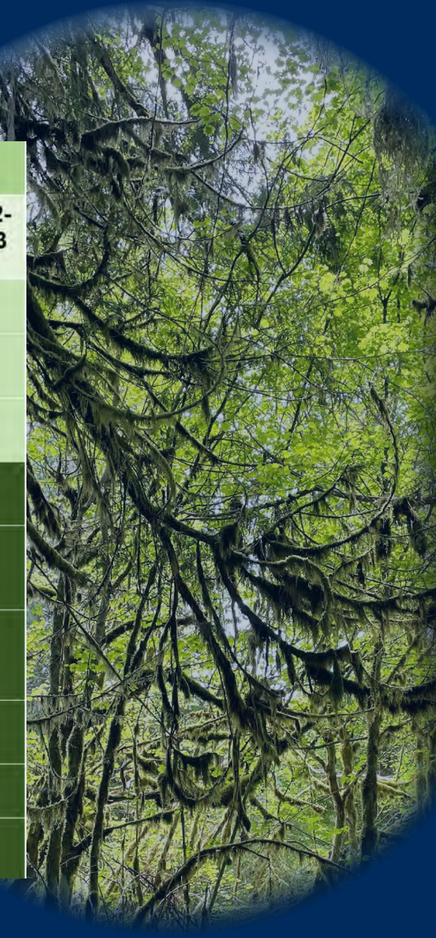


Phase 3 Technology Roadmap

	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	■	■	■	■	■



2022 IAB Attendance Summary

	June 2022 IAB Meeting				October 2022 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	9	15	3	3	6	7	4	-
University of Idaho	8	9	4	0	2	2	4	1
University of Washington	16	27	4	0	3	3	3	-
NC State University	2	2	1	4	3	3	1	1
Oregon State University	15	25	5	3	4	4	3	3
Purdue University	4	4	5	6	4	5	3	2
University of Georgia	18	25	2	2	3	3	2	2

Highlights

2022 Marked the Return to Our Annual In-Person IAB Meetings

- Held in Snoqualmie, WA, in June 2022
- 46 industry members and researchers attended in person; additional 14 joined remotely
- Held in conjunction with the National Council for Air and Stream Improvement (NCASI) Biometrics Working Group
- Full day of expanded project updates (see summaries in this report) and industry-researcher interaction

Research Priorities:

- Forest Modeling & Decision-Making Tools
- Effective use of Remote Sensing Technologies
- Improved Silvicultural Practices
- Incorporation of Advanced & Emerging Technologies
- Synthesis of Regional Datasets

- Presentation and discussion on the substantial erosion of forest resource R&D capacity over past several decades and 2020-21 summit on strengthening R&D for US forests and forest products
- Reminder of NSF supplemental funding opportunities (see INTERN and START projects in this report)

Field Tour Highlights:

- Operational LiDAR/Digital Forestry on Manulife Lands
- Federation Forest State Forest: History & Habitat, Digital Soils Mapping
- WA DNR Installation: Digital inventory, Early Stand Management

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 2021-22
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	Continuing
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
OSU*	Mainwaring	21.86 Stem form of nitrogen fertilized Douglas-fir trees	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
UI	Kimsey et al.	21.90 UI INTERN: Improving forest sample estimation through UAS canopy structure stratification	Continuing
NCSU	Cook et al.	21.91 NCSU START: NSCU & Montgomery Community College	Continuing
UM	Weiskittel et al.	21.92 UMaine START: UM & UMaine at Fort Kent	Continuing
UM	Weiskittel et al.	22.93 UMaine INTERN: Common Field Merchandising Methodologies on Sawlog Volume and Product Recovery	New (1 year)
NCSU	Cook et al.	22.94 NCSU INTERN: Soil Phosphorus Availability	New
UI	Coleman	22.95 UIdaho INTERN: Improving tree seedling survival with defense-enhancing endophytes	New
MCC	Little et al.	22.96 UM START: Monroe Community College	New

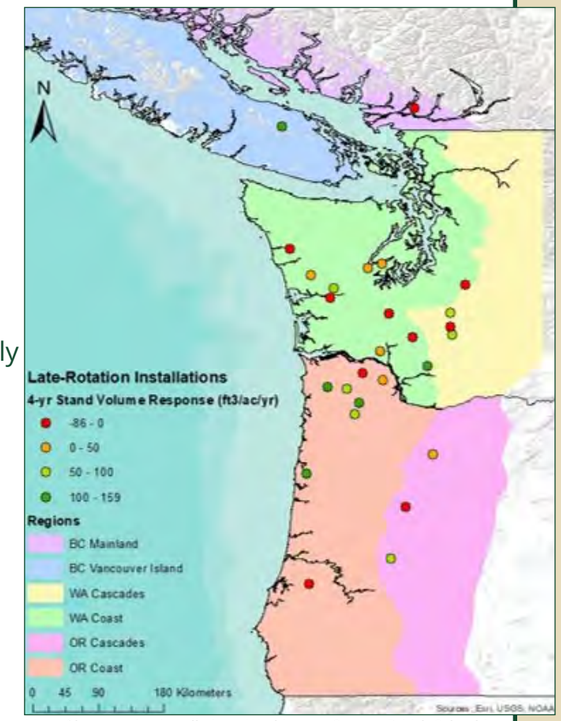
Stand and Tree Responses to Late-Rotation Fertilization

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.

Year Six Progress

- 30/34 installations measured for four-year response.
- 4 installations measured for six-year response.
- Combined paired-tree, late-rotation, and other SMC installations and compared predicted responsive and non-responsive regions.
- Predicted response regions contained significantly lower PRS NO_3, foliar N, and site index:
  - Greater forest floor and surface soil C:N ratio and tree volume response.



Map of late-rotation installations, Washington, Oregon, British Columbia.

Future Plans

- Remaining 4 installations in BC will be measured for four-year response in Fall 2022.
- Four new installations will be established by Spring 2023.
- Spring 2023: Prepare manuscript 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

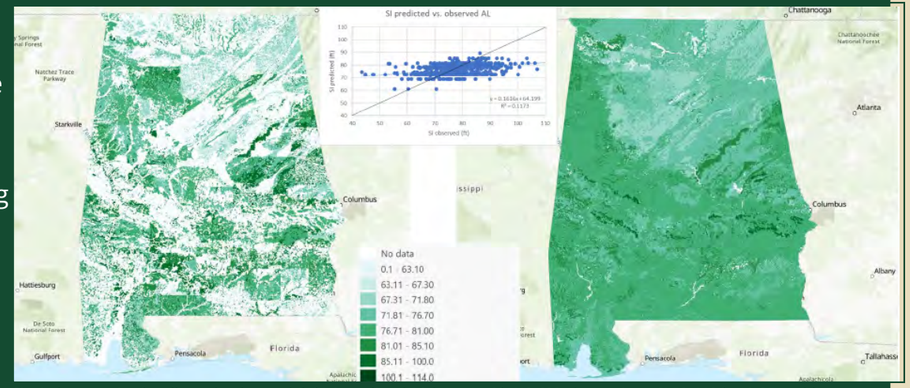
Assessing & Mapping Regional Variation in Site Productivity

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.

Year Three Progress

- Data gathering and compilation of forest soil map units and available stand data.
- Site index mapping in progress.
- Spatial modeling and model comparisons of site productivity and drivers.
- Results show strong climatic effects.
- Uncertainty in stand projections determined and modeled as well, showing uneven uncertainty values across the southeast U.S.



Site index mapping for all stands, observed (left) & predicted (right), +/- ~9ft (13,622 observations, SI 50-110 ft, 10-35 yr old).

Future Plans

- Develop web-based interface of base and potential site productivity.
- Include steady state LAI map as one of the predictors.

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.

2022 CAFS Phase 3 Progress Report

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

Mark Kimsey (UI), Jaslam Poolakkal (UI), Cristian Montes (UGA), Rachel Cook (NCSU), Aaron Weiskittel (UM), 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.

Year Three Progress

- Post-doctoral research scientist hired who is harmonizing industry/FIA datasets and associating site characteristics to these stand inventory records.
- Database draft.

From 3DEP 1 arc-second dataset from the USGS's 3D Elevation Program		Spatial Resolution
1	30 meters (1 arc-second) elevation	30 m
2	30 meters (1 arc-second) Slope	
3	30 meters (1 arc-second) Aspect	
4	Sin (Aspect)	
5	Cos (Aspect)	
6	Tan (Slope)	
7	Tan (Slope) * Cos (Aspect)	
8	Tan (Slope) * Sin (Aspect)	
9	Topographic Wetness Index	
10	Solar Radiation	
From USGS_SGMC_Geodatabase		
1	Lith1	~1:250K
2	Lith2	
3	Lith3	
4	Total_Lith	
	etc.	
From ClimateNA		
1	33 Bioclimatic variables	1km
2	48 Monthly variables	
From gSSURGO		
1	Soil organic carbon	30m
2	Available water storage	
3	Crop productivity indices	
4	Crop root zone depths	
5	Available water storage within crop root zone depths	
6	Drought-vulnerable soil landscapes	
7	Potential wetland soil landscapes	

National level physiographic datasets

Future Plans

- Finalize SDImax datasets by end of 2022.
- Begin SDImax model development, prioritizing Pacific southwest, southern US and northeastern US.
- Begin looking at pine beetle mortality incidence as a function of climate x density x site characteristics.

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), Andrei Toca (Purdue)

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.

Year Three Progress

- Simulated outplanting experiment work is ongoing to refine the models to quantitatively analyze the point cloud 3D models obtained through X-ray CT scanner of the roots system and apply them to each of the seedlings in the experiment to quantitatively evaluate the effects of the nursery drought treatments on three-dimensional root egress and architecture.
- Field experiments on effect of drought conditioning on root and shoot development varied among species (species x treatment interaction) for all measured variables; species showed significant differences in post-planting growth.

Controlled Environment Phenotyping Facility at Purdue University.

Future Plans

- Data from simulated outplanting experiment will help evaluate the effects of drought conditioning on the development of new roots and its cascading effects on seedling hydraulic conductance and photosynthetic rate of forest tree species.
- Data from the three experiments: Outplanting, Simulated outplanting and Digital phenotyping through X-ray CT is currently being analyzed and the manuscripts are under development.

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.

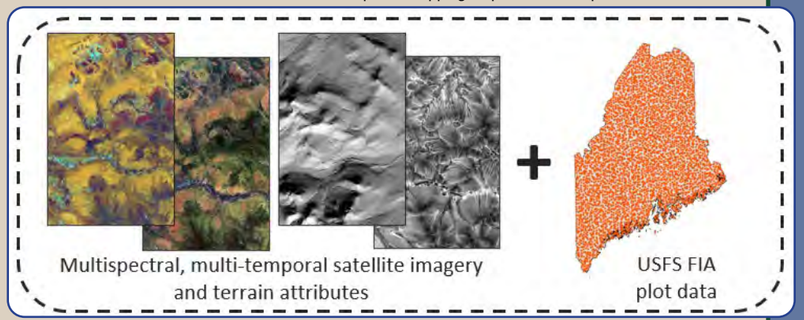
2022 CAFS Phase 3 Progress Report

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

Kasey Legaard, Aaron Weiskittel, Larry Whitsel, 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).

Species mapping for predictions of species abundance.



Year Three Progress

- Continued improvements to large-area species mapping
  - Improved Sentinel-2 haze correction and cloud masking.
  - Improved machine learning in cloud-affected areas
  - Improved prediction adjacent to edges.
- Nearing completion of workflows and software for time series harvest and disturbance mapping using multi-objective machine learning.
- Completion of large-area 3D NAIP and LiDAR point cloud processing.
- Initiated collaboration between the Monroe Community College and UMaine, supported by an NSF START supplemental funding grant.

Future Plans

- Expand processing to test sites in the NW, SE, and Upper Midwest.
- Disturbance mapping and NAIP/LiDAR processing approaching the point that we can integrate multi-source data for large projects.
- Iteratively implement and evaluate strategies for species, forest type, and biomass mapping.

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

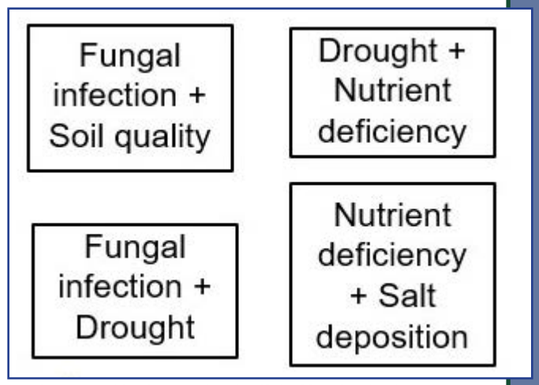
Using Hyperspectral Imaging to Evaluate Forest Health Risk

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.

Year Three Progress

- Spectral data identified different groups in drought treatment under field conditions, but the change of spectral data to field drought treatment was affected by seedling drought preconditioning.
- Spectral data classified different individual stress groups well, but the ability of spectral data to classify stress groups depended on if the stress events were applied individually or in combination.
- Leaf biochemical traits were well predicted by spectral data.



Strress combinations used to classify leaf functional traits

- Hyperspectral data can be used for fast, non-destructive measurements for tree traits related to abiotic and biotic stress.
- Spectral data identified the influence of Luna moth herbivory on trees. Differences in spectral profiles among treatment groups were well detected in the full-range of spectral region.

Future Plans

- Relate predictive leaf trait responses to hyperspectral phenotyping outcomes to interpret the classification results.
- 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.

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), Carlos Gonzalez (OSU), Doug Maguire (OSU), Aaron Weiskittel (UM)

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.

Year Three Progress

- Ongoing examination long-term soil productivity experiments (LTSP) treatments (US Forest Service sites and New Zealand) over time
- Using carbon-14 dating for soil organic matter to analyze carbon pools.
  - Organo-mineral complexes dictate forest solid C resiliency.
  - Radiocarbon can be used as a measurement of whether or not soils are “good or bad” at storing C.
  - C composition is likely changing between the two organic matter removal treatments through time.

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 (UGA), 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.

Year Three 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.

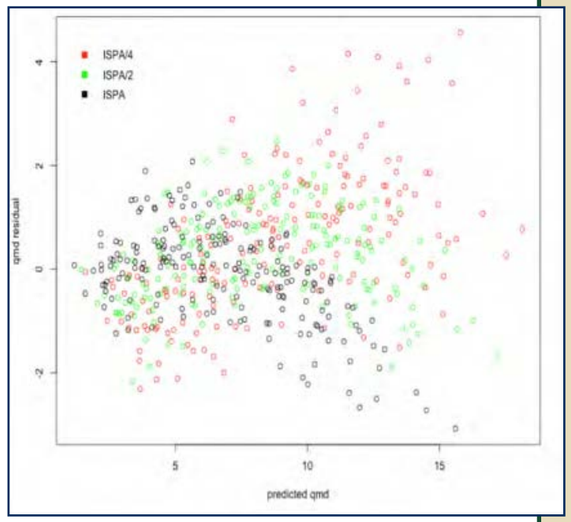
Future Plans

- ✦ Simultaneous fitting of trees per acre and basal area to derive quadratic mean diameter
- ✦ Further investigation of the mechanisms behind the differences in physiographic regions, i.e., WA coast (4), OR coast (7), OR mid-Cascades (8) – test site and soil variables.
- ✦ Extend PYC v2.0 models to incorporate PCT effects, then thinning.
- ✦ 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).

QMD residuals for Type I, II PYC model



2022 CAFS Phase 3 Progress Report

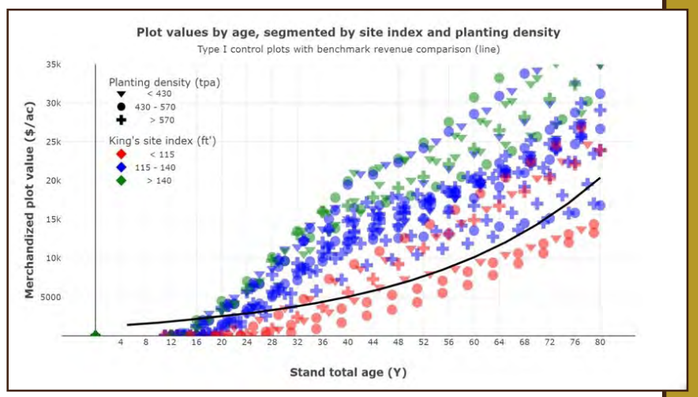
Using Predictive Analytics to Decompose Site Index

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.

Year Three Progress

- Completed model relating H40 to BHAGE, using Modified-Weibull CDF, where rate and shape parameters are functions of planting density, physiographic regions, and various measures of seasonal/annual climate.
- Working paper describing methods and results for delivery to SMC membership.
- 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.
- Include soil data attributes in RHS predictor set for both rate and shape. Shape in particular is a number that exists "in the wild" and is likely a complex function of many variables and their interactions.
- Exploration of machine-learning techniques to relate (rate, shape) to various static, periodic, and dynamic predictors.
- Online tool for mapping of base layers (predictors) and facilitating site index predictions in development through partnership with Precision Forestry Cooperative at University of 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

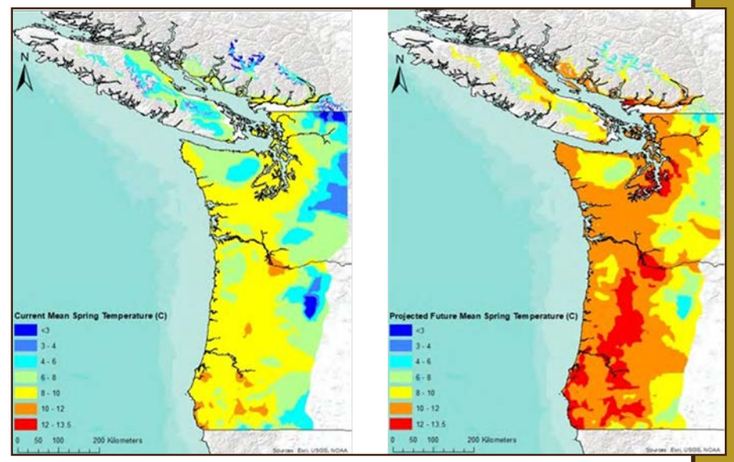
Eric Turnblom and Kim Littke (UW), Michael Premer (Rayonier)

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.

Year Three Progress

- 30 installations cored, dated, and measured for earlywood and latewood growth.
- 15 installations split into earlywood and latewood for -4 - 6 years after fertilization.
- Examined differences between responding, temporary response, and non-responding installations.
- Responders have greater elevation, forest floor and soil C:N ratio; temporary responders have the lowest PRS Fe, Cu, and Mn adsorption; on-responders had the greatest PRS NO3 adsorption.

Current and projected future mean spring temperatures.



Future Plans

- Analyze rings 2-4 years prior to fertilization.
- Analyze next 15 installations for C and O isotopes.
- Publish peer-reviewed publications from study results.

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.

Year Three Progress

- Samples taken on forest floor and in mineral soil within each plot for organic matter composition of the soil; Plant Root Simulator probes installed in all plots in order to quantify differences in soil nutrient availability across species and sites.
- Litterfall from five litterfall traps per plot were collected and used in conjunction with biomass data to determine NPP for each species at each sit.
- Dendrometer bands were installed on ten trees per plot to determine intra-annual diameter growth rate as well as the timing and length of the growing season. Wood increment cores were extracted from the ten banded trees.
- One MS student graduated summer 2022; oral presentations at the Vegetation Management Research Cooperative annual meeting.


GS: Dry Site


GS: Wet Site

Future Plans

- Litterfall collection to continue bi-monthly; monthly LAI and light interception measurements; monthly diameter growth measurements with dendrometer bands.
- Inventory of tree survival, heights, and diameter inter 2022-23.

Member Company Benefits

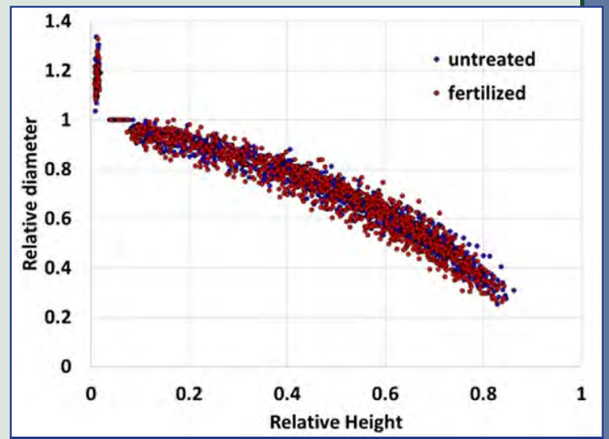
- Better understanding of the sensitivity of 10 commercially and ecologically valuable species in the PNW in terms of productivity and wood properties, to water deficit and climate variability.
- Understanding the growth-climate relationship for many alternative species, as well as its impact on wood 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

Stem Form of Nitrogen-fertilized Douglas-fir Trees

Doug Mainwaring (OSU), Kim Littke (UW), Eric Turnblom (UW), Aaron Weiskittel (UM), Sukhyun Joo (OSU), Carlos Gonzalez (OSU)

Current estimates of the positive Douglas-fir volume response to nitrogen fertilization are based entirely on measurable responses of diameter at breast height and total height despite the fact that log volumes are based on top-of-log scaling diameters. A recent analysis of stem form from a sample of Douglas-fir growing in operational stands shown to respond to nitrogen fertilization found that fertilization was a significant explanatory factor in describing the larger upper stem diameters within fertilized stands, all else being equal. The Stand Management Cooperative at the University of Washington currently has a large regional experiment studying the response of late rotation aged stands to nitrogen fertilization. Being the closest simulation of actual operational N fertilization to date, these sites provide an ideal setting to test for the upper stem response to N fertilization. Being able to estimate a more comprehensive and precise volume response to fertilization would improve the ability to assess where fertilization would be appropriate, as well as the financial benefit gained by treatment.



Taper measurements generally follow destructive sampling; despite multiple top height measurements per tree, some RD/RH results still concerning.

Year Two Progress

- Field work completed height and DOB measurements at all installations.
- Outside bark diameter was modeled using a reduced version of the previously published "Model 02" taper equation (Kozak 2004).
- Added variables to this model form included an indicator variable for fertilization treatment, various measures of crown height, and interactions between fertilization and relative height or fertilization and relative crown base height.

Future Plans

- Draft report on the final model describing stem form.
- Dataset of measurements.

Member Company Benefits

- Clarification of taper effect of fertilization and assessment of volume/financial benefit of fertilization when accounting for the upper stem.

2022 CAFS Phase 3 Progress Report

A Neural Network Approach to Generating Leaf Area Index Estimates Using the Sentinel-2 Satellite Record and LiDAR

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.

Year Two Progress

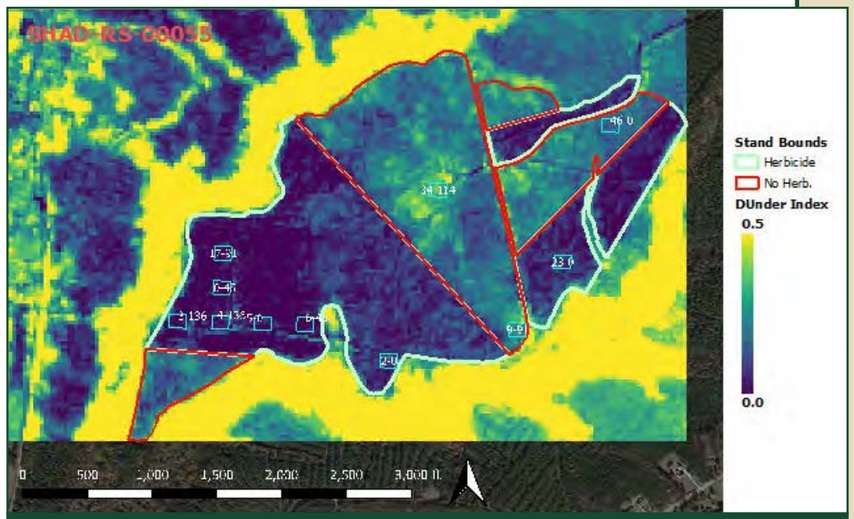
- First trials in broad-scale understory retrieval for select FPC collaborating members.
- Work to expand to other regions and species for a national level LAI model for production forests.

Future Plans

- Evaluate existing models and adapt methods using existing LAI history for Maine spruce and fir; test understory method on known beech understory.
- Evaluate the current LAI record of Pacific Northwest Douglas fir.
- Gather more ground data to refine models.

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.



Herbicide/no herbicide test plots in North Carolina.

Project Highlights

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

Joe Dahlen, Cristian Montes, and Bronson Bullock (UGA), Corey Green (VT), Harold Burkhardt (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.

Year Two Progress

- Lumber visually graded by certified SPIB graders in GA.
- MS student started in Fall 2022.
- Whole disk and ring-by-ring measurements.
- Regional effects on velocity.

Future Plans

- Continue span cutting.
- Non-destructive evaluation.
- Destructively test to failure via ASTM standards.

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.

2022 CAFS Phase 3 Progress Report

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

Joe Dahlen, Cristian Montes, Bronson Bullock, and 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.

Year Two Progress

- New MS student to work on project.
- Trees harvested and measured, discs collected from harvested trees.
- Specific gravity and carbon percentage measured on wood and bark has begun.

Future Plans

- Develop familiarity with resistance drilling and field protocols.
- Signal processing.
- Calibration to wood specific gravity, possibly bark specific gravity.

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.

Resi drill will be calibrated to loblolly pine.

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: Improving Forest Sample Estimation Through UAS Canopy Structure Stratification

Mark Kimsey and Logan Wimme (UI), Weikko Jaross (Landvest),
Peter Gould (WA DNR), Miles Micheletti (WA DNR)

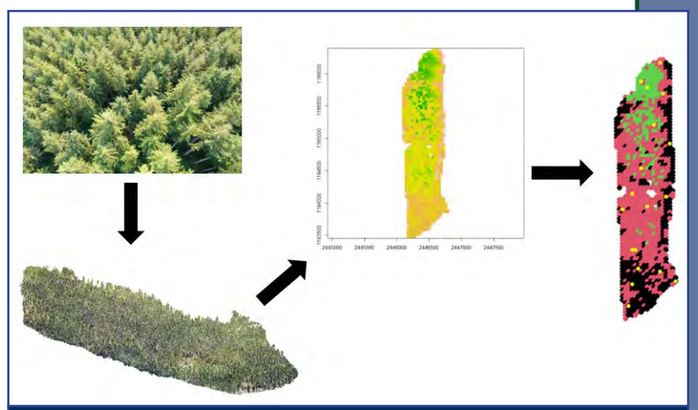
The goal of this project is to evaluate the practical use of unmanned aircraft systems (UAS) to improve traditional stand inventories through photogrammetric stratification of imagery-derived canopy height models. The INTERN program allows graduate research students to learn from experienced professionals, participate in team meetings, and gain direct performance feedback from industry professionals.

INTERN Research Experience

- Rasterized height pixels from canopy height models clustered to identify within-stand strata.
- Sample sizes created for each strata according to within strata variability and strata size.
- Plots randomly placed within strata.
- Plots cruised and compared to cruise results of traditional/current inventory methods.

INTERN Findings

- Cruise data collected using UAS height-based stratification was inferior to systematically-collected cruise data (for most stands).
- Inclusion of a density or basal area metric may improve UAS stratification.
- Improvements to UAS stratification methods are needed to yield a more accurate and operationally-feasible product.
- Positive/beneficial learning experience.



Drone captures high-resolution imagery of stands, image data passes through software to generate 3-dimentiounal point clouds and canopy height models, clustering algorithm used to create stratified plots.

Member Company Benefits

- Upon improved stratification methods, more accurate error statistics and volume estimates.
- Time and cost savings resulting from needing fewer sample plots compared to traditional systematic grids.

Project Highlights

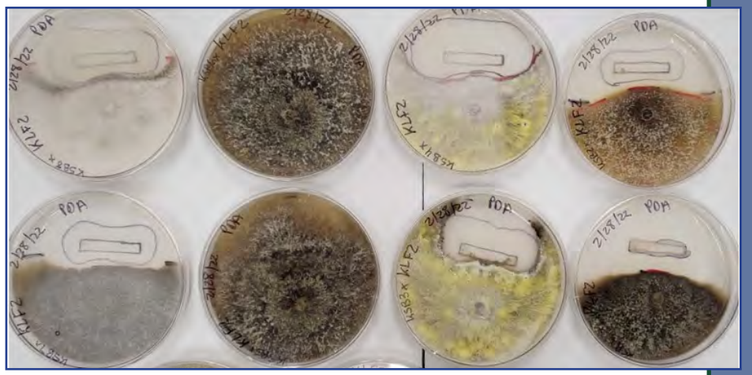
INTERN: Improving Tree Seedling Survival with Defense-enhancing Endophytes

George Newcombe, Andrew Nelson, and Abby Ferson-Mitchell (UI)

The objective of this project is to test the hypothesis that seed endophytes can mediate resistance to fungal pathogens by demonstrating enhanced survival in susceptible seed against virulent strains of problematic pathogens.

INTERN Research Experience

- Seeds acquired from 3 species (Western white pine [WWP], Port-Orford cedar [POC], Hawaiian koa), surface sterilzed, and plated on media to extract endophytes.
- 16 fungal isolates and 16 bacterial isolates selected for analysis.
- WWP seed inoculations completed and sown.
- Hawaiian koa seed coats clipped and soaked in bacterial suspension, then sown.



Future Plans

- Port-Orford cedar seed inoculations completed and sown.
- Inoculate WWP with blisther rust, collect data.
- POC growth comparison.
- All results to be acquired by end of 2023 and included in a dissertation.

INTERN Findings

- POC seed and foliar bacteria had a positive effect on seedling emergence.
- One koa seed bacterium prevented mortality for the initial 30-day period, no long-term significance.

Member Company Benefits

- *Bacillus* and *Streptomyces* are commonly used in agriculture and several products are advertised as fungicides, insecticides, probiotic treatments, soil augmentations, growth hormones, and fertilizers. By isolating these species from targeted host plants, the hope is that products similar to those used in agriculture will be developed to aid not only in seedling survival but also improved growth, stand productivity, and heightened defense against pathogens and insects for maturing trees.

2022 CAFS Phase 3 Progress Report

INTERN: The Effect of Common Field Merchandizing Methodologies on Estimates of Sawlog Volume and Product Recovery in Hardwood Stands in Northern Maine

Aaron Weiskittel and Ryan Smith (UM)

Ian Prior, Seven Island Land Co.

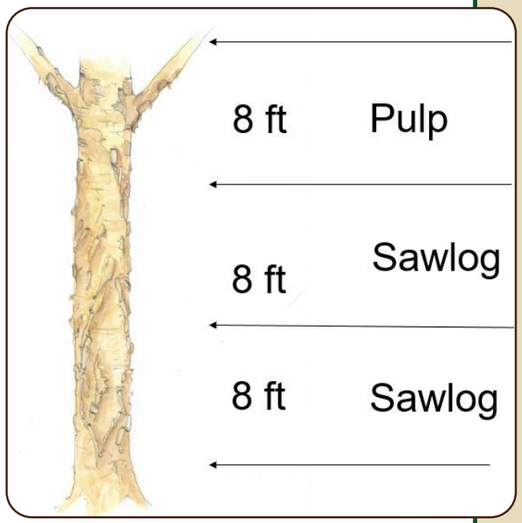
The objective of this one-year project was to identify statistically significant differences in hardwood sawlog predictions with the inclusion of significant covariates between methods and assess the variability and efficacy of each merchandizing method. A comparison of predicted sawlog volumes and variability in hardwood dominate stands in northern Maine was performed using the following field merchandizing methodologies: stick cruising, merchantable stopper heights, form and risk analysis, acceptable sawlog grade, and the forest vegetation simulator.

INTERN Research Experience

- Four field methodologies implemented in 10 stands dominated by hardwood species were identified and sampled.
- Plot level estimates of sawlog value compared using a linear mixed model and estimated marginal means.

INTERN Findings and Outcomes

- Significant differences in the estimates derived from different field inventory measurements: Variability for sawlog volume estimates were significantly higher than variability for estimates of merchantable volume.
- Higher sampling intensity may be required to accurately represent product ratios in field inventories.
- Graduate thesis. Skills developed through this funding: expertise in R Shiny, woodstock modeling, landscape-level planning.



Stick cruising.

Member Company Benefits

- Form and Risk Field Guide: methodology for more consistent and reasonable field merchandizing estimates in northeastern hardwood species.
- Understanding of the required sampling intensity for reasonable sawlog volume predications.
- The ability to more critically assess the predicted values presented by other parties for the purpose of measuring stumpage valuations.

Project Highlights

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

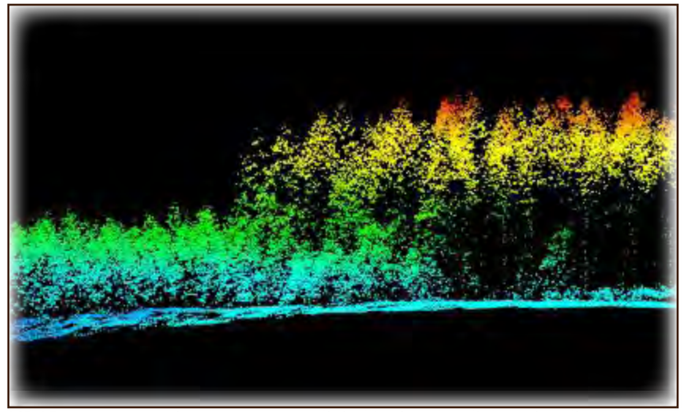
- Identify tree dominance as defined by tree height.
- LiDAR data acquired for Northwest.

Future Plans

- Create a remotely sensed dominant tree list. Cruise stands using traditional methods to obtain a georeferenced list. Compare traditional and remotely sensed tree lists and draft results.
- Analyze and compare LiDAR data sets.

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.

2022 CAFS Phase 3 Progress Report

INTERN: Soil Phosphorus Availability: New Techniques to Predict Fertilizer Response in Loblolly Pine

Rachel Cook and Jacob Hackman(NCSU)

Six-month internship with Rayonier to provide a first-hand appreciation and understanding of how to operate, manage, and maintain a pine forest from the planting of a seedling to the final destination of the tree itself at harvest time.

INTERN Research Experience

- Partnered with Rayonier for 6-month internship.
- Grafting saplings onto adult pine trees to maintain a genetic bank of material that could eventually be used for future genetic lines and crosses.
- Collecting, bagging, and pollinating loblolly pine trees.
- Timber cruising and assessing pine stands for inventory analysis.
- Collecting sample from trees for nutrient uptake.

Future Plans

- Continue tree microdialysis testing.
- Continue research efforts for PhD thesis on the influence of phosphorus on microbial communities in southeastern loblolly pine stands.

Member Company Benefits

- Improve understanding of soils located within the coastal plain and their individual strengths and weaknesses.

Project Highlights

START: NC State University, Montgomery Community College Summer Internship Program

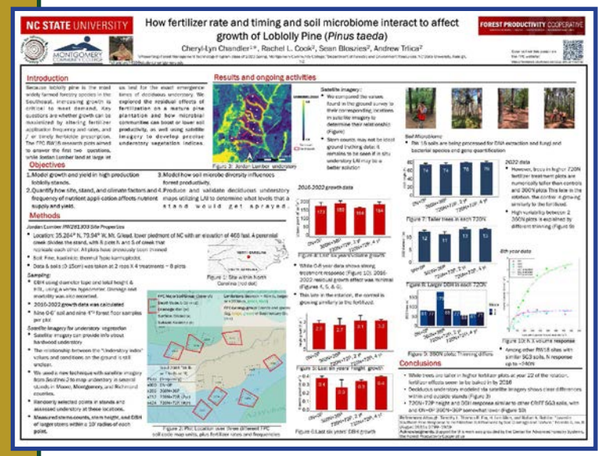
Rachel Cook and Andrew Trlica (NCSU)

Dylan Hurley, Montgomery Community College

Partnership with Montgomery Community College offering paid internships/field experience with CAFS member company and CAFS research experience at NC State. Focus on GIS and remote sensing and on the ground 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.

Summer Experiences

- Internship with Jordan Lumber working on deciduous understory mapping, fertilization trial measurements, and fungal sampling.
- Internship with North Carolina Forest Service Claridge Nursery. Special project focused on soil mapping in nursery.



MONTGOMERY COMMUNITY COLLEGE

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

Aaron Weiskittel and Nicole Rogers (UM)

Neil Thompson and Ned Rubert-Nason, University of Maine Fort Kent

Partnership with University of Maine Fort Kent's 2-year technical college to support a two-year project on spruce budworm that will use high-resolution UAVs and foliar traits to detect early defoliation or trees that are susceptible to it. Internships will encompass lab sampling and field work.

Summer Experiences

- Hyperspectral imaging to assess tree health. Skills: Tree measurement, specimen collection, phytochemical analysis.
- Effects of microclimate on forest regeneration. Skills: Install climate monitoring equipment, conduct FIG surveys.
- Estimation of wood moisture content. Skills: Operate portable NIR spectrometer, tree coring, gravimetric analysis.
- Field data collected, lab data ongoing.
- Two climate monitoring stations installed.
- ~50 wood core samples collected, scanned and analyzed for moisure content.

Future Plans

- Engage more undergraduates in research.
- Continue data curation.
- Phytochemical analysis.
- Install additional climate monitoring stations.
- Build calibration model for wood moisture content.

UNIVERSITY OF MAINE FORT KENT

Project Highlights

START: University of Maine & Monroe Community College Geospatial Research Experience

Aaron Weiskittel (UM)

Jonathon Little (State University of New York, Monroe CC)

2022 interns: Casmir Brown and Bryon Carroll (MCC)

Partnership with University of Maine focused on geographic information systems (GIS) and forestry-related fieldwork. Students will collect and process field data for remote sensing applications, particularly tree species composition, and present their work.

Summer Experiences

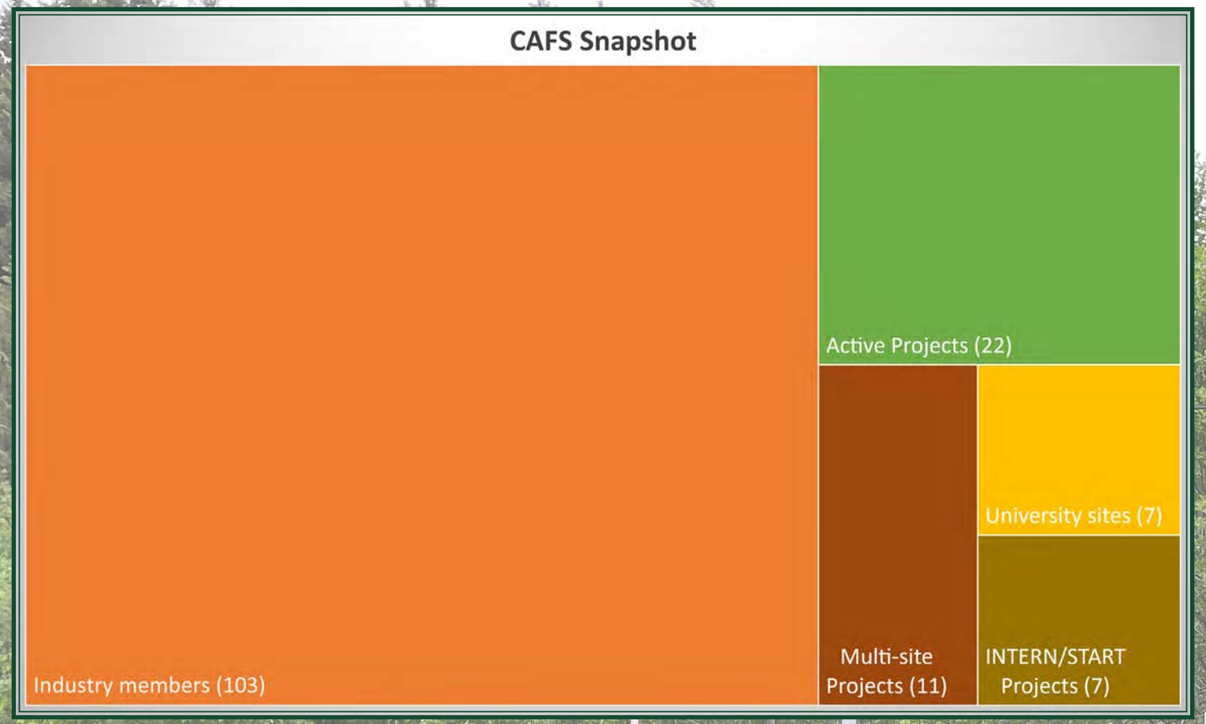
- Worked with a variety of faculty researchers at UMaine, UMaine Fort Kent, and Schoodic Institute.
- Worked with machine-learning software and artificial intelligence to create cloud-free satellite imagery; the end goal being automated calculation of tree biomass.
- Worked with LiDAR data to produce 3D maps and predictions.
- Collected tree data at continuous forestry inventory plots at the Penobscot Experimental Forest.
- Studied tree morphology, leaf data, and tree regeneration.
- Learned to measure $C0_2$ uptake and release of water vapor from plant samples.
- Worked with the Town of Orono to classify trees in poor health or impacted by pests/insects, and those with the potential to interfere with power lines.
- MCC GIS Summer Internship story maps by Casmir Brown and Bryon Carroll.

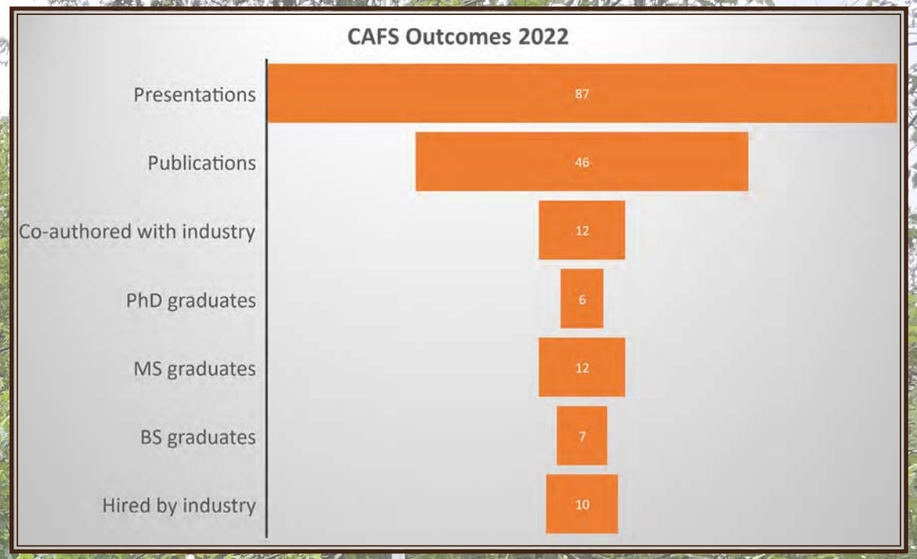
Future Plans

- Two virtual interships planned with UMaine's Barbara Wheatland Geospatial Lab in the spring of 2023.

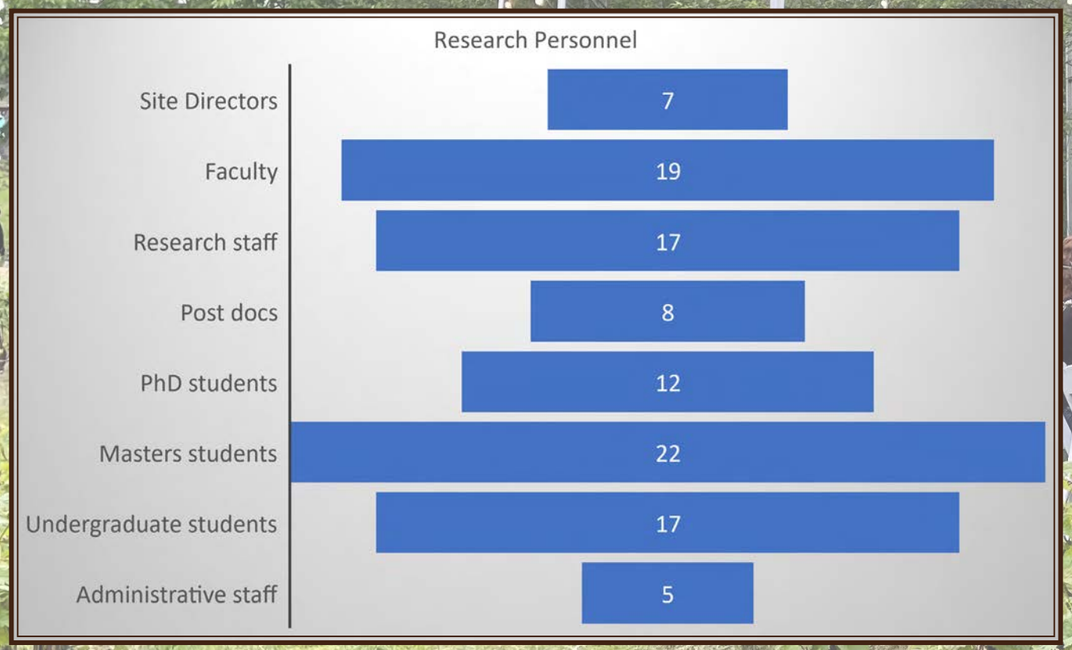
Bryon and Casmir learing to work with drones used for data collection.

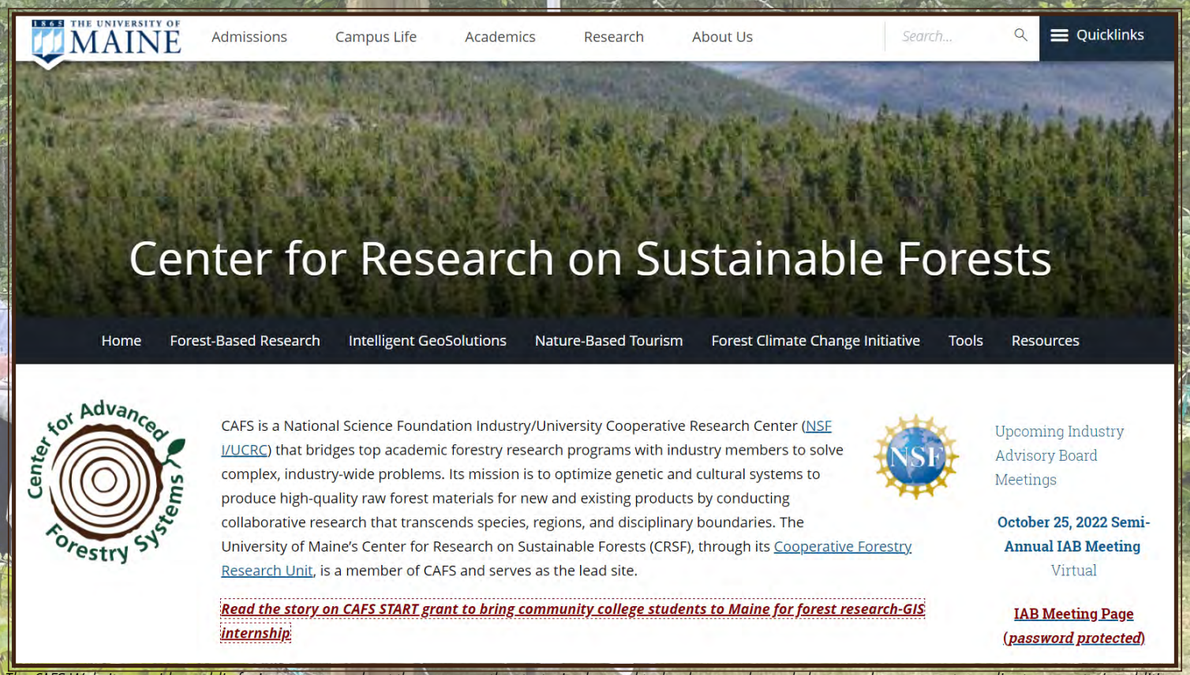
Funded by a 2022 NSF Skills Training in Advanced Research & Technology (START) Supplemental Funding Request for ATE at Monroe Community College (Award #1955256) with IUCRC Phase 3 at University of Maine - Center for Advanced Forestry Systems (CAFS).





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.umaine.edu
crsf@maine.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