National Science Foundation

I/UCRC Center for Advanced Forestry Systems
Phase II Final Report
2014-2019

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, with Dr. Aaron Weiskittel, Director of the Center for Research on Sustainable Forest, taking over as CAFS Director from previous Director Dr. Barry Goldfarb of North Carolina State University.

In 2020, Dr. Weiskittel was successful in guiding CAFS to the final segment of three, five-year phases funded by NSF. Phase III projects will 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.

Forests

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

As the world's population approaches 9 billion and as urbanization continues, pressure to increase wood production is growing on a decreasing global forestlands.

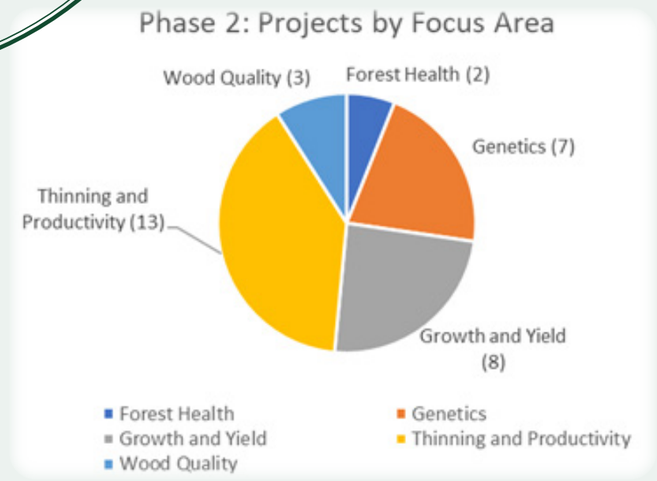
Economic opportunities exist to meet increasing demand for wood products from an increasing global population, rising living standards, greenhouse gas policies, bioenergy, and advances in green building technologies.

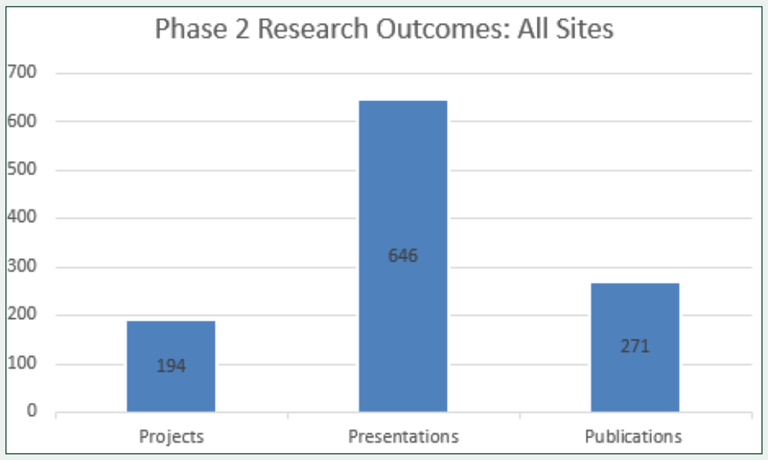
Eight member sites of the **Center for Advanced Forestry Systems (CAFS)** Phase II were funded by a National Science Foundation (NSF) Industry/Research University Cooperative (I/URC) grant to conduct collaborative research focused on optimizing the silvicultural and genetic systems needed to produce high quality, raw materials to meet the economic demands of the nation's forest products industry in the 21st century.

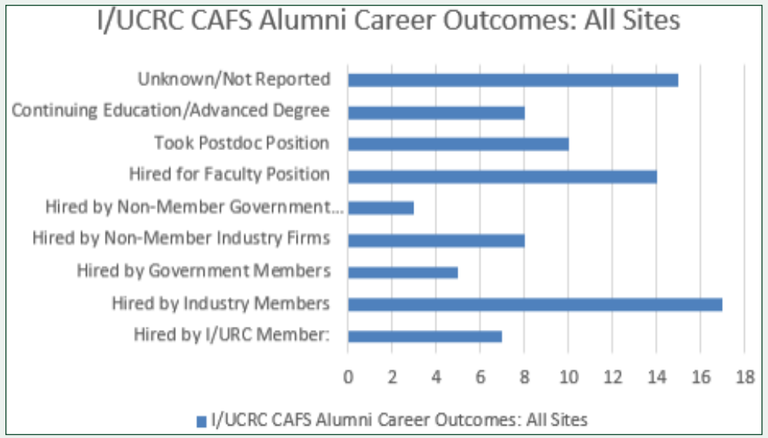
CAFS has been extraordinarily successful over the past 5 years at providing the administrative and funding structure needed for national, interdisciplinary, scientific collaboration among researchers in these coops to make significant progress in increasing forest productivity through forest genetics, site manipulation, and better growth & yield modeling.

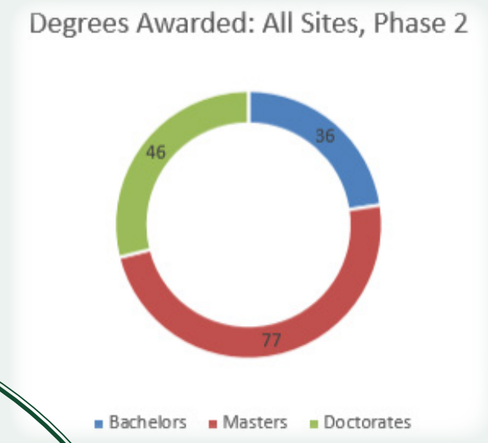
Research

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.









Impacts

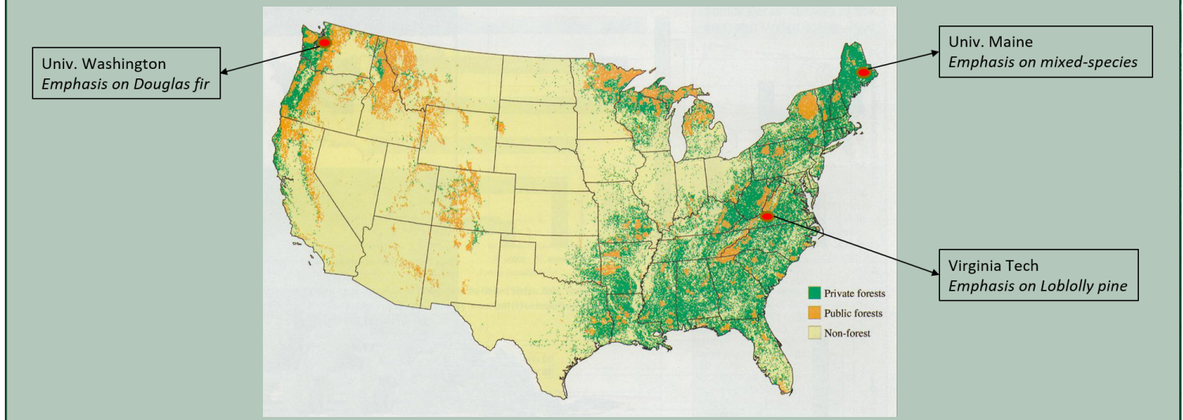
The broader scientific community benefits through refereed publications and presentations at scientific meetings. Graduate student training will continue to be featured in CAFS research and technology transfer. These students will be unique in the forestry sciences because of their applied problem-solving skills using interdisciplinary techniques across multiple scales. Aggressive recruiting for graduate students among under-represented groups will continue to be conducted, increasing the diversity of the workforce for both academia and industry in this traditionally diversity-deficient discipline. Opportunities will continue to be sought to involve undergraduate students in CAFS research activities, exposing them to the excitement of forest science and encouraging them to pursue graduate education.

Highlights: Completed Projects

Collaborative Research: Understanding and Modeling Competition Effects on Tree Growth and Stand Development Across Varying Forest Types and Management Intensities

Harold Burkhart (VT), Aaron Weiskittel (UM), Eric Turnblom (UW)

- Contemporary statistical techniques and computing technology were used to gather information from forestry field studies to develop improved quantitative measures of tree- and stand-level competition.
- Silvicultural systems varied from intensively managed even-aged plantings of single species to extensively managed uneven-aged mixed species stands (see figure).
- Synthesis of data lead to more complete understanding of the fundamental processes involved.
- Distance-independent competition metrics appear to perform just as well as distance-dependent measures.
- There are specific circumstances (dominant individuals, tree clusters, immediately post harvest, shade-intolerant species) in which two-way distance-dependent metrics outperfom distance-independent measures for predicting diameter increment.
- Study results provide a more complete understanding of and better quantitative expressions for competition effects on tree and stand growth and survival
- Enhanced quantitative expressions of competition are applicable across various forest types and management intensities.
- Increased reliability of models for predicting growth and yield.



Highlights: Completed Projects

Assessing Stand Characteristics of Enhanced Genetics in Loblolly Pine Plantations in the Southeast

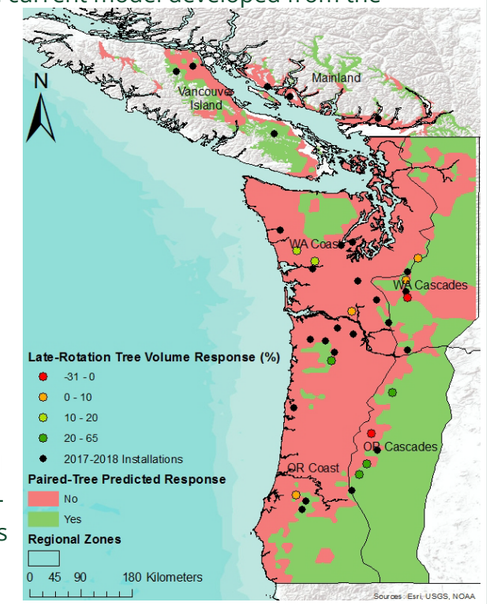
Bronson Bullock (UGA), Dehai Zhao (UGA), Mike Kane (UGA), Harold Burkhart (VT), Aaron Weiskittel (UM)

- Researchers used data from 5 large research trials across a range of stand ages to evaluate the stand characteristics of enhanced genetics in loblolly pine plantations.
- The distributional properties (diameter, height, volume, competition indices) on a range of enhanced genotypes (HS, FS, Clones) were evaluated and compared to better inform growth and yield models.
- Project has resulted in greater understanding of the distributional properties of enhanced genotypes; the ability to account for differences in growth and yield modeling by adjusting the diameter distribution models; adjustments to the height-diameter curves; increased understanding of individual stem competition for resources in stands of enhanced genetics; and understanding of variability in individual stem measures in stands of enhanced genetics.

Stand and Tree Responses to Late-Rotation Fertilization

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

- Researchers estimated the regional nitrogen fertilization response (RRE) for Douglas-fir on 38 late-rotation stands in randomly located stands within four distinct regions of Washington and Oregon and two regions in British Columbia.
- Anion and cation plant root simulator (PRS) probes and traditional available and total soil nutrient extractions were compared to understand what is affecting fertilizer response in late-rotation Douglas-fir plantations.
- Regional economic returns to late-rotation fertilization investments estimated
- Validate the site-specific responsiveness predictions of the current model developed from the Stand Management Cooperative and CAFS Paired-tree Fertilization study
- Thirty-eight installations have been installed, measured, and treated. Pretreatment soils have been analyzed on all installations.
- Major Findings: Greatest volume response at low site index and with low PRS NO_3 uptake; the Paired-Tree study showed similar relationships, less plant root simulator probe NO_3 uptake in predicted response regions (see figure).
- In coastal WA, low PRS NO_3 uptake, but no predicted response; suggests that water or other nutrients are limiting response.
- This much-needed examination of the economics involved with late-rotation fertilization will provide an average area-based volume response that will be used in growth models in six distinct regions.

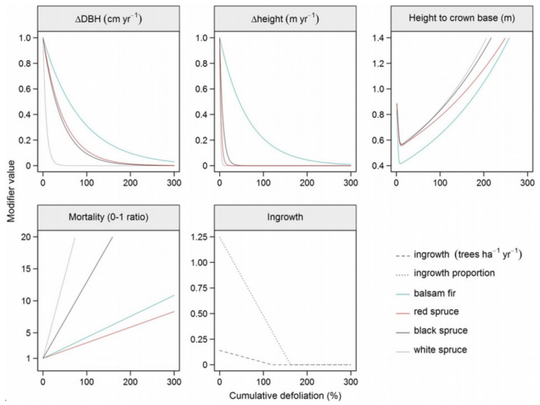


Highlights: Completed Projects

Modeling the Influence of Spruce Budworm on Forest Productivity

Cen Chen, Aaron Weiskittel, and Brian Roth (UM)

- Researchers used the Acadian variant of Forest Vegetation Simulator (FVS-ACD) with regional individual tree inventory data to perform high resolution and long-term evaluation of the influence of SBW defoliation on carbon stock in spruce-fir forests in Maine.
- The evaluation was conducted for two contrasting 40-year periods (1975-2015, 2017-2057), which are approximately the return intervals of SBW outbreaks.
- Merchantable carbon stock was not reduced between cycles of spruce budworm outbreaks.
- Merchantable carbon growth temporarily decreased immediately following spruce budworm outbreaks.
- Recovery of carbon stock was more of an effect of increased abundance of hardwood species.
- This approach could provide forest landowners with a tool for carbon management in forest planning, while assessing potential influences of disturbances like SBW defoliation on a widely used and tested platform of FVS.

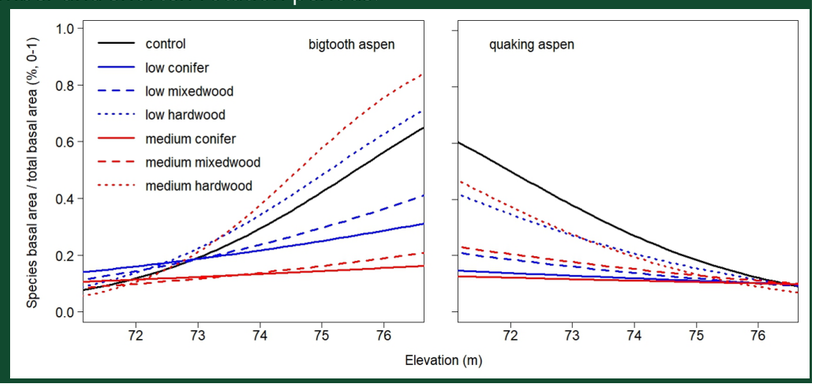


Significant influence of SBW defoliation on spruce growth and fir mortality.

Evaluation of Silvicultural Options for Increasing Productivity of Early Successional Stands in the Acadian Forest Region

Joshua Puhlick (UM), Aaron Weiskittel (UM), Brian Roth (UM), Andrew Nelson (UIdaho)

- Researchers compared individual crop tree and stand metrics among different silvicultural treatments conducted in early successional stands.
- Important forest management decisions are made before or during this stage; including planting density, competing vegetation control, and early precommercial thinning operations.
- Releasing potential future crop trees by removing competitors of undesired species could result in higher yields of marketable timber and shorten rotation periods.
- Refinements were made to a regional growth and yield model so that it takes into account early successional stand dynamics and management activities.
- Small shifts in elevation have significant implications for species composition (see figure).



Highlights: Completed Projects

Linking Growth Modeling to Product Quality for Loblolly Pine

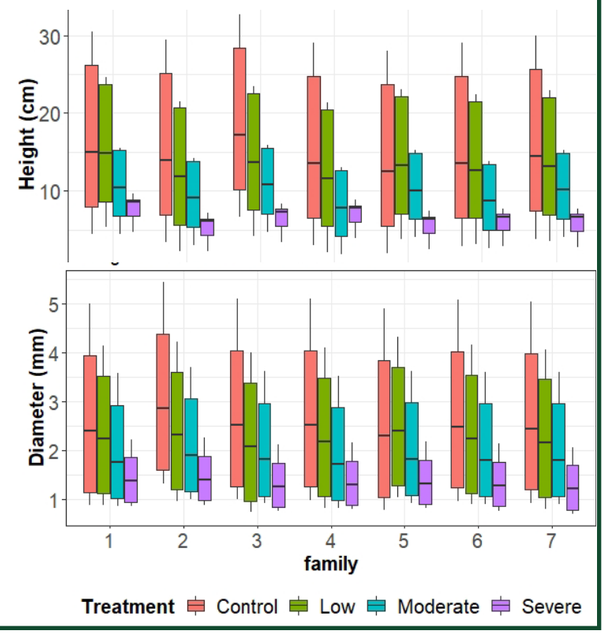
Joseph Dahlen (UGA), Cristian Montes (UGA), Thomas L. Eberhardt (USFS), John Paul McTague (Rayonier)

- Because mechanical properties are principally responsible for the utility of softwood lumber, it is critical that models be developed that predict lumber properties based on forest management.
- Image analysis was conducted on photographed lumber to determine the size, frequency, and location of the knots on the wide faces of the lumber.
- The knot area ratio (ratio of the knot area to the overall area) is the most useful indicator of the modulus of rupture: In this research, the failure location was linked for each image.
- This has proven useful as a teaching tool and it may be useful in the future as a research tool for predicting failure location.
- Work now being done to build a high resolution scanner that will be used to assess the knots on all four sides of lumber.
- Goal is to provide forest companies with models that predict the properties of end use products such as lumber
- This work will advance knowledge concerning the effect of knots on the mechanical properties of lumber cut from intensively managed stands.

Response of Superior Western Larch Families to Site Quality

Andrew Nelson, Mark Coleman, Marc Rust, and Kelsie Grover (UIdaho)

- Rapid growth and desirable wood quality make western larch one of the most commercially valuable conifers in the Inland Northwest.
- The experiments used half-sib seed collected from seven improved western larch clones, selected across a climate gradient, along with an open-pollinated orchard bulk lot.
- Individual families were grown from seed in a greenhouse study to examine family × drought intensity effects on seedling morphology and physiology over a 13-week period.
- In Study 2, drought was simulated in a greenhouse. Severe drought significantly reduced final height and diameter after 14 weeks. The range in final size was greatest for the control treatment and least for the severe drought likely because seedling growth ceased earlier than the other treatments (see figure).
- This project generated new information regarding family-specific responses of seedlings to drought. This is a first step toward future western larch selection for enhancing drought tolerance.



Ongoing Projects

Analysis of Aboveground Nutrient Biomass on LTSP Sites Due to the Effects of Site, Harvest Removals, Weed Control, and Compaction

Kim Littke, Eric Turnblom, and Rob Harrison (UW)

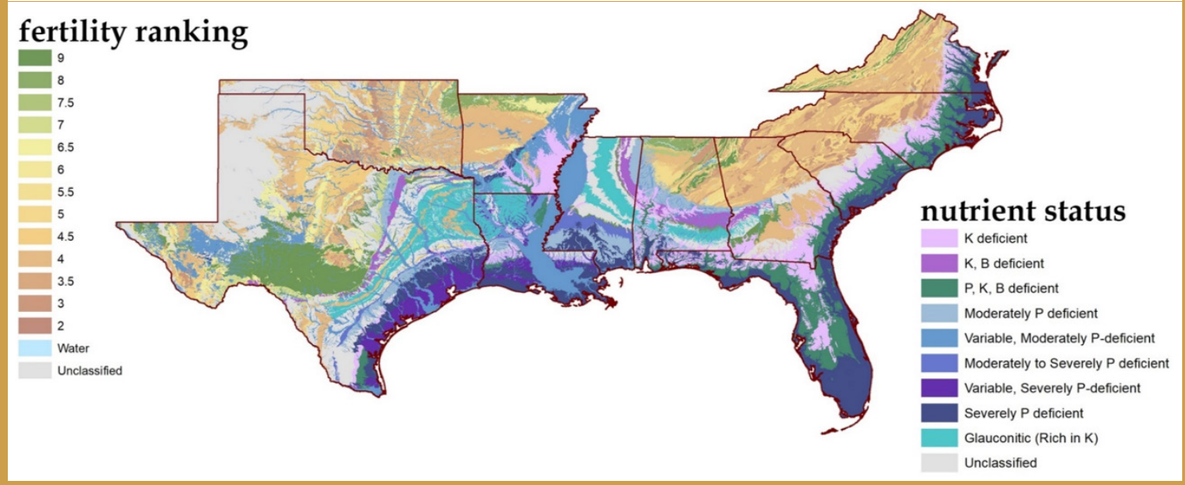
- Aboveground biomass and nutrients were examined on four Long-Term Soil Productivity (LTSP) sites.
- Effects of organic matter removals, compaction, and vegetation control treatments.
- Responses to treatments vary by site due to soil nutrition, time since harvest, and treatment severity.
- Recent soil sampling shows decreases in soil nutrients due to treatments: losses through leaching or removals, or greater uptake by trees and understory.
- At one LTSP site, the whole tree (WT) removal treatment resulted in significantly greater overstory competing vegetation biomass (primarily Scotch broom) and lower understory competing vegetation (primarily native herbaceous species) compared to the bole only (BO) treatment.
- This study will instruct forest product companies on the short- and long-term changes in soil and site productivity due to intensive forest practices. We will improve the understanding of nutrient dynamics following organic removal, vegetation control, and compaction.
- Knowledge of how these factors interact will lead to better timing and application of chemical nutrients and/or vegetation control measures.

Ongoing Projects

Assessing & Mapping Regional Variation in Site Productivity

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

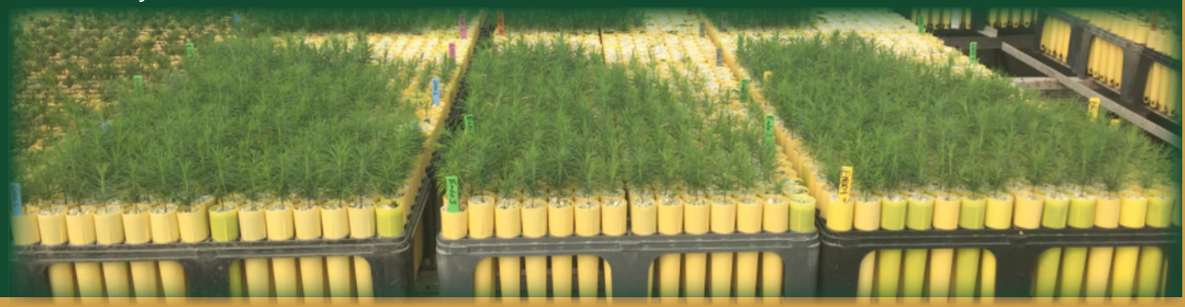
- Precision forestry could help optimize management, which is based on potential site productivity and limiting resources.
- Soil characteristics that limit productivity vary across sites and require an in-depth understanding of resource availability to predict the likelihood of response to a given input.
- Develop a consistent and biologically meaningful metric of potential site productivity.
- Relate environmental and edaphic variable to site productivity to derive a national soial productivity map for production forest systems (see figure below).
- Ultimately map across major forest regions.
- The ability to better map potential site productivity across the landscape will reduce the need for costly measurements and improved ability to better match management actions with site conditions. This improves the likely return on investment for any management actions taken.



Improving White Pine Seedling Survival by Combining Blister Rust Resistance with Defense-Enhancing Endophytes

George Newcombe (UI), Marc L. Rust (UI), Mary Frances Mahalovich (USDA Forest Service), Greg Adams (J.D. Irving), David Miller (Carleton University), Brian Roth(UM), Mark Coleman (UI)

- Researchers set out to compare Western white pine (WPBR) resistance of selected WWP seed sources that are either inoculated, or not inoculated with promising endophytes.
- The seedlings will be monitored for 3 years in the nursery and scored for WPBR resistance traits.
- In order to determine how efficiently eastern North American endophytes can infect western pine species, collaborators at J.D. Irving treated 4 seed lots of various western pine species with two eastern North American endophytes.
- While the endophyte infection appeared to be low (10% for *X. ellisii* and 1% for *H. pinicola*), significantly higher percentages of seedling infection are usually seen over time as the trees grow larger.
- Results from this ongoing study will provide information on how successfully western white pine seedlings can be colonized with six different endophytes and how the presence of those endophytes impacts resistance levels of both resistant and susceptible seedlings inoculated with WPBR in the nursery.



Ongoing Projects

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

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

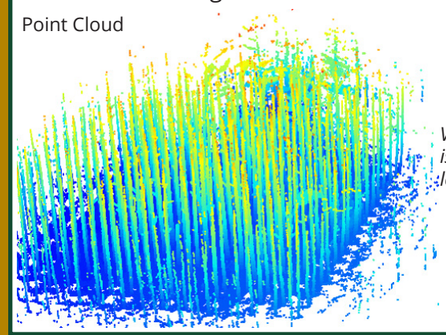
- Optimal planting or residual thinning densities are needed to support management decisions that influence the rate of stand development, attainable stand structures and final value.
- Researchers plan to synthesize a range of regional datasets to test the general robustness of prior regional research results and develop derived maps of predicted maximum site carrying capacity that can be provided to industry members.
- This is a national-scale project relevant for all industry members. Maximum site carrying capacity determines stand productivity, is necessary for optimizing planting or residual thinning schedules, refining growth and yield projections, and maintaining compatible species compositions in naturally regenerated stands.

Environmental Predictors of Form and Quality in Loblolly Pine

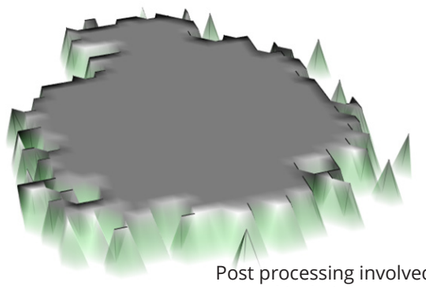
Cristian R. Montes, Joseph Dahlen and Bronson Bullock (UGA)

- Develop a cost-effective methodology to assess stem quality using ground based mobile LiDAR technology to reduce sampling cost while increasing the amount of information captured at the time of an inventory.
- Correlate defects with environmental variables to determine spatially explicit defect models.
- Plot-level observations were correlated with landscape-based environmental variables (soil particle size distribution, water deficit, excess water) to determine stochastic defect models.
- The mobile LiDAR provides much more flexibility, at the cost of a noisier dataset. Specialized algorithms of data assimilation will allow for a better location of diameters and defects along the tree.
- Our algorithm was able to accommodate fewer points compared to other published algorithms.
- This method is unbiased, allows for error estimation, and allows for all the data to be used at the moment of estimating different points.
- Environmental variables important in determining defects over a large gradient in longleaf pine.
- Growth and yield (G&Y) systems need a way to determine tree defect. A function to allow for tree defect determination will further improve lumber value estimates out of G&Y systems for improved forest management decisions.

Point Cloud



Very high resolution data, ground isolated from ground points with a local minima function.



Post processing involved ground isolation

Meetings

In-person internal advisory board (IAB) meetings have been held annually since 2008. Site directors, researchers, and members of site cooperators and invited and encouraged to attend. IAB meetings generally consist of presentations by the NSF Program Manager and CAFS Assessment Coordinator, final and progress project reports from all sites, discussion of proposed projects, Site Director's business meeting, and IAB closed door business meeting. In 2019, UMaine added an annual remote meeting (held in the winter) to allow additional time for project progress updates and stakeholder interaction.

June 4-5, 2019 Athens, GA
Field Tour hosted by UGA: UGA Whitehall Forest, Weyerhaeuser Rain Exclusion PINEMAP site, PMRC SAGS Culture Density Study and Mid-Rotation Culture and Thinning Response Trial

June 12-13, 2018 Burlington, VT
Field Tour hosted by the University of Vermont: Commercial and State Forest Management Weyerhaeuser operations, Sweet Tree Holdings maple production, Willoughby State Forest

May 2-4, 2017 Portland, OR
Field Tour hosted by Oregon State University: Mount St Helens and Intensive Forest Management in the Pacific Northwest

April 26-28, 2016 Pensacola Beach, FL
Field Tour hosted by Auburn University: Longleaf Pine Pole Production & Solon Dixon Forestry Education Center;Escambia Experimental Forest, TR Miller's Pole Manufacturing Process, Solon Dixon Forestry Education Center

May 19-21, 2015 Asheville, NC
Field Tour hosted by NCSU: Forestry in the Southern Appalachians
USDA Forest Service, Bent Creek Experimental Forest and the Cradle of Forestry

Report prepared by The University of Maine's
Center for Research on Sustainable Forests